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Developing Performance Cost Index Targets for ASHRAE Standard 90.1 Appendix G – Performance Rating Method

February 2016

M Rosenberg
R Hart

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Michael Rosenberg
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Acronyms and Abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BECP	Building Energy Codes Program
DOE	U.S. Department of Energy
ECB	Energy cost budget
IgCC	International Green Construction Code
LEED	Leadership in Energy and Environmental Design
PCI	performance cost index
PNNL	Pacific Northwest National Laboratory
SSPC	Standing Standards Project Committee
USGBC	United States Green Building Council

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1.0 Introduction

ANSI/ASHRAE/IES Standard 90.1 (referred to as Standard 90.1) is the model energy standard upon which most non-residential energy codes in the United States are based (42 U.S.C. 6833(b)(1)). The standard includes two compliance paths (ASHRAE 2013).

- The prescriptive path establishes criteria for energy-related characteristics of individual building components such as minimum R-values of insulation, maximum lighting power allowance, occupancy sensor requirements for lighting control, and economizer requirements for HVAC systems.
- The performance path, known as the Energy Cost Budget (ECB) method, provides additional 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, as demonstrated through energy simulation modeling.

In addition to the ECB method, Standard 90.1 includes a second simulation-based performance approach, Appendix G, the Performance Rating Method. While similar to ECB, Appendix G is more flexible, but through publication of the 2013 edition of the standard, has not been an approved path for demonstrating compliance. Instead, it has been used to rate the performance of buildings that exceed the requirements of Standard 90.1 for beyond code¹ programs including United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) Rating System, ASHRAE's Green Building Standard 189.1, and the International Green Construction Code (IgCC) (USGBC 2014; ASHRAE 2014; ICC 2015).

A recent modification (Addendum bm) to Standard 90.1-2013 makes two significant changes for the 2016 edition, to be published in October of 2016 (Rosenberg 2013; ASHRAE 2015). First, it allows Appendix G to be used as a third path for compliance with the standard in addition to rating beyond code building performance. This prevents modelers from having to develop separate building models for code compliance and beyond code programs. Using this new version of Appendix G to show compliance with the 2016 edition of the standard, the proposed building design needs to have a performance cost index (PCI) less than targets shown in a new table based on building type and climate zone. The second change is the baseline design is now fixed at a stable level of performance set approximately equal to the requirements in the 2004 standard. Rather than changing the stringency of the baseline with each subsequent edition of the standard, compliance with new editions will simply require a reduced PCI (a PCI of zero is a net-zero building). Using this approach, buildings of any era can be rated using the same method. The intent is that any building energy code or beyond code program can use this methodology and merely set the appropriate PCI target for their needs. This report discusses the process used to set performance criteria for compliance with ASHRAE Standard 90.1-2016 and suggests a method for demonstrating compliance with other codes and beyond code programs.

¹ Beyond code programs generally refer to regulations, incentive programs, green building standards, and the like that require or incent building energy performance that exceeds the level required by a base energy code or standard.

2.0 Setting Performance Cost Index Targets

Using the Appendix G performance path baseline that is stable at the level of the 2004 edition of Standard 90.1 means that compliance with a newer edition of the standard can no longer be determined by simply designing a building with a lower predicted energy cost than a prescriptive baseline meeting that standard. Instead, to demonstrate compliance, the design would need to demonstrate a PCI below a target PCI (PCI_t). In other words the proposed design would need to exceed the performance (have a lower energy cost) compared to a stable (90.1-2004) baseline, by some amount. That amount is indicated by the PCI_t . Buildings qualifying for beyond code programs would need to exceed the compliance threshold for the appropriate edition of the code to whatever degree is prescribed by that program. This section discusses the method used to set the performance target compared to the baseline for Appendix G with Addendum bm.

2.1 Appendix G Performance Metric

The new metric to rate building performance used by Appendix G is called the Performance Cost Index (PCI). The PCI of a proposed building design is calculated as follows:

$$\text{Performance Cost Index} = \frac{\text{Proposed Building Performance}}{\text{Baseline Building Performance}} \quad (\text{Eq. 1})$$

Where:

Proposed Building Performance = The annual energy cost for a proposed design calculated according to Standard 90.1, Appendix G

Baseline Building Performance = The annual energy cost for a baseline design calculated according to Standard 90.1, Appendix G

This results in a PCI of 1.0 for a building designed at the energy cost level of 90.1-2004, and a PCI of zero for a net-zero energy cost building. The maximum PCI (PCI target) required for compliance with any edition of Standard 90.1 can be determined based on the energy cost of a typical building designed to the mandatory and prescriptive requirements of that standard compared to a similar building designed to the mandatory and prescriptive requirements of 90.1-2004.

2.2 Use of Prototype Buildings

To determine the savings impact from various editions of Standard 90.1, Pacific Northwest National Laboratory (PNNL) developed prototype commercial building models using the EnergyPlus building simulation program (DOE 2013). These prototypes and the procedure for quantifying the progress of Standard 90.1 have previously been described in detail (Thornton et al. 2011, Goel et al. 2014). As described in these reports, PNNL developed a suite of 16 prototype buildings covering the majority of the commercial building stock and mid-rise to high-rise residential buildings that are listed in Table 2.1. Each of the 16 prototype buildings are simulated in a representative city for each of 17 climate zones, 15 of which are located in the United States. Figure 2.1 shows the United States climate zone map and lists the

representative climate locations. Climate zones for international locations are available Standard 90.1 (ASHRAE 2013).

PNNL has created versions of the prototypes for each edition of Standard 90.1 published since 2004 including the 2004, 2007, 2010, and 2013 editions. This combination of prototypes, climate locations, and standard editions results in 1,088 individual building models which are available for download (BECF 2012). Energy and energy cost details for each of the 1,088 models are also available online (PNNL 2014). PNNL’s process of using prototypes to quantify the improvement of Standard 90.1 compared to previous editions is referred to as the Progress Indicator. Using the energy cost data for each of these models it is possible to develop PCI targets for each edition of Standard 90.1 compared to the 2004 baseline for each building type and climate zone. When creating the targets, related prototype buildings were combined resulting in 8 building types, as shown in Table 2.1, and the savings for the related prototype buildings were averaged to develop the building type savings.

Table 2.1 ASHRAE Commercial Prototype Building Models

Building Type	Prototype building	Prototype Floor Area (ft ²)
Office	Small Office	5,502
	Medium Office	53,628
	Large Office	498,588
Retail	Stand-Alone Retail	24,692
	Strip Mall	22,500
School	Primary School	73,959
	Secondary School	210,887
Healthcare/hospital	Outpatient Health Care	40,946
	Hospital	241,501
Lodging/hotel	Small Hotel	43,202
	Large Hotel	122,120
Warehouse	Warehouse	52,045
Restaurant	Fast Food Restaurant	2,501
	Sit-Down Restaurant	5,502
Apartment (Multi-family)	Mid-Rise Apartment	33,741
	High-Rise Apartment	84,360

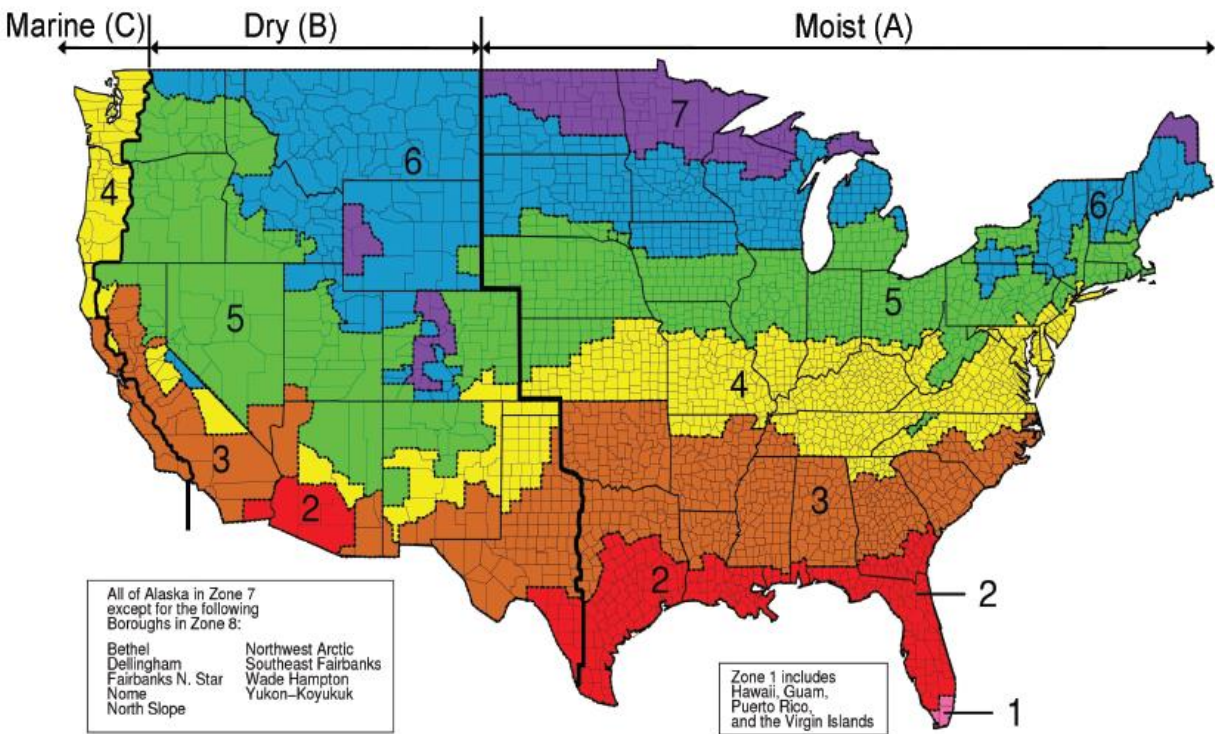


Figure 2.1 United States Climate Zone Map and Representative Cities

2.3 Performance Cost Index Targets for Compliance with Various Editions of Standard 90.1

Using the results of the Progress Indicator analysis, PCI targets have been developed for compliance with Standards 90.1-2010, 2013, and 2016. When doing this for Standard 90.1-2016, the Standing Standards Project Committee (SSPC) 90.1 took the approach of normalizing the PCI target for the amount of unregulated energy use in a proposed building model.¹ When using Appendix G for compliance, those

¹ In Standard 90.1, regulated energy use is defined as *energy used by building systems and components with requirements prescribed in Sections 5 through 10. This includes energy used for HVAC, lighting, service water heating, motors, transformers, vertical transportation, refrigeration equipment, computer-room cooling equipment, and other building systems, components, and processes with requirements prescribed in Sections 5 through 10. Unregulated energy use is energy used by building systems and components that is not regulated energy use.*

loads that are unregulated by the standard are kept the same between the proposed and baseline building models, so the PCI target can be adjusted, keeping the stringency the same between buildings with different amounts of unregulated load. When using Appendix G for quantifying building performance for beyond code programs that allow credit for improvements in unregulated loads, a different approach is taken that is described in the next section. The following equation is used to develop the PCI targets when using Appendix G for compliance:

$$PCI_t = \frac{(BBUEC + (BPF \cdot BBREC))}{BBP} \quad (\text{Eq. 2})$$

where:

- PCI_t = The maximum Performance Cost Index for a proposed design to comply with a particular edition of Standard 90.1.
- BBUEC = Baseline Building Unregulated Energy Cost. The portion of the annual energy cost of a baseline building design that is due to unregulated energy use.
- BBREC = Baseline Building Regulated Energy Cost. The portion of the annual energy cost of a baseline building design that is due to regulated energy use.
- BPF = Building Performance Factor (BPF) from Tables 2.2, 2.3, and 2.4. For building types not listed in those tables use “All Others.”¹ Where a building includes multiple building area types, the required BPF shall be equal to the area-weighted average of each building area type.
- BBP = Baseline Building Performance. The annual energy cost of the baseline building design including both regulated and unregulated energy use.

Building Performance Factors in Tables 2.2, 2.3, and 2.4 are developed according to the following equation:

$$BPF_{Year\ X} = \left(\frac{\sum \text{Prototype Building Regulated Energy Cost}_{Year\ X}}{\text{Prototype Building Regulated Energy Cost}_{2004}} \right) / N_p \quad (\text{Eq. 3})$$

where:

- Prototype Building Regulated Energy Cost_{year x} = The portion of annual energy cost due to regulated energy use from the PNNL prototype buildings for a given building prototype, climate zone and edition of Standard 90.1.
- Prototype Building Regulated Energy Cost₂₀₀₄ = The portion of annual energy cost due to regulated energy use from the PNNL prototype buildings for a given building prototype, climate zone and the 2004 edition of Standard 90.1.
- N_p = Number of prototype buildings of a particular building type from Table 2.1

¹ The BPF values for “All Others” are developed for each climate zone except 1B and 5C using weighted average values for each prototype building using national construction weights. For 1B and 5C straight numerical averages are used instead, since those climate zones do not exist in the U.S., and there are no national construction weights.

Table 2.2 Building Performance Factors (BPF) for Compliance with Standard 90.1-2010

Building Type	Climate Zone																Building Type Average	
	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7		8
Office	0.74	0.77	0.73	0.76	0.72	0.76	0.66	0.70	0.73	0.70	0.72	0.73	0.70	0.71	0.72	0.70	0.75	0.72
Retail	0.71	0.75	0.68	0.71	0.68	0.74	0.75	0.69	0.74	0.75	0.69	0.73	0.76	0.69	0.74	0.66	0.69	0.72
School	0.68	0.68	0.64	0.67	0.63	0.67	0.68	0.63	0.67	0.64	0.63	0.63	0.63	0.63	0.62	0.61	0.64	0.65
Healthcare	0.72	0.75	0.70	0.70	0.69	0.72	0.64	0.66	0.73	0.66	0.69	0.70	0.66	0.69	0.68	0.69	0.71	0.69
Restaurant	0.76	0.73	0.71	0.72	0.72	0.72	0.78	0.70	0.71	0.76	0.74	0.72	0.75	0.75	0.74	0.78	0.79	0.74
Hotel	0.80	0.82	0.76	0.77	0.77	0.81	0.80	0.76	0.81	0.78	0.72	0.77	0.73	0.71	0.73	0.69	0.70	0.76
Warehouse	0.63	0.62	0.67	0.69	0.67	0.69	0.73	0.69	0.71	0.72	0.70	0.71	0.74	0.74	0.73	0.73	0.76	0.70
Apartment	0.92	0.91	0.88	0.86	0.87	0.87	0.80	0.90	0.93	0.92	0.88	0.92	0.92	0.88	0.91	0.83	0.89	0.89
All Others	0.81	0.76	0.70	0.71	0.69	0.74	0.72	0.71	0.73	0.73	0.69	0.72	0.73	0.69	0.70	0.67	0.67	0.72

Table 2.3 Building Performance Factors (BPF) for Compliance with Standard 90.1-2013

Building Type	Climate Zone																Building Type Average	
	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7		8
Office	0.63	0.67	0.62	0.67	0.65	0.69	0.59	0.63	0.65	0.63	0.65	0.66	0.63	0.66	0.66	0.62	0.66	0.65
Retail	0.57	0.63	0.58	0.63	0.59	0.67	0.65	0.60	0.65	0.65	0.60	0.64	0.66	0.60	0.63	0.58	0.58	0.62
School	0.51	0.58	0.52	0.58	0.54	0.57	0.55	0.54	0.55	0.54	0.55	0.55	0.55	0.54	0.55	0.52	0.56	0.55
Healthcare	0.69	0.61	0.65	0.61	0.65	0.61	0.59	0.62	0.58	0.60	0.64	0.57	0.60	0.62	0.57	0.61	0.61	0.61
Restaurant	0.67	0.67	0.63	0.66	0.65	0.65	0.66	0.63	0.60	0.65	0.67	0.63	0.65	0.68	0.65	0.70	0.73	0.66
Hotel	0.69	0.70	0.67	0.65	0.68	0.70	0.69	0.67	0.69	0.67	0.65	0.66	0.65	0.64	0.66	0.62	0.63	0.67
Warehouse	0.56	0.57	0.61	0.63	0.62	0.64	0.68	0.63	0.65	0.68	0.65	0.66	0.70	0.71	0.71	0.72	0.72	0.66
Apartment	0.78	0.78	0.76	0.74	0.79	0.78	0.73	0.83	0.86	0.86	0.81	0.85	0.86	0.81	0.84	0.79	0.85	0.81
All Others	0.67	0.66	0.60	0.62	0.61	0.66	0.64	0.63	0.62	0.66	0.62	0.62	0.66	0.61	0.61	0.58	0.57	0.63

Developing BPFs for Standard 90.1-2016 posed a challenge for SSPC 90.1. The challenge was the BPFs needed to be developed in parallel with other changes to the standard, making it impossible to know what the final Progress Indicator savings for the 2016 edition will be. Based on the addenda to the standard already approved and a knowledge of addenda that could potentially be approved, the SSPC decided on an estimated reduction of 5% of the 2004 regulated energy cost beyond that achieved in 2013 for the 2016 BPFs. Table 2.4 includes a reduction of 0.05 from the 2013 BPFs.

Table 2.4 Building Performance Factors (BPF) for Compliance with Standard 90.1-2016

Building Type	Climate Zone																Building Type Average	
	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7		8
Office	0.58	0.62	0.57	0.62	0.60	0.64	0.54	0.58	0.60	0.58	0.60	0.61	0.58	0.61	0.61	0.57	0.61	0.60
Retail	0.52	0.58	0.53	0.58	0.54	0.62	0.60	0.55	0.60	0.60	0.55	0.59	0.61	0.55	0.58	0.53	0.53	0.57
School	0.46	0.53	0.47	0.53	0.49	0.52	0.50	0.49	0.50	0.49	0.50	0.50	0.50	0.49	0.50	0.47	0.51	0.50
Healthcare	0.64	0.56	0.60	0.56	0.60	0.56	0.54	0.57	0.53	0.55	0.59	0.52	0.55	0.57	0.52	0.56	0.56	0.56
Restaurant	0.62	0.62	0.58	0.61	0.60	0.60	0.61	0.58	0.55	0.60	0.62	0.58	0.60	0.63	0.60	0.65	0.68	0.61
Hotel	0.64	0.65	0.62	0.60	0.63	0.65	0.64	0.62	0.64	0.62	0.60	0.61	0.60	0.59	0.61	0.57	0.58	0.62
Warehouse	0.51	0.52	0.56	0.58	0.57	0.59	0.63	0.58	0.60	0.63	0.60	0.61	0.65	0.66	0.66	0.67	0.67	0.61
Apartment	0.73	0.73	0.71	0.69	0.74	0.73	0.68	0.78	0.81	0.81	0.76	0.80	0.81	0.76	0.79	0.74	0.80	0.76
All Others	0.62	0.61	0.55	0.57	0.56	0.61	0.59	0.58	0.57	0.61	0.57	0.57	0.61	0.56	0.56	0.53	0.52	0.58

Example 1 shows how compliance with Standard 90.1-2013 would be determined for a mixed use building in climate zone 5A.

Example 1. Code Compliance for a Mixed Use Building in Climate Zone 5A

The design for a mixed use building in Chicago, climate zone 5A is trying to determine if it complies with ASHRAE Standard 90.1-2013. The building is 50,000 ft² with 10,000 ft² of retail space and 40,000 ft² of residential apartments. Building simulation performed according to the rules of Appendix G-2013 result in the following:

Proposed building performance	=	\$32,000/year
Baseline building performance (BBP)	=	\$49,000/year
Baseline building regulated energy cost (BBREC)	=	\$34,000/year
Baseline building unregulated energy cost (BBUEC)	=	\$15,000/year

Question: Does the proposed building design comply with 90.1-2013?

Step 1. Determine Performance Cost Index from Equation 1:

$$\text{Performance Cost Index} = \frac{\text{Proposed Building Performance}}{\text{Baseline Building Performance}}$$

$$\text{Performance Cost Index} = \frac{\$32,000/\text{year}}{\$49,000/\text{year}} = 0.65$$

Step 2. Determine Building Performance Factor from Table 2.3:

Since the project is a mixed use building, the BPF is the area-weighted average of the appropriate building type BPFs for climate zone 5A from Table 2.3.

$$\text{Building Performance Factor} = \frac{40,000 \text{ ft}^2 * 0.81 + 10,000 \text{ ft}^2 * 0.60}{50,000 \text{ ft}^2} = 0.77$$

Step 3. Determine Performance Cost Index Target from Equation 2:

$$PCI_t = \frac{(BBUEC + (BPF \cdot BBREC))}{BBP}$$

$$PCI_t = \frac{(\$15,000 + (0.77 \cdot \$34,000))}{\$49,000} = 0.84$$

Answer: Yes, Performance Cost Index < Performance Cost Index Target (0.65 < 0.84)

2.4 Performance Cost Index Targets for Beyond Code Programs Referencing Various Editions of Standard 90.1

The process for developing PCI targets for beyond code programs that allow credit for improvements that are not regulated by Standard 90.1, such as cooking equipment, computer equipment, and commercial and industrial processes is more straight forward than developing similar targets for code compliance.

The biggest difference is that it is not necessary to normalize for the unregulated loads in a particular building. Most of these programs in fact encourage or incent reductions in these unregulated loads as well. The PCI target for these programs could simply be set to the ratio of the energy cost of any edition of a code or standard to the energy cost of the Standard 90.1-2004 baseline. No intermediate step of creating a building performance factor like that used for compliance is necessary. Nor is normalization for the energy cost of unregulated loads.

$$PCI_t = \left(\frac{\sum \text{Prototype Building Energy Cost}_Y}{\text{Prototype Building Energy Cost}_{2004}} \right) / N_p \quad (\text{Eq. 4})$$

where:

- PCI_t = The Performance Cost Index to which a proposed design is compared to determine the level to which that design exceeds the minimum requirements of a particular edition of Standard 90.1.
- $\text{Prototype Building Energy Cost}_Y$ = The annual energy cost of all energy use from the PNNL prototype buildings for a given building prototype, climate zone and edition of Standard 90.1¹.
- $\text{Prototype Building Energy Cost}_{2004}$ = The annual energy cost of all energy use from the PNNL prototype buildings for a given building prototype, climate zone and the 2004 edition of Standard 90.1.
- N_p = Number of prototype buildings of a particular building type from Table 2.1.

Performance Cost Index targets for used with beyond code programs referencing Standards 90.1-2010 and 90.1-2013 are shown in Tables 2.4 and 2.5 respectively. Values for 90.1-2016 can be calculated when the progress indicator for that standard is complete. The PCI_t s in Tables 2.4 and 2.5 can be used the same way a typical baseline value has been used historically in beyond code programs. The performance beyond code for a proposed building would then be calculated as follows:

$$\% \text{ Improvement beyond code} = 100 * \frac{PCI_t - PCI}{PCI_t} \quad (\text{Eq. 5})$$

where:

- PCI_t = Performance Cost Index Target taken from Tables 2.5, 2.6, and 2.7 for the appropriate standard, building type and climate zone. For building types not listed in those tables use “All Others.”² Where a building includes multiple building area types, the required PCI_t shall be equal to the area-weighted average of each building area type.
- PCI = Performance Cost Index calculated according to equation 1.

¹ This formula assumes the beyond code program will be based on an edition of Standard 90.1. An alternative approach is discussed in Section 2.5.

² The PCI_t values for “All Others” are developed for each climate zone except 1B and 5C using weighted average values for each prototype building using national construction weights. For 1B and 5C straight numerical averages are used instead, since those climate zones do not exist in the U.S., and there are no national construction weights.

Example 2 shows how this approach could be used for a beyond code program that references Standard 90.1-2013 as the basis of comparison.

Table 2.5 Performance Cost Index Targets (PCI_i) for Beyond Code Programs Citing Standard 90.1-2010

Building Type	Climate Zone																Building Type Average	
	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7		8
Office	0.81	0.82	0.80	0.82	0.80	0.82	0.78	0.79	0.81	0.80	0.80	0.81	0.80	0.79	0.80	0.78	0.81	0.80
Retail	0.73	0.77	0.71	0.73	0.71	0.76	0.78	0.72	0.77	0.78	0.72	0.76	0.79	0.72	0.76	0.69	0.71	0.74
School	0.75	0.75	0.72	0.75	0.72	0.76	0.78	0.72	0.76	0.74	0.73	0.73	0.74	0.72	0.73	0.71	0.72	0.74
Healthcare	0.80	0.82	0.79	0.79	0.79	0.81	0.77	0.77	0.81	0.78	0.79	0.79	0.78	0.79	0.78	0.78	0.79	0.79
Restaurant	0.86	0.84	0.83	0.84	0.84	0.84	0.89	0.83	0.84	0.87	0.85	0.84	0.86	0.85	0.85	0.86	0.86	0.85
Hotel	0.85	0.86	0.83	0.83	0.83	0.87	0.87	0.83	0.87	0.85	0.80	0.84	0.82	0.79	0.81	0.77	0.77	0.83
Warehouse	0.68	0.65	0.71	0.72	0.71	0.73	0.77	0.73	0.74	0.76	0.73	0.75	0.77	0.77	0.77	0.75	0.78	0.74
Apartment	0.94	0.93	0.91	0.89	0.91	0.91	0.87	0.93	0.95	0.94	0.91	0.94	0.94	0.91	0.93	0.87	0.92	0.92
All Others	0.85	0.82	0.77	0.77	0.76	0.81	0.81	0.78	0.80	0.81	0.77	0.79	0.81	0.77	0.78	0.75	0.74	0.79

Table 2.6 Performance Cost Index Targets (PCI_i) for Beyond Code Programs Citing Standard 90.1-2013

Building Type	Climate Zone																Building Type Average	
	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7		8
Office	0.72	0.76	0.72	0.76	0.75	0.78	0.74	0.74	0.76	0.75	0.75	0.76	0.75	0.75	0.76	0.72	0.74	0.75
Retail	0.60	0.66	0.62	0.66	0.63	0.70	0.70	0.64	0.69	0.69	0.64	0.68	0.70	0.64	0.67	0.62	0.61	0.66
School	0.59	0.65	0.60	0.66	0.62	0.66	0.66	0.63	0.65	0.64	0.64	0.65	0.65	0.64	0.65	0.62	0.64	0.64
Healthcare	0.78	0.72	0.76	0.72	0.76	0.73	0.74	0.73	0.71	0.74	0.75	0.71	0.74	0.74	0.70	0.72	0.72	0.73
Restaurant	0.80	0.79	0.77	0.78	0.78	0.79	0.81	0.77	0.76	0.79	0.79	0.77	0.79	0.80	0.78	0.80	0.81	0.79
Hotel	0.76	0.77	0.74	0.73	0.76	0.78	0.79	0.76	0.77	0.76	0.73	0.75	0.75	0.73	0.75	0.71	0.71	0.75
Warehouse	0.62	0.61	0.66	0.67	0.67	0.69	0.73	0.68	0.70	0.72	0.69	0.70	0.74	0.74	0.74	0.74	0.75	0.70
Apartment	0.84	0.83	0.83	0.81	0.85	0.85	0.83	0.88	0.90	0.90	0.86	0.89	0.90	0.86	0.88	0.84	0.89	0.86
All Others	0.75	0.73	0.69	0.70	0.70	0.74	0.75	0.72	0.71	0.75	0.70	0.71	0.75	0.70	0.70	0.68	0.64	0.71

2.5 Customizing Performance Targets

The intent of the new stable baseline for Appendix G is that it can be used for any code or beyond code program, even those not based on an edition of Standard 90.1. The key is that if the baseline remains consistent with that described in Appendix G, a user can use the same baseline model for multiple purposes and take advantage of software tools that automate the process of creating the baseline model. This requires creation of custom PCI targets using the methodology described in this report. By modifying the PNNL prototype building models to be consistent with an alternative code or beyond code performance threshold, the numerator in equations 3 or 4 can be changed to produce the new PCI_s.

One alternative which may be appropriate, especially for beyond code programs, is to reduce the number PCI_s. Instead of having a specific PCI_i for each building type and climate zone, the average improvement across all 16 climate locations can be used to create a consolidated PCI_i, shown as the building type average in the tables above.

Example 2. Beyond Code Performance for a Mixed Use Building in Climate Zone 5A

The building described in example 1 is trying to determine by what percentage it exceeds the minimum compliance requirements of Standard 90.1-2013 for use in a green building rating system.

Question: For this building, what is the percent improvement over the Standard 90.1-2013?

Step 1. Determine Performance Cost Index from Equation 1:

The Performance Cost Index is the same as was determined in Example 1.

$$\text{Performance Cost Index} = \frac{\$32,000/\text{year}}{\$49,000/\text{year}} = 0.65$$

Step 2. Determine the Performance Cost Index Target from Table 2.6:

Since the project is a mixed use building, the PCI_t is the area-weighted average of the appropriate PCI_t s for the building types and climate zone 5A from Table 2.6.

$$\text{Performance Cost Index Target } (PCI_t) = \frac{40,000 \text{ ft}^2 * 0.86 + 10,000 \text{ ft}^2 * 0.64}{50,000 \text{ ft}^2} = 0.82$$

Step 2. Determine the percent improvement beyond 90.1-2013 from Equation 5:

$$\% \text{ Improvement beyond code} = 100 * \frac{PCI_t - PCI}{PCI_t}$$

$$\% \text{ Improvement beyond 90.1 - 2013} = 100 * \frac{0.82 - 0.65}{0.82} = 21\%$$

Answer: The proposed design is 21% better than 90.1-2013

3.0 References

42 U.S.C. 6833. Chapter 42, U.S. Code, Section 6833. <http://www.gpo.gov/fdsys/pkg/USCODE-2010-title42/pdf/USCODE-2010-title42-chap81-subchapII-sec6833.pdf>.

ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers). 2013. *Energy Standard for Buildings Except Low-Rise Residential Buildings*. ANSI/ASHRAE/IES Standard 90.1-2013, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.

ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers). 2015. *Energy Standard for Buildings Except Low-Rise Residential Buildings-Addenda 2015 Supplement*. ANSI/ASHRAE/IES Standard 90.1-2013, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA. https://www.ashrae.org/File%20Library/docLib/StdAddenda/2015_Supplement_to_Standard_90_1_2013.pdf

ASHRAE. 2014. *Standard for the Design of High-Performance Green Buildings*. ANSI/ASHRAE/IES Standard 189.1-2014, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, GA.

BECP (U.S. Department of Energy, Building Energy Codes Program). 2012. *Commercial Building Prototype Models*. Accessed October 23, 2012 at http://www.energycodes.gov/development/commercial/90.1_models.

DOE (U.S. Department of Energy). 2013. *Energy Plus Energy Simulation Software, Version 8.0*. U.S. Department of Energy, Washington, D.C. Available at <http://apps1.eere.energy.gov/buildings/EnergyPlus/>.

Goel S, M Rosenberg, R Athalye, Y Xie, W Wang, R Hart, J Zhang, V Mendon 2014. *Enhancements to ASHRAE Standard 90.1 Prototype Building Models*. Pacific Northwest National Laboratory, Richland, Washington. Available at https://www.energycodes.gov/development/commercial/90.1_models.

ICC (International Code Council). 2015. *2015 International Green Construction Code*. Washington, D.C.

PNNL (Pacific Northwest National Laboratory). 2014. *2013EndUseTables.xlsx*. Pacific Northwest National Laboratory, Richland, WA. Available at <http://www.energycodes.gov/sites/default/files/documents/2013EndUseTables.zip>.

Rosenberg, M., C. Eley, 2013. *A Stable Whole Building Performance Method for Standard 90.1* ASHRAE Journal May 2013.

Thornton BA, M Rosenberg, EE Richman, W Wang, Y Xie, J Zhang, H Cho, VV Mendon, RA Athalye, and B Liu. 2011. *Achieving the 30% Goal: Energy and Cost Savings Analysis of ASHRAE Standard 90.1-2010*. PNNL-20405, Pacific Northwest National Laboratory, Richland, Washington.

USGBC (United States Green Building Council). 2014. *LEED V4 for Building Design and Construction*. http://www.usgbc.org/sites/default/files/LEED%20v4%20BDC_10%2001%2014_current.pdf.



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