ASHRAE/IES Standard 90.1-2022 Performance Path Changes

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Many changes to the whole-building performance paths in ASHRAE/IES Standard 90.1 were made between the 2019 and 2022 versions, based on addenda that have gone through the public review process and achieved consensus. Many addressed feedback received by the Energy Cost Budget subcommittee from modelers, jurisdictions and beyond-code program administrators. Addenda included adding new appendices as well as major changes to language of the Energy Cost Budget Method (ECBM) and Performance Rating Method (PRM). This article is intended to help those familiar with the performance paths understand the major changes in the 2022 edition of ASHRAE/IES Standard 90.1, *Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings*.

If you have looked through the standard already, one of the first questions you might have had was: "Where is the Energy Cost Budget Method section?" Don't worry. This section has simply been renumbered to Section 12 after many years of being Section 11. A new section called "Additional Efficiency Requirements" is now Section 11 and includes the energy credit requirements that were explained in an article in the August 2023 *ASHRAE Journal* ("Energy Credits—A New Way to Save in ASHRAE/IES Standard 90.1-2022"). All the requirements for ECBM are still present, but with some changes. These changes, as well as ones to PRM and some brand-new appendices that may be useful to modelers and rating authorities, will be discussed below. A summary of all the changes is shown in Standard 90.1-2022 Appendix M, but if you want more details and want to see the exact changes, take a look at the following: https://tinyurl.com/y8zxv3ez.

Building Performance Factors (Addendum *bv*)

One of the more impactful changes is the update to Table 4.2.1.1, which contains the Building Performance Factors (BPFs). These factors indicate the required improvement in regulated energy use compared to the baseline. The Performance Cost Index Target (PCI_t) is derived from the BPFs, and due to a new and more accurate approach, about 60% of the BPFs have become less stringent. *Table 1* shows the

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2019 and 2022 factors, and the coloration indicates the change in stringency.

Historically, the BPFs were determined as a ratio of regulated loads in prototype building models compliant with the current edition of Standard 90.1 to those compliant with Standard 90.1-2004. This methodology, while capturing the general logic of quantifying the performance of a proposed design relative to the Appendix G stable baseline, did not account for differences between the configuration of the 2004 prototype models and the baseline modeling requirements of Appendix G. Pacific Northwest National Laboratory (PNNL) has since developed a set of prototype models configured to align more closely with the Appendix G baseline rules, such as for HVAC system types, HVAC system assignments and construction materials. Using this new set of prototypes resulted in significant differences in the BPFs.

Chiller Performance Curves (Addendum *bd*)

Energy simulation software relies on a series of performance curves to represent the part-load performance of chillers (as well as other HVAC equipment). Developing or finding appropriate performance curves for budget or baseline equipment has been challenging for energy modelers. When the proposed building does not use a chiller, and one is required in the baseline, getting data from manufacturers on detailed chiller performance is especially difficult. As a first step to consistently providing this information, chiller performance curves developed by PNNL were added in a new Appendix J, Sets of Performance Curves, and referenced in both ECBM and PRM.

For the ECBM, the chillers in the budget design must minimally comply with the full- and part-load efficiency requirements in Section 6, Heating, Ventilating, and

TABLE 1 Changes to the Building Performance Factors (BPFs).

2019 BUILDING PERFORMANCE FACTORS

BUILDING AREA TYPE	CLIMATE ZONE																
	0A AND 1A	0B AND 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.68	0.70	0.66	0.66	0.69	0.68	0.59	0.74	0.76	0.74	0.70	0.73	0.75	0.68	0.71	0.68	0.72
Healthcare/hospital	0.60	0.60	0.58	0.54	0.56	0.55	0.55	0.55	0.54	0.54	0.57	0.52	0.54	0.57	0.52	0.57	0.57
Hotel/motel	0.55	0.53	0.53	0.52	0.53	0.54	0.54	0.53	0.53	0.52	0.50	0.51	0.51	0.50	0.51	0.50	0.50
Office	0.52	0.57	0.50	0.56	0.53	0.56	0.48	0.51	0.52	0.49	0.51	0.51	0.49	0.52	0.51	0.49	0.51
Restaurant	0.63	0.64	0.60	0.60	0.60	0.61	0.58	0.62	0.57	0.61	0.63	0.60	0.64	0.65	0.62	0.67	0.70
Retail	0.51	0.54	0.49	0.55	0.51	0.55	0.53	0.51	0.55	0.54	0.50	0.54	0.55	0.50	0.51	0.48	0.50
School	0.39	0.47	0.38	0.43	0.38	0.42	0.40	0.37	0.40	0.38	0.36	0.40	0.36	0.36	0.37	0.36	0.37
Warehouse	0.38	0.42	0.40	0.42	0.43	0.44	0.43	0.44	0.43	0.46	0.49	0.47	0.48	0.54	0.51	0.57	0.57
All others	0.56	0.57	0.50	0.52	0.50	0.54	0.53	0.53	0.52	0.54	0.51	0.51	0.50	0.50	0.50	0.50	0.46

2022 BUILDING PERFORMANCE FACTORS

BUILDING AREA TYPE	CLIMATE ZONE																
	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.69	0.68	0.71	0.70	0.72	0.72	0.71	0.76	0.63	0.69	0.76	0.71	0.66	0.72	0.71	0.65	0.67	0.65	0.67
Healthcare/Hospital	0.69	0.69	0.70	0.68	0.67	0.65	0.65	0.66	0.64	0.64	0.66	0.63	0.67	0.65	0.65	0.66	0.67	0.68	0.70
Hotel/Motel	0.66	0.66	0.69	0.65	0.65	0.64	0.64	0.65	0.65	0.63	0.65	0.63	0.62	0.63	0.62	0.61	0.62	0.59	0.58
Office	0.54	0.54	0.53	0.52	0.52	0.52	0.50	0.54	0.48	0.48	0.53	0.48	0.49	0.52	0.48	0.48	0.49	0.46	0.48
Restaurant	0.62	0.59	0.57	0.57	0.57	0.53	0.57	0.53	0.51	0.55	0.54	0.54	0.57	0.56	0.55	0.59	0.58	0.61	0.64
Retail	0.51	0.49	0.48	0.48	0.44	0.43	0.43	0.43	0.44	0.42	0.43	0.46	0.43	0.42	0.47	0.43	0.43	0.41	0.44
School	0.52	0.57	0.57	0.56	0.52	0.53	0.52	0.49	0.50	0.46	0.47	0.47	0.47	0.46	0.46	0.46	0.44	0.45	0.45
Warehouse	0.26	0.26	0.22	0.25	0.21	0.22	0.25	0.21	0.19	0.25	0.22	0.22	0.28	0.24	0.22	0.31	0.28	0.29	0.32
All Others	0.62	0.60	0.62	0.59	0.55	0.51	0.53	0.52	0.55	0.53	0.52	0.55	0.53	0.53	0.56	0.54	0.54	0.54	0.54

Increase in Stringency Decrease in Stringency

Air Conditioning, for the appropriate chiller type and capacity. Appendix G's baseline chillers must be modeled with part- and full-load efficiencies specified in Table G3.5.3. Chillers in the proposed designs must be modeled with the specified equipment's part- and full-load efficiency. Most simulation programs do not accept IPLV as an input and require specifying performance curves that define variations in system performance depending on the operating conditions.

Since the performance curves for the budget/baseline chillers were not prescribed, modelers often had to rely on software default performance curves, which differ between simulation programs and do not reflect the intended IPLV. While performance curves can be generated based on detailed information for the specified chiller obtained from the manufacturer, these equipment-specific curves are often unavailable during the preliminary analysis before the chiller make and model is known. Furthermore, creating custom performance curves requires knowledge and time modelers often do not have; thus, the software default curves are often used even after chillers are specified. This change addresses these issues by prescribing the performance curves that must be used for the baseline and budget chillers and providing default performance curves that may be modeled for the chillers in the proposed design if the actual equipment curves are not available.

Lighting Clarifications (Addendum *af*)

Several clarifications to how lighting is modeled were made in the PRM. The first ensures that lighting power is determined using the same approach (Building Area Method versus Space-by-Space Method) for situations where a lighting system neither exists nor has been designed. Table G3.1, Part 6 (Lighting), item c for the proposed building now reads:

"Where lighting neither exists nor is submitted with design documents, lighting shall comply with but not exceed the requirements of Section 9. Where space types are known, lighting power shall be determined in accordance with the Space-by-Space Method. Where space types are not known, lighting power shall be determined in accordance with the Building Area Method."

Table G3.1, Part 6, the baseline building reads, in part:

"Interior lighting power in the baseline building design shall be determined using the values in Table G3.7-1 and G3.7-2. However, where lighting neither exists nor is submitted with design documents, and the proposed design lighting power is determined in accordance with the Building Area Method, the baseline building design lighting power shall be determined in accordance with Table G3.8."

The second change removed baseline exterior lighting power allowances for non-tradable surfaces and clarified that the baseline lighting power for all such exterior lighting applications must be modeled the same as specified for the proposed design.

The third change adds a baseline allowance for retail display lighting that is equal to the proposed design. Table G3.1, Part 6, the baseline building now reads, in part:

"Where retail display lighting is included in the proposed building design in accordance with Section 9.5.2.2(b), the baseline building design retail display lighting additional power shall be equal to the limits established by Section 9.5.2.2(b) or same as proposed, whichever is less."

Section 9.5.2.2(b) is where the additional lighting power for retail displays is described.

Alternative Metrics (Addendum *ch*)

The addition of informative Appendix I, Using Other Metrics in Conjunction with Appendix G Performance Rating Method When Approved by the Rating Authority, is intended for jurisdictions and beyond-code programs that choose to use Appendix G compliance metrics other than energy cost. It addresses concerns expressed by some adopters that using cost metric in conjunction with the PRM independent baseline discourages electrification in locations with high electricity costs relative to gas. The new appendix includes BPF tables based on site energy, source energy or carbon emissions to replace the cost-based BPF values from Section 4.2.1.1. *Table 2* is an example BPF table from the new Appendix I.

The new Appendix I also includes a methodology for calculating custom BPFs for jurisdictions and beyond-code programs that choose to use local energy costs or conversion factors when emissions or source energy is the selected metric.

The appendix includes sample language showing how a jurisdiction would amend Standard 90.1 to adopt alternate compliance metrics. The example shows the proper changes using strikeout and underline markups and how to make changes to Section 3, Section 4 and Appendix G and includes an example of the changes. If a jurisdiction or beyond-code program were to adopt Appendix I, they would provide the details to the

TABLE 2 Example Building Performance Factors (BPF) table from Standard 90.1's new Appendix I.

Table I3-1 Building Performance Factors (BPF), Carbon Emission

	Climate Zone																		
Building Area Type	**0A**	**0B**	**1A**	**1B**	**2A**	**2B**	**3A**	**3B**	**3C**	**4A**	**4B**	**4C**	**5A**	**5B**	**5C**	**6A**	**6B**	**7**	**8**
Multifamily	0.71	0.69	0.73	0.71	0.74	0.74	0.74	0.75	0.67	0.64	0.73	0.67	0.60	0.67	0.66	0.59	0.61	0.58	0.60
Healthcare/hospital	0.68	0.67	0.69	0.67	0.66	0.63	0.64	0.65	0.63	0.63	0.65	0.62	0.66	0.64	0.67	0.65	0.67	0.69	0.70
Hotel/motel	0.67	0.67	0.70	0.66	0.67	0.66	0.66	0.68	0.68	0.64	0.67	0.65	0.63	0.65	0.65	0.61	0.63	0.59	0.58
Office	0.54	0.54	0.53	0.52	0.52	0.52	0.50	0.54	0.48	0.47	0.52	0.48	0.49	0.52	0.49	0.48	0.50	0.45	0.47
Restaurant	0.63	0.60	0.59	0.58	0.58	0.55	0.59	0.58	0.56	0.61	0.60	0.60	0.64	0.63	0.62	0.66	0.66	0.68	0.70
Retail	0.51	0.49	0.48	0.48	0.44	0.43	0.43	0.43	0.44	0.44	0.44	0.48	0.47	0.45	0.49	0.47	0.46	0.45	0.47
School	0.52	0.57	0.57	0.56	0.52	0.53	0.53	0.51	0.52	0.44	0.48	0.50	0.45	0.48	0.48	0.45	0.43	0.43	0.45
Warehouse	0.26	0.26	0.22	0.25	0.21	0.22	0.25	0.21	0.18	0.31	0.24	0.27	0.38	0.31	0.26	0.41	0.36	0.37	0.41
All others	0.63	0.61	0.63	0.60	0.55	0.52	0.54	0.54	0.57	0.54	0.53	0.56	0.55	0.55	0.58	0.56	0.56	0.55	0.56

modelers on what tables to use and the appropriate language changes.

Renewable Energy (Addenda *ck*, *cp*)

A new prescriptive requirement in Standard 90.1-2022 requires on-site renewable energy of "not less than 0.50 W/ft^2 [5.4 W/m^2] multiplied by the sum of the gross conditioned floor area for all floors up to the three largest floors," with some exceptions. This new prescriptive requirement prompted new rules for both the ECBM and the PRM to allow buildings that cannot meet that requirement or allow limited credit to buildings that exceed it.

For ECBM, which already had a section on renewables, the existing 5% limit on renewable energy trade-offs has been changed to 5% in excess of the new required amount. To support this requirement, a new row was added to Table 12.5.1 that describes the configuration of on-site renewable energy systems that must be modeled in the budget design. For proposed designs that include the on-site renewable energy systems, the budget design must be modeled with renewable energy systems of the same system type but with capacity minimally compliant with the applicable prescriptive requirements in Section 10.5.1.1. For proposed designs with no on-site renewable systems, the modeling assumptions for a default unshaded photovoltaic system to be modeled in the budget design are provided.

For PRM, Table G3.1 also has a new section on on-site renewable energy, but the baseline does not include renewable energy in this case. Instead, in Section 4, the Performance Cost Index Target (PCI_t) equation has been modified to account for the prescriptively required renewable energy. Similar to the ECBM, the equation caps the contribution of renewable energy toward compliance at 5% over the prescriptively required amount. The equation also requires modeling the proposed design with a virtual, minimally code-compliant on-site renewable energy system in place of the specified system. Configuration of this virtual system is determined following the same rules as prescribed for the ECBM budget design.

ECBM Economizers and Budget HVAC System Cleanup (Addendum *u*)

A significant change was made related to the type of economizer used in Section 12.5.2, HVAC Systems.

The previous version of the standard set the type of economizer, air or fluid, in the budget to be the same type as used in the proposed building. The update requires the budget to simply use air economizers no matter what is in the proposed building. This update clarifies what should be done if the proposed design does not have an economizer and makes the budget simpler to model since modeling air economizers is generally straightforward, but modeling fluid economizers is often more complicated.

Separate from the economizer change, language was added to ECBM to align with the approach used in PRM and describe the methodology for determining budget system capacity in cases when multiple thermal blocks that may be served by different HVAC systems in the proposed design are aggregated. Some of the text was originally in a different subsection on Supply Fan Energy in Certain Packaged Equipment but has been moved to a subsection of 12.5.2 HVAC Systems, which now reads:

"i. Equipment Capacities. The equipment capacities for the budget building design shall be sized proportionally to the capacities in the proposed design based on sizing runs, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the proposed design and budget building design. Where multiple HVAC zones are combined into a single thermal block or modeled as identical thermal blocks to which multipliers are applied in accordance with Table 12.5.1, the equipment capacities for the budget building design shall be determined as follows:

1. For budget system Types 8 and 10, equipment capacity shall be 9,000 Btu/h [2.6 kW].

2. For budget system Types 5, 6, 7, 9, and 11, equipment capacity shall be based on the load of the thermal block divided by the number of combined HVAC zones.

3. For budget system Types 1, 2, 3, and 4, equipment capacity shall be based on the total load of all associated thermal blocks, including multipliers, divided by the total number of corresponding HVAC systems specified in the design documents.

Unmet load hours for the proposed or baseline building designs shall not exceed 300 hours (of the 8,760 hours simulated). The unmet load hours for the proposed design shall not exceed the unmet load hours for the budget building design. Alternatively, unmet load hours exceeding these limits may be approved by the building official, provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads."

PRM Baseline System Section Clarifications (Addendum *ab*)

An update to the PRM Baseline HVAC System Type and Description section and subsections helps to clarify the selection process for the baseline system.

1. All residential spaces, regardless of size in any building, shall be modeled with a baseline system type 1 or 2, depending on the climate zone.
2. Where a building includes nonresidential spaces such as corridors, storage rooms, rest rooms, a small lounge or office that are designed to primarily serve the residents of a building and that are located on a floor where the majority of the gross floor area is a residential space types, such nonresidential spaces are to be modeled as system types 3 and 4.
3. The proposal clarifies how baseline HVAC systems shall be selected.

a. First, the combined floor area of conditioned and semi-heated floors is determined for the building area types used to determine baseline HVAC systems.

b. Second, the nonresidential building area type with the largest floor area calculated in Step 1 is classified as the predominant nonresidential building area type. Any building area type with less than 20,000 ft^2 (1858 m^2) from Step 1 is considered part of the predominant nonresidential building area type.

c. Assign baseline HVAC system types for the residential building area type, the predominant building area type and any other nonresidential building area types with more than 20,000 ft^2 (1858 m^2) from Step 1.

d. Once baseline HVAC systems are determined, they shall be added or altered for individual HVAC zones based on certain criteria. Criteria related to HVAC zone-specific baseline system changes were put in a new section.

PRM Retrofits (Addendum *co*)

The standard has requirements that apply only to building alterations for the envelope, HVAC&R and service water heating. These requirements typically apply only to the systems that are being altered and are often less stringent than requirements for new construction projects. Prior to Addendum *co*, PRM did not differentiate between new construction and retrofit projects, resulting in PRM having greater stringency for some retrofit projects compared to other compliance options. Addendum *co* adopted different approaches

for substantial alterations versus limited retrofits.

1. For substantial alterations, Section 4.2.1.3 was modified to increase the BPF by 5% relative to the values for new construction projects. The BPF increase is a relaxation in stringency that was selected based on committee judgment and experience of several beyond-code programs and jurisdictions.

2. For limited alterations that do not qualify as substantial alterations, a new PRM Section G3.3 was added with the modeling rules that are conceptually similar to ECBM.

a. The proposed design is modeled following existing requirements in Table G3.1—new and retrofitted systems and equipment are modeled based on the design documents, while systems and equipment excluded from the scope of retrofit are modeled based on the existing conditions.

b. The baseline design is modeled the same as the proposed design, except the system and equipment included in the retrofit scope are modeled at the efficiency levels minimally compliant with the mandatory and prescriptive requirements in Sections 5–10 applicable to retrofit projects.

Section 4.2.1.3 was modified to prescribe BPF = 1 for such projects. The BPF reflects the difference in stringency of the baseline model, which is generally aligned with the requirements of Standard 90.1- 2004 and the edition of Standard 90.1 for which compliance is demonstrated. Since the modeling rules in Section G3.3 prescribe modeling baseline for the limited retrofits as minimally compliant with the current edition of 90.1, the BPF of 1 is appropriate.

In addition, Section 4.2.1.1 was modified to indicate that for projects involving an existing building and an addition, the BPF must be calculated as an area-weighted average of the existing building BPF from Section 4.2.1.3 and the addition BPF from Table 4.2.1.1.

FIGURE 1 Overall approach to envelope backstop.

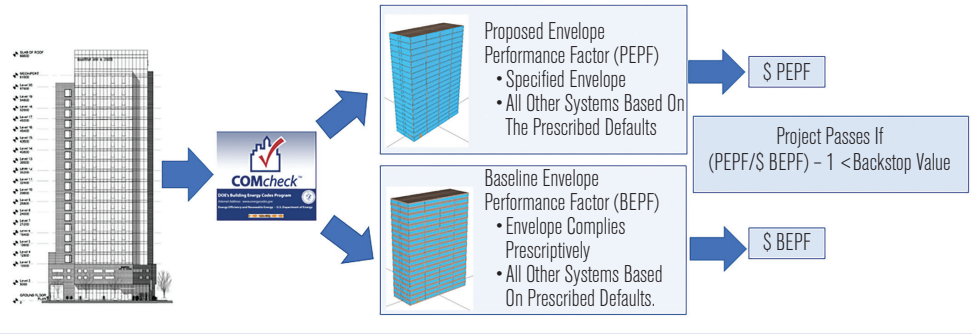
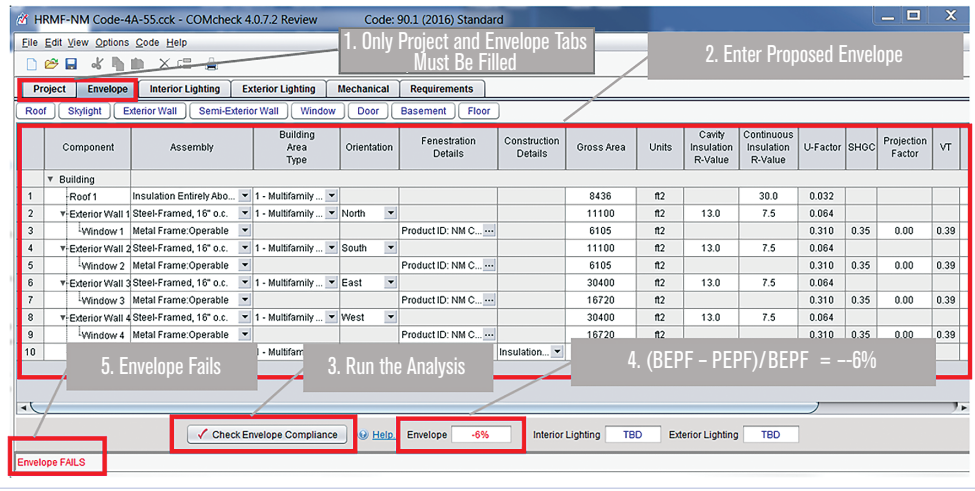


FIGURE 2 Example use of COMcheck for envelope backstop.



Envelope Backstop (Addendum *cr*)

A new requirement was added to the performance-based compliance pathways of both ECBM and PRM that limits the trade-off of prescriptive envelope performance. Some studies[1,2] have concluded that weaker building envelopes can permanently limit building energy performance even as lighting and HVAC components are upgraded over time because retrofitting the envelope is less likely and more expensive. States and jurisdictions around the country have raised this issue. The trade-off limits are based on the envelope performance factors and are calculated in accordance with the building envelope performance compliance option (Appendix C, Methodology For Building Envelope Trade-Off Option In Section 5.6), which is implemented in the COMcheck software. The new language says:

"For new buildings, one of the following is met:

1. The building envelope complies with Section 5.5, "Prescriptive Building Envelope Compliance Path"; or

2. Using Section 5.6, "Building Envelope Trade-Off Option," the proposed envelope performance factor shall not exceed the base envelope performance factor by more than 15% in multifamily, hotel/motel, and dormitory building area types. For all other building area types, the limit shall be 7%. For buildings with both residential and nonresidential occupancies, the limit shall be based on the area weighted average of the gross conditioned floor area."

This requirement preserves design flexibility and minimizes documentation effort while improving long-term building performance (*Figures 1* and *2*).

Other ECBM and PRM Changes

PRM Addenda

Addendum *db*. Clarifications for determining base space conditioning categories.

Addendum *h*. Clarifies procedure for area weight BPFs for mixed-use buildings.

Addendum *l*. Clarifies how fenestration is apportioned in the baseline building.

Addendum *aa*. Fixes inconsistencies in the SI version for fan power and italicizes "on-site."

Addendum *aj*. Clarifies that transformers falling between size ranges in Table 8.4.4 shall use linear interpolation for baseline efficiency.

Addendum *an*. Clarifies and consolidates requirements for fan system operation.

Addendum *bt*. Requires baseline chilled water (CW) and hot water (HW) pumps to run only when load exists.

Addendum *cq*. Changes "water-cooled" to "fluid-cooled" and other minor edits.

Addendum *da*. Aligns PRM documentation simulation program requirements with ECB.

Addendum *i*. Provides exception from baseline energy recovery requirements for systems serving a laboratory zone with a total laboratory exhaust volume greater than 15,000 cfm (7079 L/s).

Addendum *w*. Clarifies baseline chillers are sized based on peak coincident load.

Addendum *ct*. Clarifies how window to wall ratio (WWR) is determined; specifies baseline does not include automatic shading, removed redundant reference to roof albedo.

ECBM

Addendum *bh*. Updates the temperature coefficient of performance (COP) for photovoltaic (PV) baseline systems for consistency with PV Watts.

Addendum *cs*. Requires baseline high-capacity gas boilers to meet increased efficiency and baseline service water heating (SWH) equipment to meet prescriptive requirements.

Addendum *k*. Eliminates baseline fan power credit for energy recovery when energy recovery is not in the baseline design.

Addendum *s*. Establishes solar reflectance requirements for baseline walls.

ECBM and PRM

Addendum *be*. Updates Standard 140 required testing for simulation programs.

Addendum *bg*. Expands applicability to buildings sites and properties in accordance with the general expansion of Standard 90.1 scope.

Addendum *bu*. Informative note recommending the use of ASHRAE Standard 209.

Addendum v. Clarifies the documentation (including the simulation file) submitted to the authority having jurisdiction [AHJ]).

Addendum *t*. Specifies requirements for simulating envelope air leakage in baseline and proposed building.

Addendum *ad*. Renumbers reference sections for consistency with changes to other sections.

Addendum *av*. Specifies how thermal bridges are modeled in the baseline and proposed designs.

Summary

Many changes to performance paths, ECBM and PRM, are based on feedback from the modeling and compliance communities. We will continue to balance the needs of different groups in future changes to these performance paths. If you would like to be involved in the process of future updates, consider attending Energy Cost Budget subcommittee meetings. Many thanks to the ECB subcommittee, SSPC 90.1 and ASHRAE staff.

References

1. Thornton, B.A., G.P. Sullivan, M.I. Rosenberg, M.C. Baechler. 2015. "Preserving Envelope Efficiency in Performance Based Code Compliance." PNNL-24359. Pacific Northwest National Laboratory for the United States Department of Energy.

2. Jonlin, D., B. Thornton, M. Rosenberg. 2016. "Can High-Performance Equipment Lead to a Low-Performance Building?" ACEEE Summer Study on Energy Efficiency in Buildings. ■