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The Evolution of Energy Modelling

LEED v4 vs. v5: ASHRAE 90.1 Appendix G

7 March 2025

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8

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Introduction



Energy Modelling

Energy modelling is the process of simulating a building's energy performance to assess efficiency and compliance with standards



Why Energy Modelling in LEED

To demonstrate compliance with LEED's energy efficiency requirements:

- EAp: Minimum Energy Efficiency
- EAc: Optimized/Enhanced Energy Efficiency

LEED v4

Option 1: Whole Building Simulation - ASHRAE 90.1 2010

Appendix G: Performance Rating Method (PRM)

LEED v5

Option 1: ASHRAE 90.1-2019
Option 2: ASHRAE 90.1-2022

Section 4.2 of ASHRAE

Appendix G: PRM



LEED v5

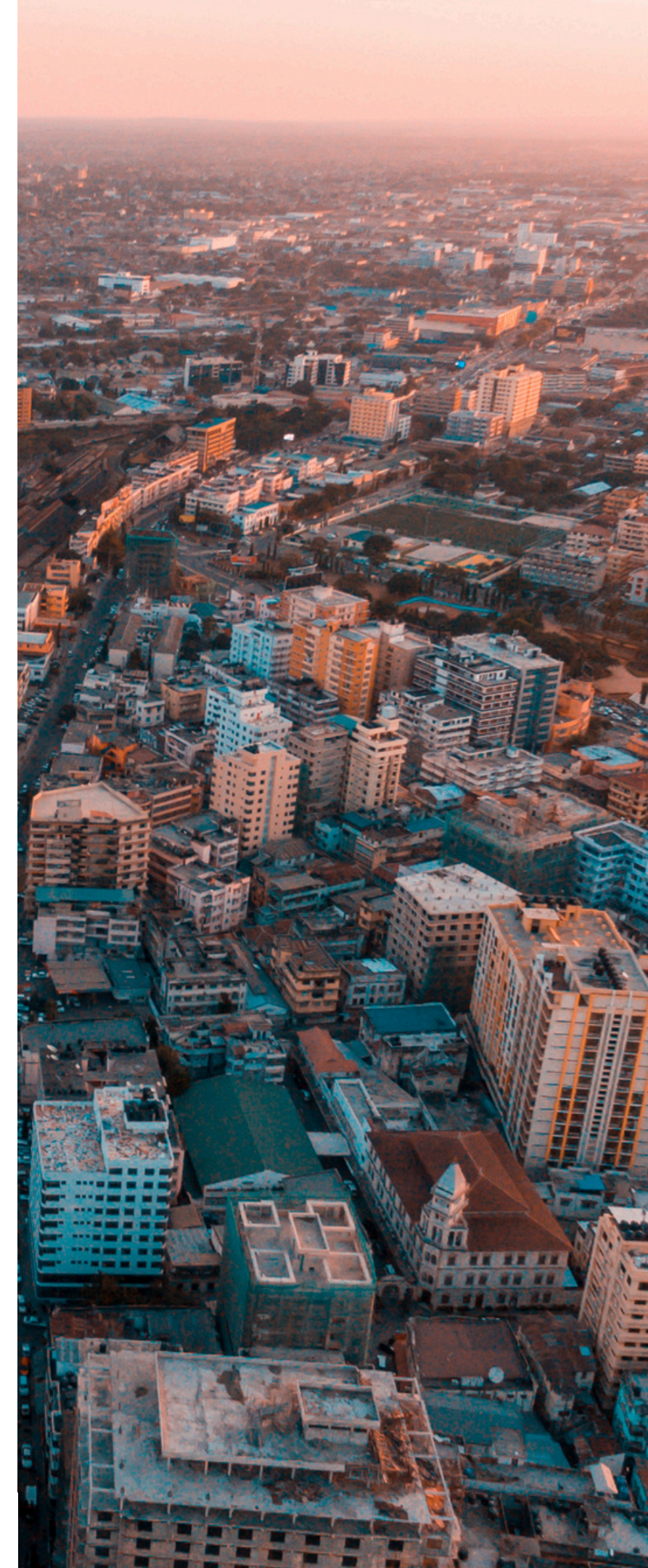
- Before January 1, 2028: Option 1 or 2
- After January 1, 2028: Only Option 2

ASHRAE 90.1-2010 vs. ASHRAE 90.1-2022
(LEED v4 vs. LEED v5)

Two Main Aspects

How Baseline Buildings Are
Defined in Different ASHRAE
Versions

How Performance Metrics &
Savings Comparisons Have
Changed





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How ASHRAE Appendix G Defines the Baseline Model (Old vs. New Versions)

Proposed Model

A model created using simulation software (e.g., IES VE) based on the actual design documents of the building.

Baseline Model

A model created following predefined rules in ASHRAE 90.1 Appendix G, serving as a consistent reference for evaluating energy savings.

Appendix G: Baseline Model (ASHRAE 90.1-2010 vs. ASHRAE 90.1-2022)

The Main Differences

Selecting the Baseline HVAC
System Type

Changes in Baseline Model
Requirements



Selecting the Baseline HVAC System Type

ASHRAE 90.1-2010 (LEED v4): The baseline HVAC system was determined based on the heating type of the proposed building + building type.

ASHRAE 90.1-2019/2022 (LEED v5): The baseline HVAC system is now selected based on climate zone + building type.

Changes in Baseline Model Requirements

Building Envelope

- Stricter U-values for opaque and transparent surfaces
- Tighter air infiltration requirements

HVAC Systems

- Higher minimum equipment efficiency requirements
- New subsections added (e.g., refrigeration)

Lighting

- Significant reduction in Lighting Power Densities (LPD)
- More advanced lighting controls are now required

Baseline Model Values

- **ASHRAE 90.1-2010:** Mandatory Provisions
- **ASHRAE 90.1-2019/2022:** Data inside Appendix G

Final Impact

Since baseline models are now more energy-efficient, the proposed model has less room for improvement, leading to:

- Lower savings
- Fewer credits awarded in LEED



Baseline Model System Selection

2010

Building Type	Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat	Electric and Other
Residential	System 1—PTAC	System 2—PTHP
Nonresidential and 3 Floors or Less and <2300 m ²	System 3—PSZ-AC	System 4—PSZ-HP
Nonresidential and 4 or 5 Floors and <2300 m ² or 5 Floors or Less and 2300 m ² to 14,000 m ²	System 5—Packaged VAV with Reheat	System 6—Packaged VAV with PFP Boxes
Nonresidential and More than 5 Floors or >14,000 m ²	System 7—VAV with Reheat	System 8—VAV with PFP Boxes
Heated Only Storage	System 9—Heating and Ventilation	System 10—Heating and Ventilation

2019

Building Type, Number of Floors, and Gross Conditioned Floor Area	Climate Zones 3B, 3C, and 4 to 8	Climate Zones 0 to 3A
<i>Residential</i>	<i>System 1—PTAC</i>	<i>System 2—PTHP</i>
Public assembly <11,000 m ²	<i>System 3—PSZ-AC</i>	<i>System 4—PSZ-HP</i>
Public assembly ≥11,000 m ²	<i>System 12—SZ-CV-HW</i>	<i>System 13—SZ-CV-ER</i>
Heated-only storage	<i>System 9—Heating and ventilation</i>	<i>System 10—Heating and ventilation</i>
Retail and 2 floors or fewer	<i>System 3—PSZ-AC</i>	<i>System 4—PSZ-HP</i>
Other nonresidential and 3 floors or fewer and <2300 m ²	<i>System 3—PSZ-AC</i>	<i>System 4—PSZ-HP</i>
Other nonresidential and 4 or 5 floors and <2300 m ² or 5 floors or fewer and 2300 m ² to 14,000 m ²	<i>System 5—Packaged VAV with reheat</i>	<i>System 6—Packaged VAV with PFP boxes</i>
Other nonresidential and more than 5 floors or >14,000 m ²	<i>System 7—VAV with reheat</i>	<i>System 8—VAV with PFP boxes</i>

2022

Building Area Types ^a , Number of Stories ^b , and Combined Floor Area ^c	Climate Zones 3B, 3C, and 4 to 8	Climate Zones 0 to 3A
<i>Residential</i>	<i>System 1—PTAC</i>	<i>System 2—PTHP</i>
Public assembly area smaller than 11,000 m ²	<i>System 3—PSZ-AC</i>	<i>System 4—PSZ-HP</i>
Public assembly area equal to or larger than 11,000 m ²	<i>System 12—SZ-CV-HW</i>	<i>System 13—SZ-CV-ER</i>
Heated-only storage	<i>System 9—Heating and ventilation</i>	<i>System 10—Heating and ventilation</i>
Retail in a <i>building</i> that is 1 or 2 stories	<i>System 3—PSZ-AC</i>	<i>System 4—PSZ-HP</i>
Hospital that is either <ul style="list-style-type: none"> • larger than 14,000 m² or • in a <i>building</i> greater than 5 stories. 	<i>System 7—VAV with reheat</i>	<i>System 7—VAV with reheat</i>
Hospital—all other	<i>System 5—Packaged VAV with reheat</i>	<i>System 5—Packaged VAV with reheat</i>
Other <i>Nonresidential</i> area that is both <ul style="list-style-type: none"> • smaller than 2300 m² and • in a <i>building</i> 3 stories or fewer. 	<i>System 3—PSZ-AC</i>	<i>System 4—PSZ-HP</i>
Other <i>Nonresidential</i> area that is both <ul style="list-style-type: none"> • smaller than 2300 m² and • in a <i>building</i> with 4 or 5 stories. 	<i>System 5—Packaged VAV with reheat</i>	<i>System 6—Packaged VAV with PFP boxes</i>
Other <i>nonresidential</i> area that is both <ul style="list-style-type: none"> • 2300 m² to 14,000 m² and • in a <i>building</i> that is 5 stories or fewer. 	<i>System 5—Packaged VAV with reheat</i>	<i>System 6—Packaged VAV with PFP boxes</i>
Other <i>Nonresidential</i> area that is either <ul style="list-style-type: none"> • larger than 14,000 m² or • in a <i>building</i> greater than 5 stories. 	<i>System 7—VAV with reheat</i>	<i>System 8—VAV with PFP boxes</i>



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Performance Metrics & Savings Comparisons (Baseline vs. Proposed Model)

After defining the baseline and proposed models, we compare their performance to evaluate energy savings.

The comparison formula has significantly changed from ASHRAE 90.1-2010 to ASHRAE 90.1-2019/2022.

ASHRAE 90.1: 2010

Percentage improvement = $100 \times (\text{BBP} - \text{PBP}) / \text{BBP}$

Key Notes

- Energy cost-based comparison
- Greenhouse gas emissions reduction (1 Mar 2024)
- Minimum 5% savings before considering renewables (for new construction)
- Renewable energy added afterward for further improvement

- BBP: Baseline Building Performance
- PBP: Proposed Building Performance

Requirement

Performance Cost Index (PCI) shall be less than or equal to the Performance Cost Index Target (PCIt).

ASHRAE 90.1-2019/2022: Appendix G

$$PCI = PBP/BBP$$

ASHRAE 90.1: 2019

$$PCIt=[BBUEC+(BPF\times BBREC)]/BBP$$

ASHRAE 90.1: 2022

$$PCIt=[BBUEC+(BPF\times BBREC)-PRE]/BBP$$

Key Notes

- Baseline model now includes new breakdowns (BBUEC, BBREC)
- Building Performance Factor ensures climate & building-type specific comparison
- Renewable energy is still considered but now adjusted with new limitations

- BBUEC: Baseline building unregulated energy cost
- BBREC: Baseline building regulated energy cost
- BPF: Building performance factor
- PRE: PBPnre - PBPpre
- PBPnre: Proposed building performance - With no renewables
- PBPpre: Proposed building performance - Prescriptive renewables



Building performance factor (BPF)

2019

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 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

EAp: Minimum Energy Efficiency

Option 1: ASHRAE 90.1-2019

- **May** replace “cost” with “future source energy”
- Use country-specific site-to-source conversion factors
- Use LEED-specific BPF table, not ASHRAE’s BPF

Option 2: ASHRAE 90.1-2022

- **May** replace “cost” with one of the following:
 1. Future source energy
 2. Site energy or source energy - Appendix I
- Use country-specific site-to-source conversion factors
- Use LEED-specific BPF table, not ASHRAE’s BPF



Building performance factor (BPF)

LEED Option 1

	Climate Zone																		
Building Type	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.74	0.69	0.73	0.70	0.73	0.70	0.71	0.70	0.63	0.70	0.71	0.69	0.68	0.70	0.70	0.68	0.68	0.68	0.74
Healthcare/hospital	0.72	0.72	0.73	0.73	0.74	0.71	0.72	0.74	0.71	0.72	0.73	0.71	0.74	0.73	0.80	0.73	0.77	0.78	0.79
Hotel/motel	0.72	0.71	0.72	0.71	0.71	0.70	0.71	0.73	0.72	0.71	0.73	0.73	0.71	0.73	0.74	0.70	0.72	0.70	0.70
Office	0.62	0.63	0.61	0.62	0.58	0.60	0.57	0.62	0.55	0.55	0.61	0.57	0.58	0.61	0.59	0.58	0.60	0.54	0.58
Restaurant	0.65	0.62	0.63	0.61	0.62	0.58	0.63	0.63	0.63	0.67	0.66	0.66	0.70	0.70	0.68	0.73	0.72	0.74	0.77
Retail	0.57	0.54	0.53	0.53	0.48	0.47	0.47	0.47	0.47	0.52	0.50	0.56	0.57	0.53	0.59	0.58	0.56	0.53	0.60
School	0.57	0.57	0.58	0.57	0.55	0.54	0.57	0.51	0.49	0.48	0.51	0.52	0.51	0.53	0.51	0.53	0.50	0.51	0.58
Warehouse	0.28	0.30	0.24	0.27	0.23	0.24	0.27	0.23	0.20	0.33	0.26	0.28	0.40	0.32	0.29	0.44	0.38	0.40	0.44
All others	0.65	0.62	0.64	0.62	0.57	0.54	0.57	0.56	0.58	0.59	0.57	0.60	0.60	0.59	0.65	0.62	0.62	0.61	0.64

LEED Option 2

	Climate Zone																		
Building Type	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.64	0.59	0.62	0.60	0.61	0.59	0.61	0.60	0.49	0.57	0.59	0.56	0.55	0.57	0.57	0.55	0.55	0.55	0.60
Healthcare/hospital	0.64	0.64	0.66	0.65	0.66	0.63	0.64	0.65	0.63	0.64	0.65	0.62	0.64	0.62	0.69	0.63	0.68	0.69	0.70
Hotel/motel	0.65	0.63	0.64	0.63	0.62	0.61	0.62	0.63	0.62	0.59	0.60	0.60	0.57	0.58	0.59	0.56	0.58	0.56	0.56
Office	0.54	0.54	0.53	0.54	0.49	0.52	0.49	0.52	0.45	0.46	0.52	0.47	0.48	0.51	0.48	0.48	0.50	0.45	0.49
Restaurant	0.61	0.58	0.58	0.57	0.57	0.54	0.58	0.59	0.57	0.62	0.61	0.61	0.65	0.64	0.63	0.67	0.66	0.69	0.72
Retail	0.47	0.45	0.44	0.44	0.40	0.39	0.37	0.39	0.36	0.40	0.41	0.42	0.45	0.43	0.46	0.44	0.43	0.42	0.46
School	0.52	0.53	0.53	0.53	0.51	0.51	0.53	0.48	0.46	0.43	0.48	0.47	0.45	0.49	0.46	0.46	0.44	0.44	0.48
Warehouse	0.25	0.25	0.21	0.24	0.20	0.21	0.24	0.20	0.17	0.30	0.22	0.25	0.36	0.28	0.25	0.40	0.34	0.36	0.40
All others	0.58	0.56	0.56	0.56	0.50	0.47	0.49	0.48	0.48	0.49	0.49	0.50	0.51	0.50	0.55	0.52	0.52	0.52	0.55

EAc: Enhanced Energy Efficiency

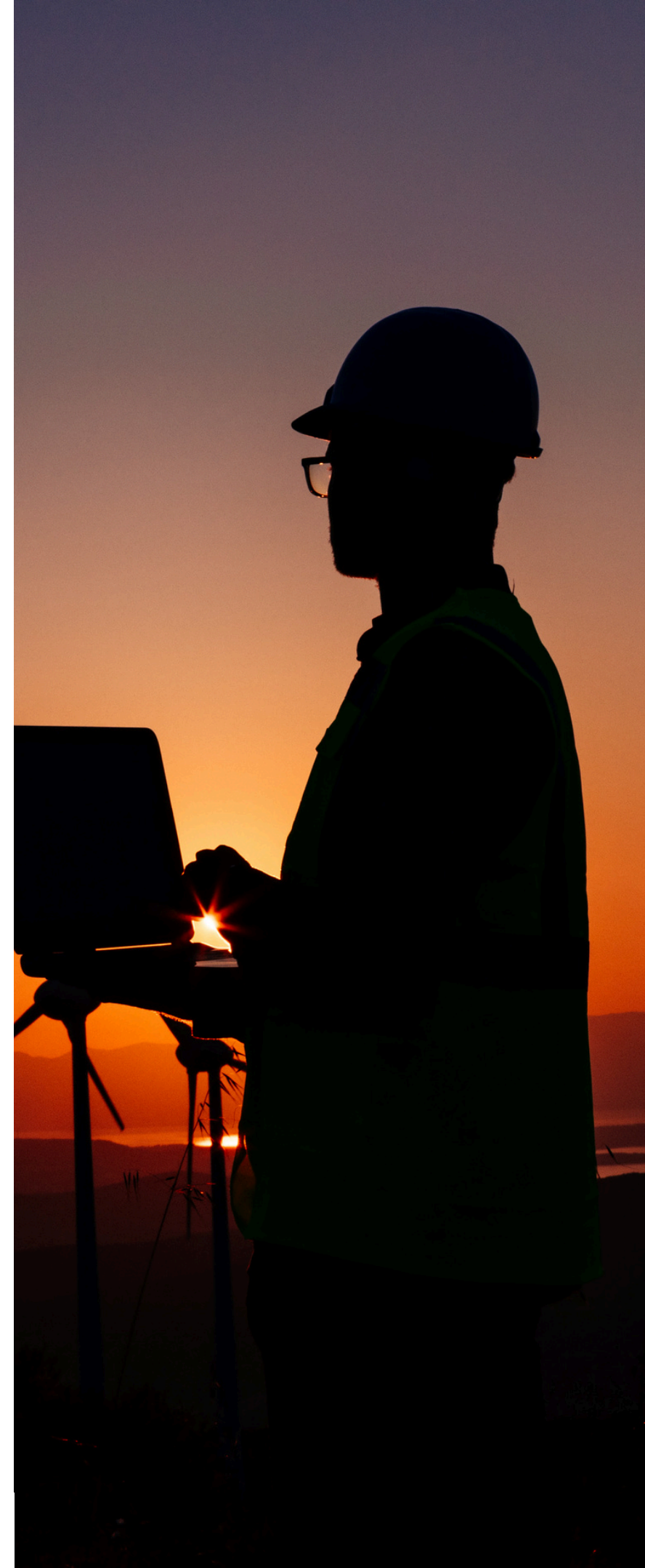
Both Options

- **Replace** “cost” with “future source energy”
- Use country-specific site-to-source conversion factors
- Use LEED-specific BPF table, not ASHRAE’s BPF

Maximum 10 points

- $PI_{nre} = PBP_{nre} / BBP$
- $PI = PBP / BBP$
- $PI_t = [BBUE - (BPF \times BBRE)] / BBP$

- PI_{nre} : Performance index for future source energy excluding on-site renewable contribution
- PI : Performance index for future source energy including on-site renewable contribution
- PI_t : Performance index target for future source energy use
- BBP : Baseline building performance for baseline building future source energy use
- $BBUE$: Baseline building unregulated future source energy use
- $BBRE$: Baseline building regulated future source energy use
- PBP_{nre} : Proposed building performance - Without any on-site renewable systems
- PBP : Proposed building performance - With on-site renewable systems



EAc: Enhanced Energy Efficiency

BPF

	Climate Zone																		
Building Type	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.74	0.69	0.73	0.70	0.73	0.70	0.71	0.70	0.63	0.70	0.71	0.69	0.68	0.70	0.70	0.68	0.68	0.68	0.74
Healthcare/hospital	0.72	0.72	0.73	0.73	0.74	0.71	0.72	0.74	0.71	0.72	0.73	0.71	0.74	0.73	0.80	0.73	0.77	0.78	0.79
Hotel/motel	0.72	0.71	0.72	0.71	0.71	0.70	0.71	0.73	0.72	0.71	0.73	0.73	0.71	0.73	0.74	0.70	0.72	0.70	0.70
Office	0.62	0.63	0.61	0.62	0.58	0.60	0.57	0.62	0.55	0.55	0.61	0.57	0.58	0.61	0.59	0.58	0.60	0.54	0.58
Restaurant	0.65	0.62	0.63	0.61	0.62	0.58	0.63	0.63	0.63	0.67	0.66	0.66	0.70	0.70	0.68	0.73	0.72	0.74	0.77
Retail	0.57	0.54	0.53	0.53	0.48	0.47	0.47	0.47	0.47	0.52	0.50	0.56	0.57	0.53	0.59	0.58	0.56	0.53	0.60
School	0.57	0.57	0.58	0.57	0.55	0.54	0.57	0.51	0.49	0.48	0.51	0.52	0.51	0.53	0.51	0.53	0.50	0.51	0.58
Warehouse	0.28	0.30	0.24	0.27	0.23	0.24	0.27	0.23	0.20	0.33	0.26	0.28	0.40	0.32	0.29	0.44	0.38	0.40	0.44
All others	0.65	0.62	0.64	0.62	0.57	0.54	0.57	0.56	0.58	0.59	0.57	0.60	0.60	0.59	0.65	0.62	0.62	0.61	0.64

Ponits

Path 1. Percentage Reduction excluding On-Site Renewable Contribution (100% - PI_{nre} / PI_t)	or	Path 2. Percentage Reduction including On-Site Renewable Contribution (100% - PI / PI_t)	Points
3%		10%	1
6%		20%	2
9%		30%	3
12%		40%	4
15%		50%	5
18%		60%	6
21%		70%	7
24%		80%	8
27%		90%	9
30%		100%	10



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Upcoming Challenges



Technical Limitations & Performance Gap



Investment & Cost Barriers



Limitations on Renewable Energy Contribution



Electrification & Grid Decarbonization Uncertainty





CATALYST

Thank you for your attention

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