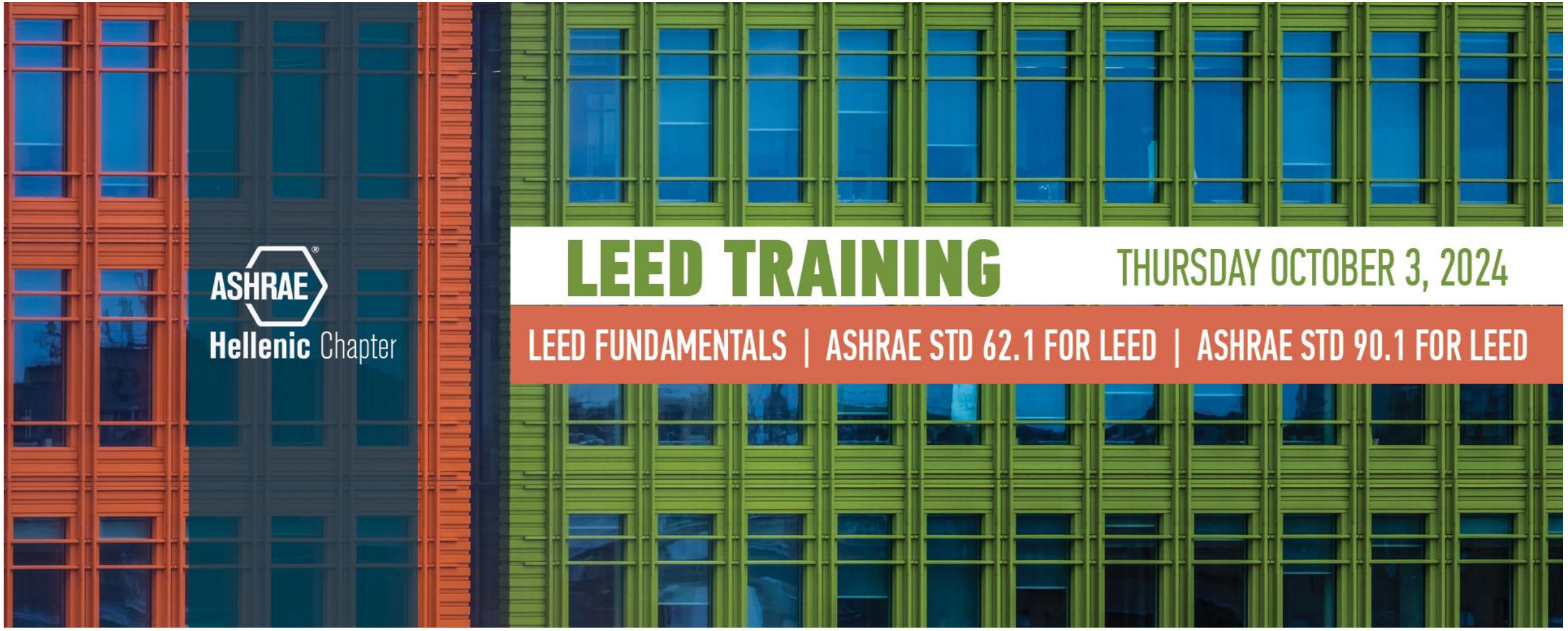

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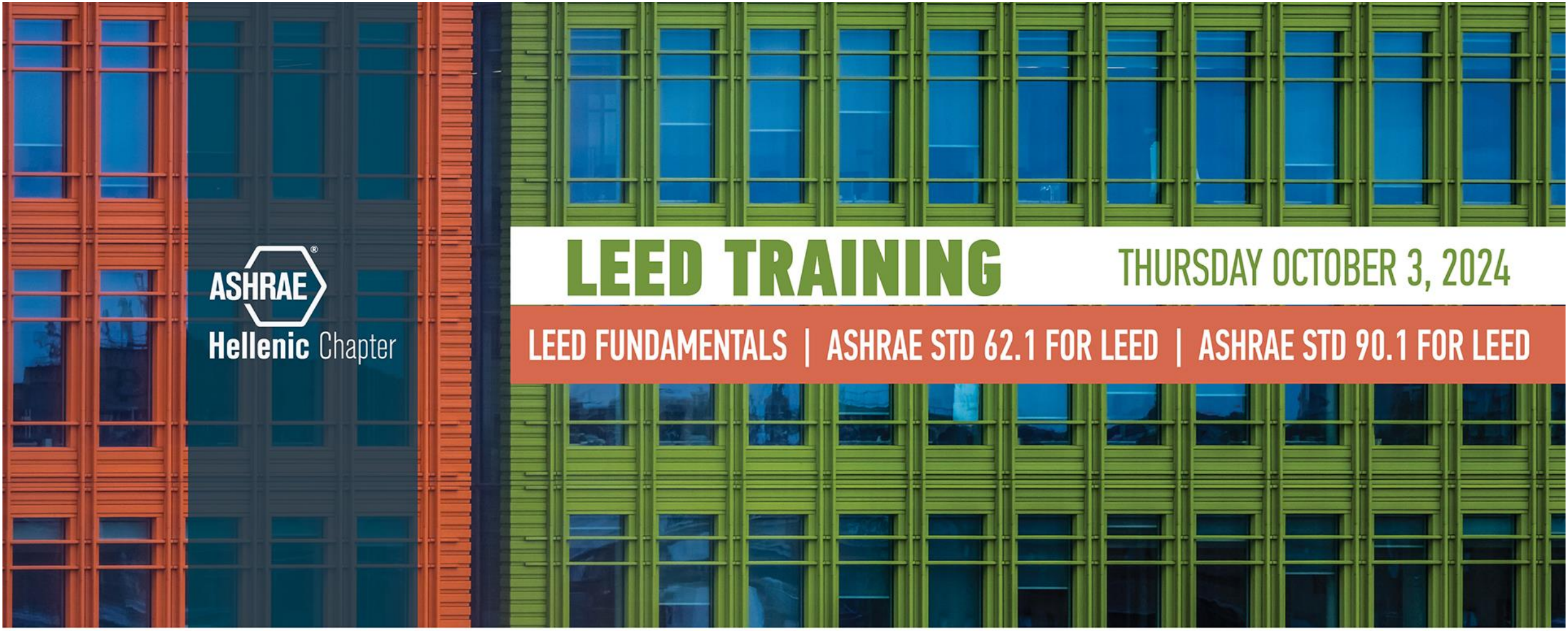

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ASHRAE Std 90.1 for LEED

zeb
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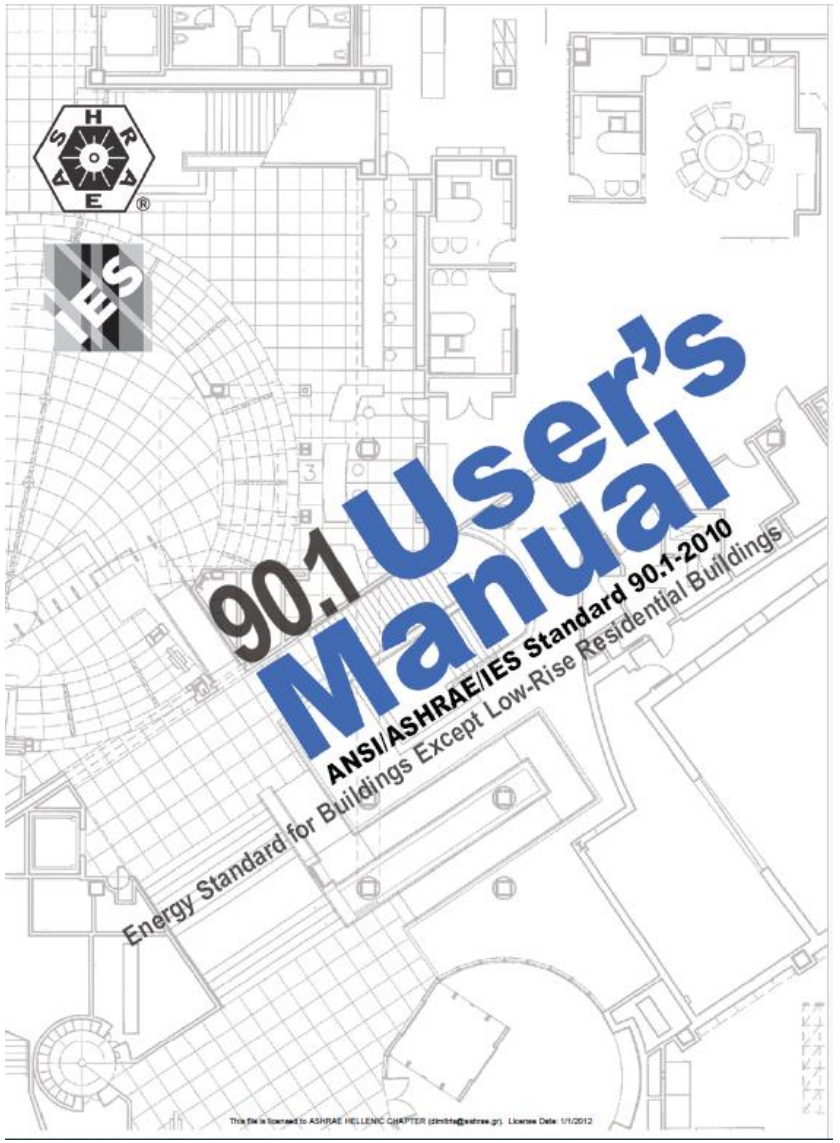
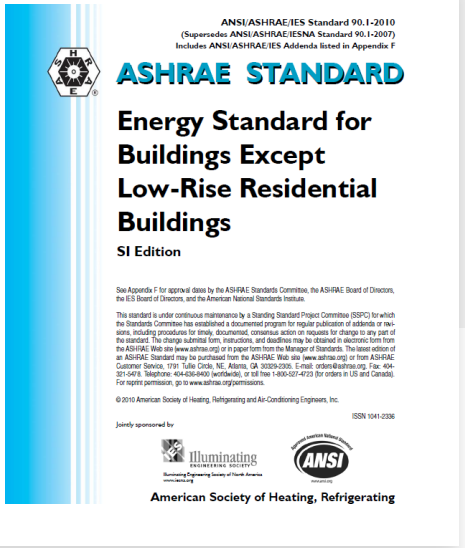
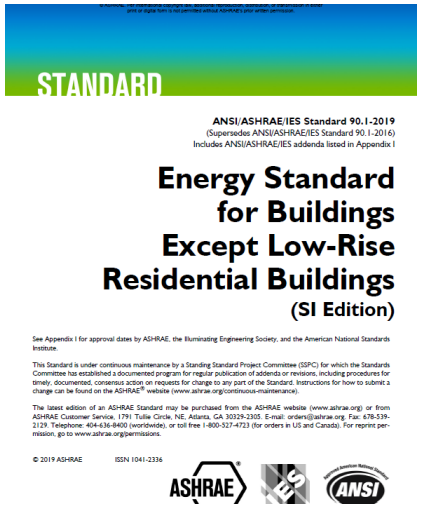
Bibliography







Why ASHRAE for LEED?

LEED v4 for BD+C: New Construction and Major Renovation

Project Checklist

Project Name:
Date:

Y	?	N			
			Credit	Integrative Process	1

Y	?	N		Location and Transportation	16
			Credit	LEED for Neighborhood Development Location	16
			Credit	Sensitive Land Protection	1
			Credit	High Priority Site	2
			Credit	Surrounding Density and Diverse Uses	5
			Credit	Access to Quality Transit	5
			Credit	Bicycle Facilities	1
			Credit	Reduced Parking Footprint	1
			Credit	Green Vehicles	1

Y	?	N		Sustainable Sites	10
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Site Assessment	1
			Credit	Site Development - Protect or Restore Habitat	2
			Credit	Open Space	1
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1

Y	?	N		Water Efficiency	11
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	2
			Credit	Water Metering	1

Y	?	N		Energy and Atmosphere	33
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
			Credit	Optimize Energy Performance	18
			Credit	Advanced Energy Metering	1
			Credit	Demand Response	2
			Credit	Renewable Energy Production	3
			Credit	Enhanced Refrigerant Management	1
			Credit	Green Power and Carbon Offsets	2

Y	?	N		Materials and Resources	13
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Planning	Required
			Credit	Building Life-Cycle Impact Reduction	5
			Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	2
			Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	2
			Credit	Building Product Disclosure and Optimization - Material Ingredients	2
			Credit	Construction and Demolition Waste Management	2

Y	?	N		Indoor Environmental Quality	16
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
			Credit	Indoor Air Quality Assessment	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight	3
			Credit	Quality Views	1
			Credit	Acoustic Performance	1

Y	?	N		Innovation	6
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1

Y	?	N		Regional Priority	4
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1

Y	?	N		TOTALS	Possible Points: 110
0	0	0			

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

Why ASHRAE for LEED?

Category Energy & Atmosphere:

Fundamental (P) & Enhanced (C) Commissioning (up to 6 pts) — **ASHRAE Guideline 0 & Guideline 1.1**

Minimum (P) & Optimize (C) Energy Performance (up to 18 pts) — **ASHRAE std 90.1**

Category Indoor Enviromental Quality:

Minimum (P) & Enhanced (C) Indoor Air Quality Performance (up to 2 pts) — **ASHRAE std 62.1**

Thermal Comfort (C) (1pt) — **ASHRAE std 55**

ASHRAE 90.1

PURPOSE

To establish the minimum energy efficiency requirements of buildings, other than *low-rise residential buildings

Low-rise residential buildings: single-family, or multi-family structures of three stories and fewer -> ASHRAE 90.2

SCOPE:

- **Set the minimum energy efficient requirements for design, construction and a plan for O+M**
- **Set the criteria for compliance**

ASHRAE 90.1 - Structure

Section 1: Purpose

Section 2: Scope

Section 3: Definitions, Abbreviations and Acronyms

Section 4: Administration and Enforcement

Section 5: Building Envelope

Section 6: Heating, Ventilating and Air Conditioning

Section 7: Service Water Heating

Section 8: Power

Section 9: Lighting

Section 10: Other Equipment

Section 11: Additional Efficiency Requirements

Section 12: Energy Cost Budget Method

Section 13: Normative References

***** As of ASHRAE 90.1-2022

ASHRAE 90.1 - Appendices

Appendix A: Rated R-value of insulation and assembly U-factor, C-Factor and F-factor determinations

Appendix B: Building Envelope Climate Criteria Retained for future use

Appendix C: Methodology for building envelope trade-off option in subsection 5.6

Appendix D: Climatic Data Retained for future use

Appendix E: Informative References

Appendix F: Addenda Description Information US DOE Minimum Energy Efficiency Requirements ….

Appendix G: Performance Rating Method

Appendix H: Additional Guidance for Verification, Testing and Commissioning

Appendix I: Using Other Metrics in Conjunction with Appendix G ……..

Appendix J: Sets of Performance Curves

Appendix K: Informative Figures – Thermal Bridges

Appendix L: Mechanical System Performance Rating Method

Appendix M: Addenda Description

**As of ASHRAE 90.1-2022*

ASHRAE 90.1 – Climate Data

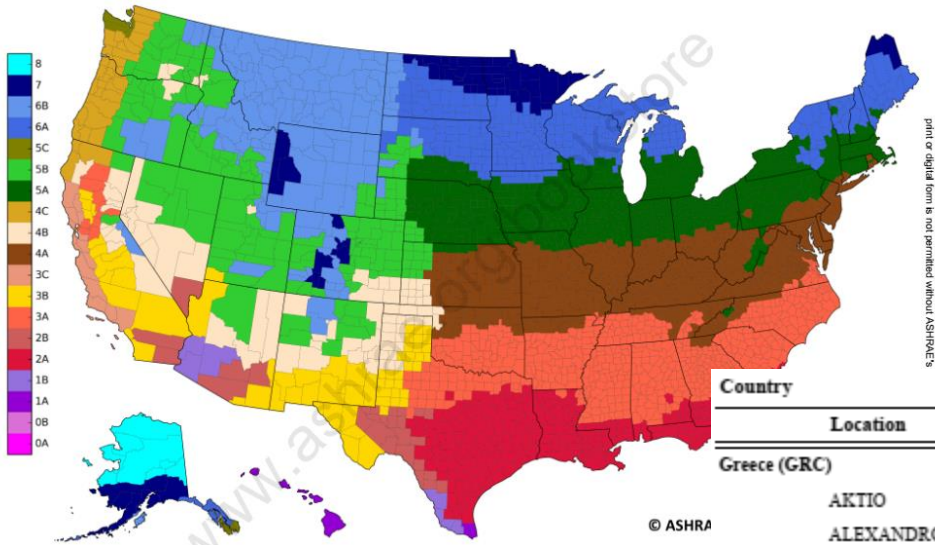


Figure A-2 Climate zones for United States counties.

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Table A-6 International Stations and Climate Zones (Design Conditions tables [I–P and SI]) for each station, named by WMO#, can be accessed online at www.ashrae.org/169-2021.)

Country / Location	WMO #	Latitude	Longitude	Climate Zone
RHEINE BENTLAGE	103060	52.289	7.387	5A
ROSTOCK LAAGE	101720	53.916	12.279	5A
ROTH	107650	49.216	11.104	5A
SAARBRUCKEN	107080	49.213	7.108	5A
SCHLESWIG JAGEL	100370	54.457	9.52	5A
SCHMUECKE	105520	50.654	10.769	6A
SCHORTENS JEVER	101220	53.534	7.889	5A
SCHWERIN	101620	53.642	11.387	5A
SEEHAUSEN ALTMARK	102610	52.891	11.73	5A
SONNEBERG NEUFANG	105580	50.383	11.183	6A
SPANGDAHLEM AB	106070	49.973	6.693	5A
ST PETER-ORDING	100280	54.328	8.603	5A
STRAUBING	107080	48.828	12.56	5A
STUTTGART ECHTERDINGEN	107380	48.688	9.224	5A
STUTTGART SCHNARREN	107390	48.833	9.2	5A
TETEROW	101770	53.767	12.617	5A
TRIER PETRISBERG	106090	49.748	6.658	5A
UECKERMUENDE	101930	53.744	14.07	5A
WAREN	102680	53.52	12.665	5A
WARNEMUENDE	101700	54.18	12.081	5A
WASSERKUPPE	105440	50.497	9.943	6A
WEEZE LAARBRUCH	100001	51.602	6.142	4A
WEIMAR	105550	50.983	11.317	5A
WERL	104240	51.576	7.888	5A
WERNIGERODE	104540	51.846	10.769	5A
WIESBADEN	106330	50.05	8.325	4A
WIESENBURG	103600	52.121	12.459	5A
WILDENRATH	104020	51.117	6.217	5A
WITTENBERG	104740	51.889	12.644	5A
WITTMUNDHAFEN	101260	53.55	7.667	5A
WUNSTORF	103340	52.461	9.431	5A
ZINNWALD GEORGENFE	105320	50.731	13.752	6A
ZUGSPITZE	109610	47.421	10.985	8

ANSI/ASHRAE Standard 169-2021

Table A-6 International Stations and Climate Zones (Design Conditions tables [I–P and SI]) for each station, named by WMO#, can be accessed online at www.ashrae.org/169-2021.)

Country / Location	WMO #	Latitude	Longitude	Climate Zone
Ghana (GHA)				
ACCRA				
Gibraltar (GIB)				
GIBRALTAR AP				
Greece (GRC)				
AKTIO	166430	38.925	20.765	3A
ALEXANDROUPOLI	166270	40.856	25.956	3A
ANDRAVIDA	166820	37.923	21.288	3A
ARAXOS	166870	38.149	21.422	3A
ATHINAI ELEFTHERIOS VENIZELOS	167161	37.936	23.944	3A
ATHINAI HELLINIKON	167160	37.89	23.742	3B
CHANIA SOUDA	167460	35.532	24.15	3A
CORFU KERKYRA	166410	39.602	19.912	3A
ELEFSIS	167180	38.064	23.556	3A
HERAKLION	167540	35.34	25.18	3A
KALAMATA	167260	37.068	22.026	3A
KARPATHOS	167650	35.428	27.147	2A
KASTORIA ARISTOTELIS	166140	40.446	21.282	4A
KAVALA MEGAS ALEXANDROS	166240	40.913	24.619	3A
KITHIRA	167430	36.274	23.017	3A
KOS	167420	36.793	27.092	3A
LAMIA	166750	38.877	22.436	3A
LARISSA	166480	39.65	22.466	3B
LIMNOS	166500	39.917	25.236	3A
METHONI	167340	36.825	21.704	3A
MILOS	167300	36.739	24.429	3A
MITILINI	166670	39.057	26.598	3A
NAXOS	167320	37.101	25.373	3B
NEA ANCHIALOS	166650	39.22	22.794	3A
RHODES DIAGORAS	167400	36.405	28.086	2A
SAMOS	167230	37.69	26.912	3A
SANTORINI	167443	36.399	25.479	3B
SKIROS	166840	38.963	24.491	3A
TANAGRA	166990	38.335	23.563	3A

Country / Location	WMO #	Latitude	Longitude	Climate Zone
Greece (GRC)				
AKTIO	166430	38.925	20.765	3A
ALEXANDROUPOLI	166270	40.856	25.956	3A
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MITILINI	166670	39.057	26.598	3A
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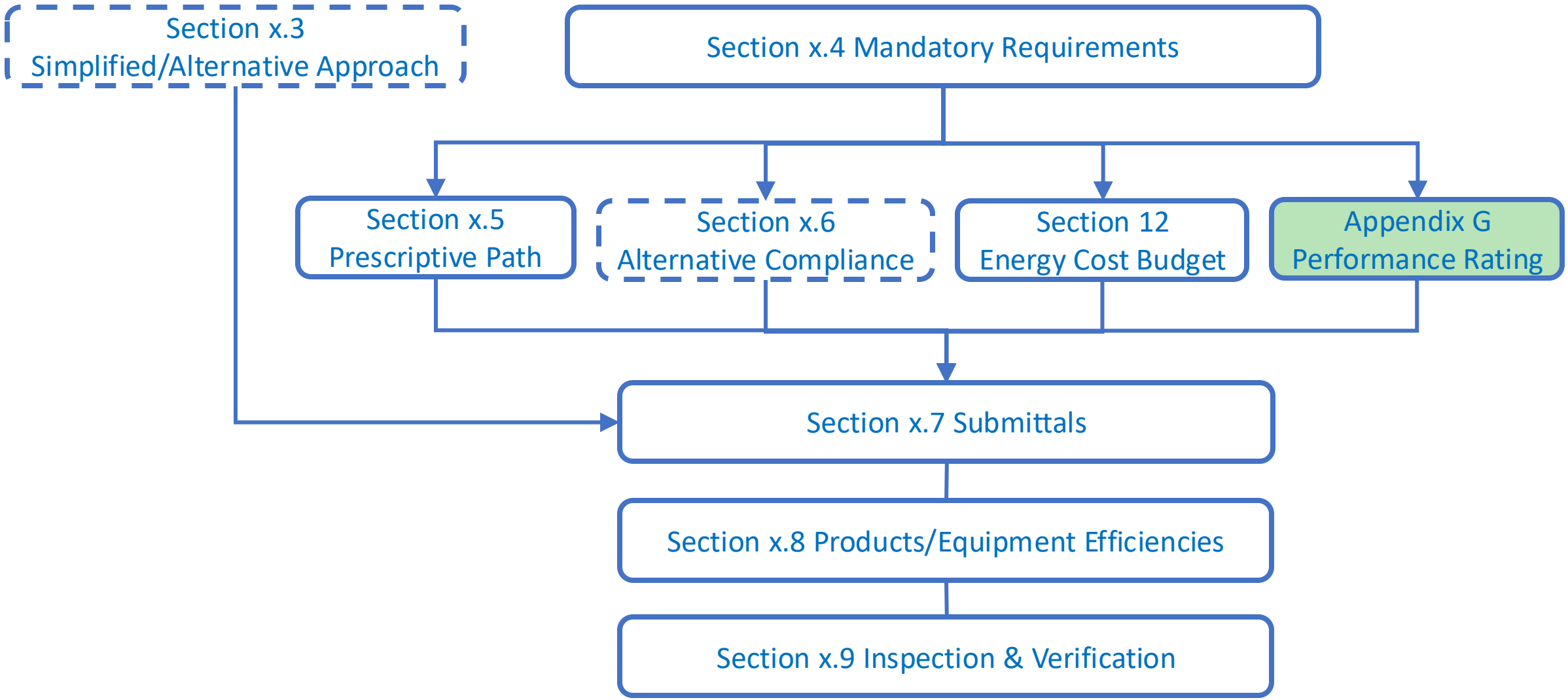
ASHRAE 90.1 - Compliance



Energy Cost Budget Method

$$Design\ Energy\ Cost\ \leq Energy\ Cost\ Budget \times \left(1 - \frac{EC_{req}}{1000} \times A_{adj}\right)^{*}$$

Design Energy Cost: The annual energy cost calculated for the proposed design

Energy Cost Budget: The annual energy cost for the budget building design intended for use in determining minimum compliance with this standard

EC_{req} Energy credits required for the building (Section 11.5.1)

A_{adj} Adjustment factor if the project includes additions or alterations

**ASHRAE 90.1-2022*

Energy Cost Budget Method

Model requirements

- *Minimum 1400 hours per year / 8760 hours per year*
- *Hourly variations (occupancy, lighting, HVAC operation etc)*
- *Thermal mass effects*
- *Ten or more thermal zones*
- *Part-load performance curves for mechanical equipment*
- *Capacity and efficiency correction curves for mechanical heating and cooling equipment*
- *Air-side economizers with integrated control*
- *Budget building design characteristics as per Section 11.2.5*

**ASHRAE 90.1-2022*

Energy Cost Budget Method

Budget Building characteristics

- ***Space usage, schedules, HVAC zones**: same as proposed*
- ***Building Envelope - Fenestrations:** Specific characteristics*
- ***Lighting:** LPDs based on tables 9.5.1 and 9.6.1*
- ***HVAC system**: Type and characteristics based on building size*
- ***Service hot-water systems:** same as proposed with specific characteristics*
- ***Other loads**: same as proposed*
- ***On-site renewable: Based on section 10.5.1***

**ASHRAE 90.1-2022*

Requirements for LEED

v4	v4.1	v4 Energy Update
Energy Simulation (90.1-2010 Appendix G) 5% NC – 3% MR – 2% CS 1-18 points	Energy Simulation (90.1-2016 Appendix G) 1-9 points Cost + 1-9 points GHG	Energy Simulation (90.1-2010 Appendix G + On-site RES) 10% NC/MR – 8% CS 1-9 points Cost / Source + 1-9 points GHG
Comply with AEGD 50% (Mandatory & Prescriptive) 1-6 pts NC, 1-4 pts CS	Comply with AEGD 50% (Mandatory & Prescriptive) 1-6 pts NC, 1-4 pts CS	
Comply with 90.1/2010 (Mandatory & Prescriptive) For projects ≤ 10.000sqm No points	Comply with 90.1/2010 (Mandatory & Prescriptive) & System Optimization 1-6 points	

Mandatory Requirement – LEED Prerequisite

Minimum Energy Performance – **PREREQUISITE**

- *Comply with all mandatory requirements of ASHRAE 90.1-2010 (v4) ή 90.1-2016 (v4.1)*, Appendices:*
  - ❑ *5.4: Building Envelope*
  - ❑ *6.4: HVAC*
  - ❑ *7.4: Service Water Heating*
  - ❑ *8.4: Power*
  - ❑ *9.4: Lighting*
  - ❑ *10.4: Other equipment*

**Alternative Compliance Path for Europe*

Mandatory Requirement – LEED Prerequisite

Section 5.4: Envelope

- *Insulation complies with labeling and other requirements*
- *Fenestration: CE marking**
- *Continuous Air Barrier*
- *Fenestration and Doors air leakage requirements*
- *Vestibules*

Envelope for 3B Athens-3A Elliniko

TABLE 5.5-3 Building Envelope Requirements for Climate Zone 3 (A, B, C)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.273	R-3.5 c.i.	U-0.273	R-3.5 c.i.	U-0.982	R-0.9 c.i.
Metal Building[a]	U-0.312	R-2.3+R-2.3	U-0.312	R-2.3+R-2.3	U-0.551	R-1.8
Attic and Other	U-0.153	R-6.7	U-0.153	R-6.7	U-0.300	R-3.3
Walls, Above-Grade						
Mass	U-0.701	R-1.3 c.i.	U-0.592	R-1.7 c.i.	U-3.293	NR
Metal Building	U-0.477	R-3.3	U-0.476	R-3.3	U-0.642	R-2.3
Steel-Framed	U-0.479	R-2.3 + R-0.7 c.i.	U-0.365	R-2.3 + R-1.3 c.i.	U-0.705	R-2.3
Wood-Framed and Other	U-0.504	R-2.3	U-0.504	R-2.3	U-0.504	R-2.3
Walls, Below-Grade						
Below-Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-0.606	R-1.1	U-0.496	R-1.5	U-1.825	NR
Steel-Joist	U-0.296	R-3.3	U-0.296	R-3.3	U-0.390	R-2.3
Wood-Framed and Other	U-0.288	R-3.3	U-0.188	R-5.3	U-0.376	R-2.3
Slab-On-Grade Floors						
Unheated	F-1.264	NR	F-1.264	NR	F-1.264	NR
Heated	F-1.558	R-1.8 for 600 mm	F-1.558	R-1.8 for 600 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-3.975		U-3.975	
Nonswinging	U-8.233		U-2.839		U-8.233	

Mandatory Requirement – LEED Prerequisite

Section 6.4: HVAC

Minimum equipment efficiencies

*Based on Ecodesign**

Calculations

Load and pump head calculations

Zone Thermostatic Control

- *Per Zone*
- *Dead band 3°C*
- *Setpoint Overlap Restriction*
- *Automatic shutdown*
- *Setback (13-32°C)*
- *Optimum Start*
- *Zone Isolation*

Mandatory Requirement – LEED Prerequisite

Section 6.4: HVAC

Ventilation System Control

- *Stair and shaft vents*
- *Shutoff dampers / Damper leakage*
- *Automatic Shutdown*
- *Garage ventilation with contaminant levels*

Auxiliary Heat / Freeze protection / Humidifier Preheat

Automatic control for no operation if not required

Humidification and Dehumidification

Automatic control for no concurrent operation

Mandatory Requirement – LEED Prerequisite

Section 6.4: HVAC

High-Occupancy Areas

Demand Control Ventilation (DCV) in rooms >50m² and occupancy > 40people/100m²

And served by systems with one or more of the following:

a. an air-side economizer,

b. automatic modulating control of the outdoor air damper,

or

c. a design outdoor airflow greater than 1400 L/s.

Variable-Air-Volume controls

AHUs & FCUs with fan motor >4kW and direct expansion units with cooling capacity > 32kW – Supply fans with two or variable speed motors

Direct Digital Controls (DDC)²

Required for specific applications (Air handling systems, Chilled/Hot-water plant and terminal units)

Mandatory Requirement – LEED Prerequisite

Section 6.4: HVAC

Chilled-water Plant Monitoring[2]

Monitor, record and report on energy consumption and performance

Economizer Fault Detection Diagnosis (FDD)[2]

In air-cooled direct expansion units with an economizer on the air side, FDD systems are required

Construction

- *Air duct and plenum insulation based on ASHRAE 90.1*
- *Pipe insulation according to EN ISO 12241**

TABLE 6.8.2B Minimum Duct Insulation R-Value,[a] Combined Heating and Cooling Supply Ducts and Return Ducts

Climate Zone	Duct Location						
	Exterior	Ventilated Attic	Unvented Attic Above Insulated Ceiling	Unvented Attic with Roof Insulation[a]	Unconditioned Space[b]	Indirectly Conditioned Space[c]	Buried
	Supply Ducts						
1	R-1.06	R-1.06	R-1.41	R-0.62	R-0.62	none	R-0.62
2	R-1.06	R-1.06	R-1.06	R-0.62	R-0.62	none	R-0.62
3	R-1.06	R-1.06	R-1.06	R-0.62	R-0.62	none	R-0.62
4	R-1.06	R-1.06	R-1.06	R-0.62	R-0.62	none	R-0.62
5	R-1.06	R-1.06	R-1.06	R-0.34	R-0.62	none	R-0.62
6	R-1.41	R-1.06	R-1.06	R-0.34	R-0.62	none	R-0.62
7	R-1.41	R-1.06	R-1.06	R-0.34	R-0.62	none	R-0.62

Duct Insulation

Piping Insulation

TABLE 6.8.3A Minimum Pipe Insulation Thickness
Heating and Hot Water Systems[a,b,c,d]
(Steam, Steam Condensate, Hot Water Heating and Domestic Water Systems)

Fluid Operating Temperature Range (°C) and Usage	Insulation Conductivity		Nominal Pipe or Tube Size (mm)				
	Conductivity W/(m°C)	Mean Rating Temperature, °C	<25	25 to <40	40 to <100	100 to <200	≥200
			Insulation Thickness (mm)				
>177 °C	0.046–0.049	121	115	125	125	125	125
122°C–177°C	0.042–0.046	93	80	100	115	115	115
94°C–121°C	0.039–0.043	66	65	65	80	80	80
61°C–93°C	0.036–0.042	52	40	40	50	50	50
41°C–60°C	0.032–0.040	38	25	25	40	40	40

TABLE 6.8.3B Minimum Pipe Insulation Thickness
Cooling Systems (Chilled Water, Brine, and Refrigerant)[a,b,c]

Fluid Operating Temperature Range (°C) and Usage	Insulation Conductivity		Nominal Pipe or Tube Size (mm)				
	Conductivity W/(m°C)	Mean Rating Temperature, °C	<25	25 to <40	40 to <100	100 to <200	≥200
			Insulation Thickness (mm)				
4°C–16°C	0.030–0.039	24	15	15	25	25	25
<4°C	0.029–0.037	10	15	25	25	25	40

Economizers

TABLE 6.5.1.1.3A High-Limit Shutoff Control Options for Air Economizers

Climate Zones	Allowed Control Types	Prohibited Control Types
1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	Fixed dry bulb Differential dry bulb Electronic enthalpy[a] Differential enthalpy Dew-point and dry-bulb temperatures	Fixed enthalpy
1a, 2a, 3a, 4a	Fixed enthalpy Electronic enthalpy Differential enthalpy Dew-point and dry-bulb temperatures	Fixed dry bulb Differential dry bulb
5a, 6a	Fixed dry bulb Differential dry bulb Fixed enthalpy Electronic enthalpy[a] Differential enthalpy Dew-point and dry-bulb temperatures	

TABLE 6.5.1.1.3B High-Limit Shutoff Control Settings for Air Economizers

Device Type	Climate	Required High Limit (Economizer Off When):	
		Equation	Description
Fixed dry bulb	1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8 5a, 6a	$T_{OA} > 24°C$ $T_{OA} > 21°C$	Outdoor air temperature exceeds 24°C Outdoor air temperature exceeds 21°C
Differential dry bulb	1b, 2b, 3b, 3c, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 7, 8	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
Fixed enthalpy	2a, 3a, 4a, 5a, 6a	$h_{OA} > 47$ kJ/kg[a]	Outdoor air enthalpy exceeds 47 kJ/kg of dry air[a]
Electronic enthalpy	All	$(T_{OA}, RH_{OA}) > A$	Outdoor air temperature/RH exceeds the "A" setpoint curve[b]
Differential enthalpy	All	$h_{OA} > h_{RA}$	Outdoor air enthalpy exceeds return air enthalpy
Dew-point and dry-bulb temperatures	All	$DP_{oa} > 13°C$ or $T_{oa} > 24°C$	Outdoor air dry bulb exceeds 24°C or outside dew point exceeds 13°C (0.009 kg/kg)

Heat Recovery

TABLE 6.5.6.1 Exhaust Energy Recovery Requirement

Zone	% *Outdoor Air* at Full Design Airflow Rate					
	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%
	Design Supply Fan Airflow Rate (L/s)					
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥2360	≥2360
1B, 2B,5C	NR	NR	≥12271	≥5663	≥2360	≥1888
6B	≥5191	≥2596	≥2124	≥1652	≥1180	≥708
1A, 2A, 3A, 4A, 5A, 6A	≥2596	≥2124	≥1652	≥944	≥472	>0
7,8	≥1180	≥472	>0	>0	>0	>0

NR—Not required

Heat Recovery (2016)

Table 6.5.6.1-1 Exhaust Air *Energy* Recovery Requirements for *Ventilation Systems* Operating Less than 8000 Hours per Year

	% *Outdoor Air* at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
Climate Zone	Design Supply Fan Airflow Rate, L/s							
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	NR	NR	NR	NR
0B, 1B, 2B,5C	NR	NR	NR	NR	≥12271	≥5663	≥2360	≥1888
6B	≥13215	≥12507	≥5191	≥2596	≥2124	≥1652	≥1180	≥708
0A, 1A, 2A, 3A, 4A, 5A, 6A	≥12271	≥7551	≥2596	≥2124	≥1652	≥944	≥472	≥60
7,8	≥2124	≥1888	≥1180	≥472	≥70	≥60	≥50	≥40

NR—Not required

Table 6.5.6.1-2 Exhaust Air *Energy* Recovery Requirements for *Ventilation Systems* Operating Greater than or Equal to 8000 Hours per Year

	% *Outdoor Air* at Full Design Airflow Rate							
	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
Climate Zone	Design Supply Fan Airflow Rate, L/s							
3C	NR	NR	NR	NR	NR	NR	NR	NR
0B, 1B, 2B, 3B, 4C, 5C	NR	≥9203	≥4248	≥2360	≥1888	≥1416	≥708	≥60
0A, 1A, 2A, 3A, 4B, 5B	≥1180	≥944	≥472	≥236	≥35	≥60	≥50	≥40
4A, 5A, 6A, 6B, 7, 8	≥100	≥65	≥50	≥40	≥35	≥30	≥25	≥20

NR—Not required

(Not only) Fans Power

TABLE 6.5.3.1.1A Fan Power Limitation[a]

	Limit	Constant Volume	Variable Volume
Option 1: Fan System Motor Nameplate kW	Allowable Nameplate Motor kW	$kW \le L/S_S \cdot 0.0017$	$kW \le L/S_S \cdot 0.0024$
Option 2: Fan System input kW	Allowable Fan System input kW	$kW_i \le L/S_S \cdot 0.0015 + A$	$kW_i \le L/S_S \cdot 0.0021 + A$

TABLE 6.5.3.1.1B Fan Power Limitation Pressure Drop Adjustment

Device	Adjustment
Credits	
Fully ducted return and/or exhaust air systems	125 Pa (535 Pa for laboratory and vivarium systems)
Return and/or exhaust airflow *control devices*	125 Pa
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate Filtration Credit: MERV 9 through 12	125 Pa
Particulate Filtration Credit: MERV 13 through 15	225 Pa
Particulate Filtration Credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2× clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Biosafety cabinet	Pressure drop of device at fan system design condition
Energy Recovery Device, other than Coil Runaround Loop	(550 × Energy Recovery Effectiveness)—125 Pa for each airstream
Coil Runaround Loop	150 Pa for each airstream
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound Attenuation Section	38 Pa
Exhaust system serving fume hoods	85 Pa
Laboratory and vivarium exhaust systems in high-rise buildings	60 Pa/30 m of vertical duct exceeding 25 m

Piping Design!

TABLE 6.5.4.5 Piping System Design Maximum Flow Rate in L/s

Operating Hours/Year	≤2000 Hours/Year		>2000 and ≤ 4400 Hours/Year		>4400 Hours/Year	
DN, mm	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed	Other	Variable Flow/ Variable Speed
75	8	11	5	8	4	7
90	1	17	9	13	7	11
110	22	33	16	25	13	20
140	26	39	20	30	16	23
160	47	69	36	54	28	43
225	76	114	57	88	44	69
280	114	170	82	126	63	101
315	158	240	120	183	95	145
Maximum Velocity for Pipes over 315 mm Size	2.6 m/s	4.0 m/s	2.0 m/s	2.9 m/s	1.5 m/s	2.3 m/s

Mandatory Requirement – LEED Prerequisite

Section 7.4: Service Water Heating

Calculations

Service water heating design loads

Equipment efficiency

*Class C energy efficiency rating EU Regulation 814/2013 & 812/2013**

Insulation

*DHW insulation based on KENAK**

Controls

Temperature, Outlet temperature and circulating pump controls

Pools

Pool heaters ON/OFF, Poll covers, Time switches

Heat traps

Mandatory Requirement – LEED Prerequisite

Section 8.4: Power

Voltage drop

Feeders 2%, Branch circuits 3%

Automatic Receptacle Control

Automatic control device for at least 50% of receptacles in

- *Private offices*
- *Open offices*
- *Computer classrooms*

Mandatory Requirement – LEED Prerequisite

Section 9.4: Lighting

Controls

Automatic shutoff 😊

Space control 😊

Parking Garage Lighting Control 😊

Automatic Daylight Controls for Primary Sidelighted Areas & Topligting 😊

Exterior Lighting Control

😊 Exempt if improvement of more than 10% than LPDs*

Exterior Lighting

Power allowance based on Table 9.4.3B

Functional Testing

Temperature, Outlet temperature and circulating pump controls

Mandatory Requirement – LEED Prerequisite

Section 10.4: Other Equipment

Electric motors

Comply with rating class IE3 according to EU regulation 640/2009 or IEC 60034-30-1

Service water pressure booster systems

Pressure sensors to vary pump speed, no pressure reducers and no pump operation at no flow

Elevators

Requirements for lighting, ventilation and standby mode.

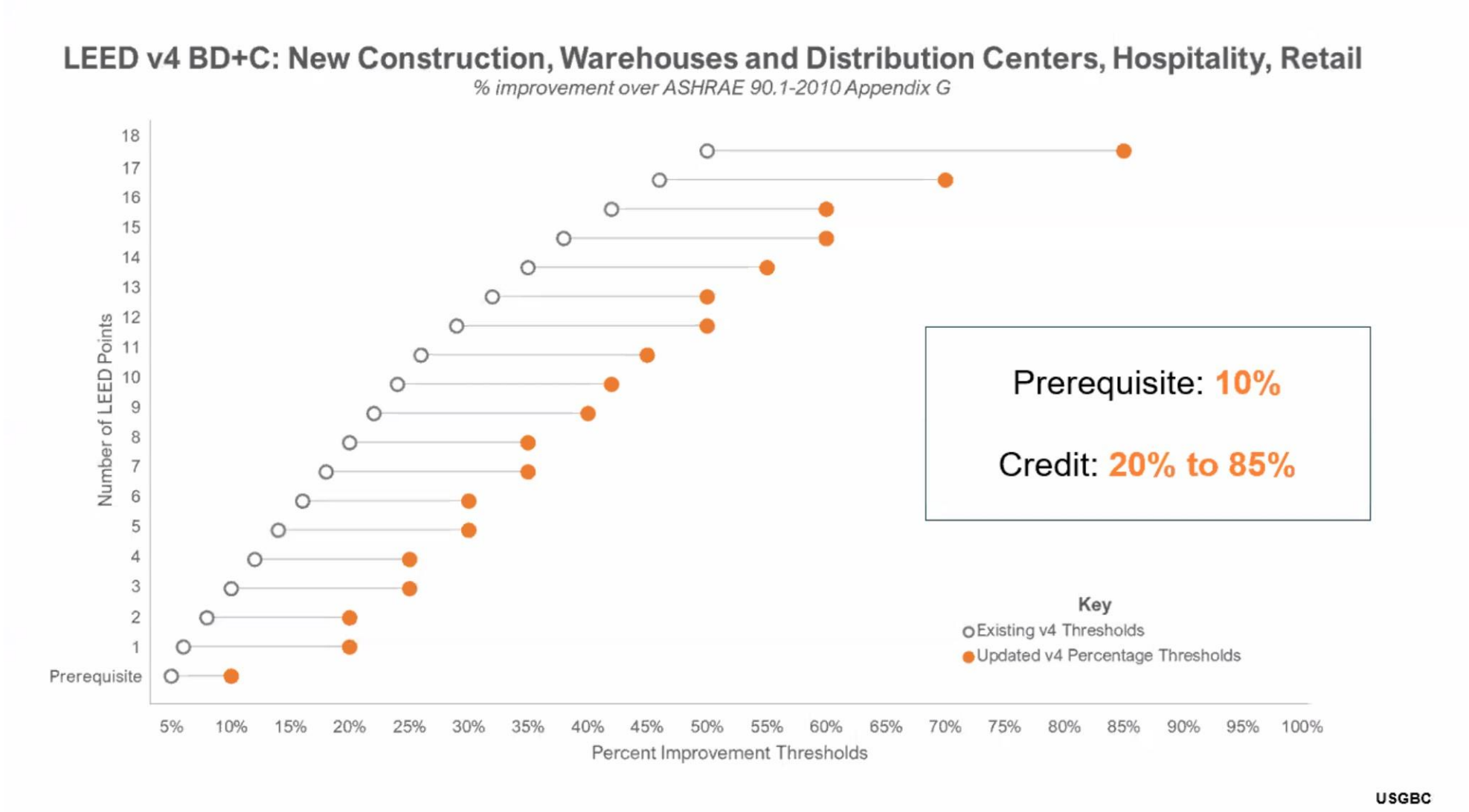
Escalators and Moving Walks[2]

Slow down to minimum speed when not conveying passengers

Whole-Building Energy Monitoring[2]

Measurement devices to monitor building use of energy with recording and reporting capabilities

Energy Performance Updated v4



Energy Performance Updated v4

Building	Gross Floor Area (m^2)	Proposed (kWh)	Baseline (kWh)	Savings	Score (v4)	Score (Updated v4)
Office building NC	2,200	139,329	262,681	46.96%	17	11
Multiuse space NC	2,400	87,287	197,459	55.79%	18	14
Logistic Center NC	9,700	30,623	339,394	90.98%	18	18
Office building C+S	5,500	251,622	377,790	33.40%	13	10

Energy Simulation (Appendix G)

Energy Model vs KENAK

- *Hourly step*
- *Full building model with internal partitions*
- *Technical specifications of all equipment (HVAC, ventilation, lighting, Service Water, RES)*
- *Characteristics of other process loads*
- *Operational data per zone/room (occupancy, lighting, fresh air)*

- *Monthly step*
- *Only building shell*
- *Basic characteristics of the main installation elements*

- *No process loads*
- *Operational data are taken by default based on the zone use*

Energy Simulation (Appendix G)

Simulation Program Requirements

- *8760 hours per year*
- *Hourly variations (occupancy, lighting, HVAC operation etc)*
- *Thermal mass effects*
- *Ten or more thermal zones*
- *Part-load performance curves for mechanical equipment*
- *Capacity and efficiency correction curves for mechanical heating and cooling equipment*
- *Air-side economizers with integrated control*
- *Baseline building design characteristics as per Appendix G3*

Energy Simulation (Appendix G)

Performance rating

90.1/2010

$$Percentage\ improvement = 100 \times \frac{Baseline\ building\ performance - Proposed\ building\ performance}{Baseline\ building\ performance}$$

90.1/2016

$$Performance\ Cost\ Index = \frac{Proposed\ building\ performance}{Baseline\ building\ performance}$$

Energy Simulation (Appendix G)

Baseline Building characteristics

- ***Space usage, schedules, HVAC zones**: same as proposed*
- ***Orientation**: Average for 4 orientations (actual and plus 90°, 180° and 270°)*
- ***Building Envelope:** Specific characteristics*
- ***Vertical fenestration** ≤ 40% gross above-grade wall area / Per building type (Table G3.1.1-1)*
- ***Skylights** ≤ 5% gross roof area / ≤ 3% gross roof area*
- ***HVAC system**: Type and characteristics based on building size*
- ***Lighting and service hot-water systems:** as per Appendixs 7.4 and 9.4 / Specific characteristics*
- ***Other loads**: same as proposed*

**ASHRAE 90.1-2022*

Energy Simulation (Appendix G)

HVAC Baseline System Types

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

ASHRAE 90.1-2022

Energy Simulation (Appendix G)

HVAC Baseline System Descriptions

System No.	*System* Type	Fan *Control*	Cooling Type [a]	Heating Type [a]
1. *PTAC*	*Packaged terminal air conditioner*	Constant volume	Direct expansion	Hot-water *fossil fuel boiler*
2. *PTHP*	*Packaged terminal heat pump*	Constant volume	Direct expansion	Electric heat pump
3. PSZ-AC	Packaged rooftop air conditioner	Constant volume	Direct expansion	*Fossil fuel* furnace
4. PSZ-HP	Packaged rooftop heat pump	Constant volume	Direct expansion	Electric heat pump
5. Packaged *VAV* with *reheat*	Packaged rooftop *VAV* with *reheat*	*VAV*	Direct expansion	Hot-water *fossil fuel boiler*
6. Packaged *VAV* with PFP boxes	Packaged rooftop *VAV* with parallel fan power boxes and *reheat*	*VAV*	Direct expansion	*Electric resistance*
7. *VAV* with *reheat*	*VAV* with *reheat*	*VAV*	Chilled water	Hot-water *fossil fuel boiler*
8. *VAV* with PFP boxes	*VAV* with parallel fan-powered boxes and *reheat*	*VAV*	Chilled water	*Electric resistance*
9. Heating and *ventilation*	Warm air furnace, gas fired	Constant volume	None	*Fossil fuel* furnace
10. Heating and *ventilation*	Warm air furnace, electric	Constant volume	None	*Electric resistance*
11. SZ–*VAV*	Single-zone *VAV*	*VAV*	Chilled water	See note (b).
12. SZ-CV-HW	*Single-zone system*	Constant volume	Chilled water	Hot-water *fossil fuel boiler*
13. SZ-CV-ER	*Single-zone system*	Constant volume	Chilled water	*Electric resistance*

Minimum Requirements for Heat Pumps

TABLE 6.8.1A Electronically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements *(continued)*

Equipment Type	Size Category	Heating Section Type	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air conditioners, water cooled	≥223 kW	Electric Resistance (or None)	Split System and Single Package	3.22 COP_c (before 6/1/2011) 3.57 COP_c (as of 6/1/2011) 3.25 ICOP (before 6/1/2011) 3.63 ICOP (as of 6/1/2011)	AHRI 340/360
		All other	Split System and Single Package	3.16 COP_c (before 6/1/2011) 3.51 COP_c (as of 6/1/2011) 3.19 ICOP (before 6/1/2011) 3.57 ICOP (as of 6/1/2011)	
Air conditioners, evaporatively cooled	< 19 kW	All	Split System and Single Package	3.54 COP_c 3.60 ICOP	AHRI 210/240
	≥19 kW and <40 kW	Electric Resistance (or None)	Split System and Single Package	3.37 COP_c (before 6/1/2011) 3.54 COP_c (as of 6/1/2011) 3.43 ICOP (before 6/1/2011) 3.60 ICOP (as of 6/1/2011)	AHRI 340/360
		All other	Split System and Single Package	3.31 COP_c (before 6/1/2011) 3.48 COP_c (as of 6/1/2011) 3.37 ICOP (before 6/1/2011) 3.54 ICOP (as of 6/1/2011)	
	≥40 kW and <70 kW	Electric Resistance (or None)	Split System and Single Package	3.22 COP_c (before 6/1/2011) 3.51 COP_c (as of 6/1/2011) 3.28 ICOP (before 6/1/2011) 3.57 ICOP (as of 6/1/2011)	
		All other	Split System and Single Package	3.16 COP_c (before 6/1/2011) 3.46 COP_c (as of 6/1/2011) 3.22 ICOP (before 6/1/2011) 3.51 ICOP (as of 6/1/2011)	
	≥70 kW and < 223	Electric Resistance (or None)	Split System and Single Package	3.22 COP_c (before 6/1/2011) 3.48 COP_c (as of 6/1/2011) 3.25 ICOP (before 6/1/2011) 3.54 ICOP (as of 6/1/2011)	

COP is not calculated with the fan motor loses nor the heat gains of the motor to the system!

Economizers

TABLE G3.1.2.6A Climate Conditions under which Economizers are Included for Baseline Systems 3 through 8

Climate Zone	Conditions
1a, 1b, 2a, 3a, 4a	N.R.
Others	Economizer Included

N.R. means that there is no conditioned building floor area for which economizers are included for the type of zone and climate.

TABLE G3.1.2.6B Economizer High-Limit Shutoff

Climate Zone	High-Limit Shutoff
1b, 2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	24°C
5a, 6a, 7a	21°C
Others	18°C

Fan Power

- *System* fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered VAV boxes) shall be calculated using the following formulas:
- For Systems 1 and 2, $P_{fan} = CFMs \times 0.3$
- For Systems 3 through 8

Fan Motor Efficiency = the efficiency from Table 10.8B for the next motor size greater than the input kW using a totally enclosed fan cooled motor at 1800 rpm.

TABLE G3.1.2.9 Baseline Fan Motor Power

Baseline Fan Motor Power	
Constant Volume Systems 3–4	**Variable Volume Systems 5–8**
$kW_i = L_S \cdot 0.0015 + A$	$kW_i = L_S \cdot 0.0021 + A$

Where *A* is calculated according to Section 6.5.3.1.1 using the pressure drop adjustment from the proposed building design and the design flow rate of the baseline building *system*.

Do not include pressure drop adjustments for evaporative coolers or heat recovery devices that are not required in the baseline building *system* by Section G3.1.2.10.

Fan Part Load for VAV

TABLE G3.1.3.15 Part-Load Performance for VAV Fan Systems

Method 1—Part-Load Fan Power Data	
Fan Part-Load Ratio	**Fraction of Full-Load Power**
0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	0.83
1.00	1.00

Method 2—Part-Load Fan Power Equation

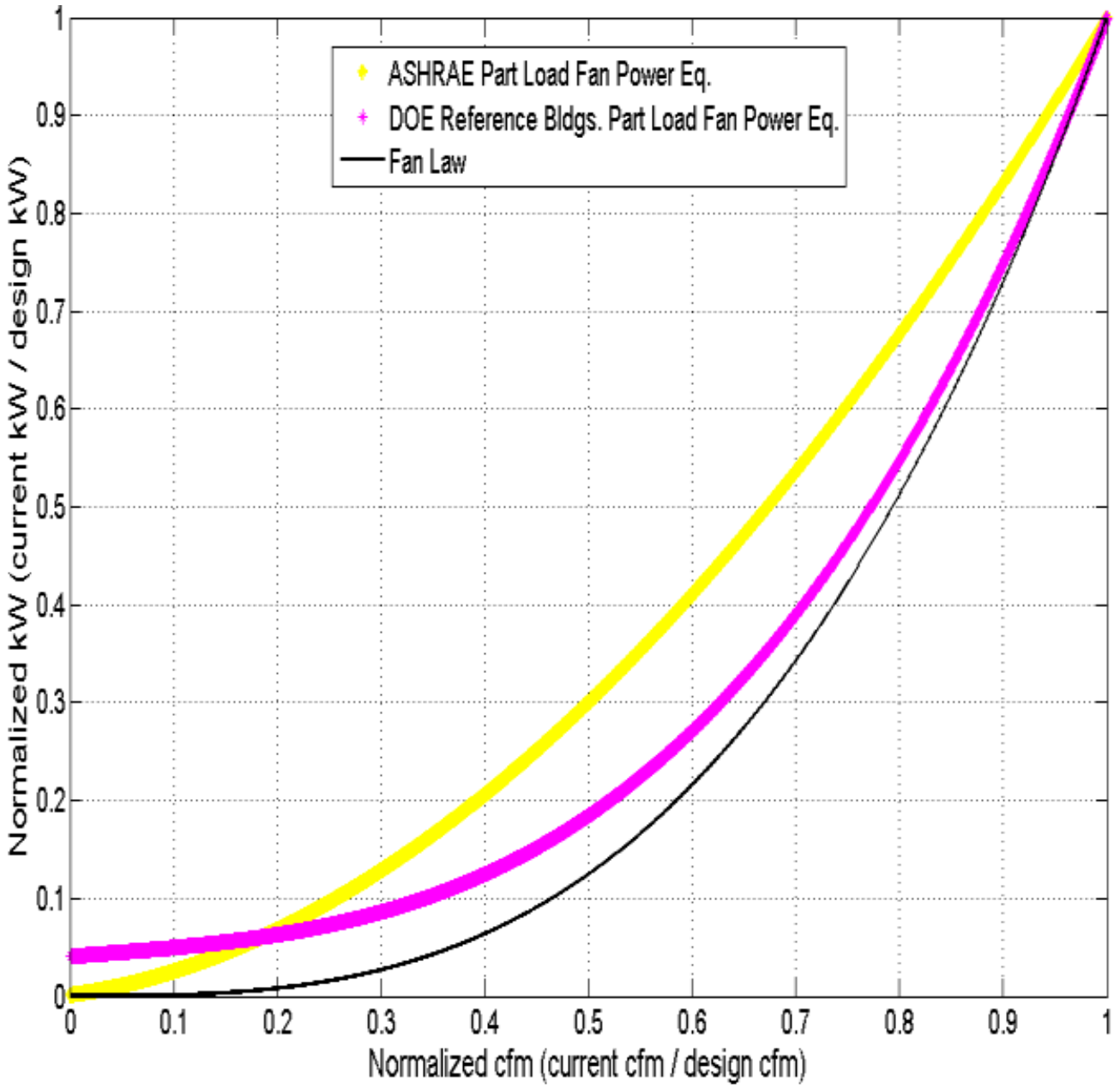
$$P_{fan} = 0.0013 + 0.1470 \times PLR_{fan} + 0.9506 \times (PLR_{fan})^2 - 0.0998 \times (PLR_{fan})^3$$

where

P_{fan} = fraction of full-load fan power and

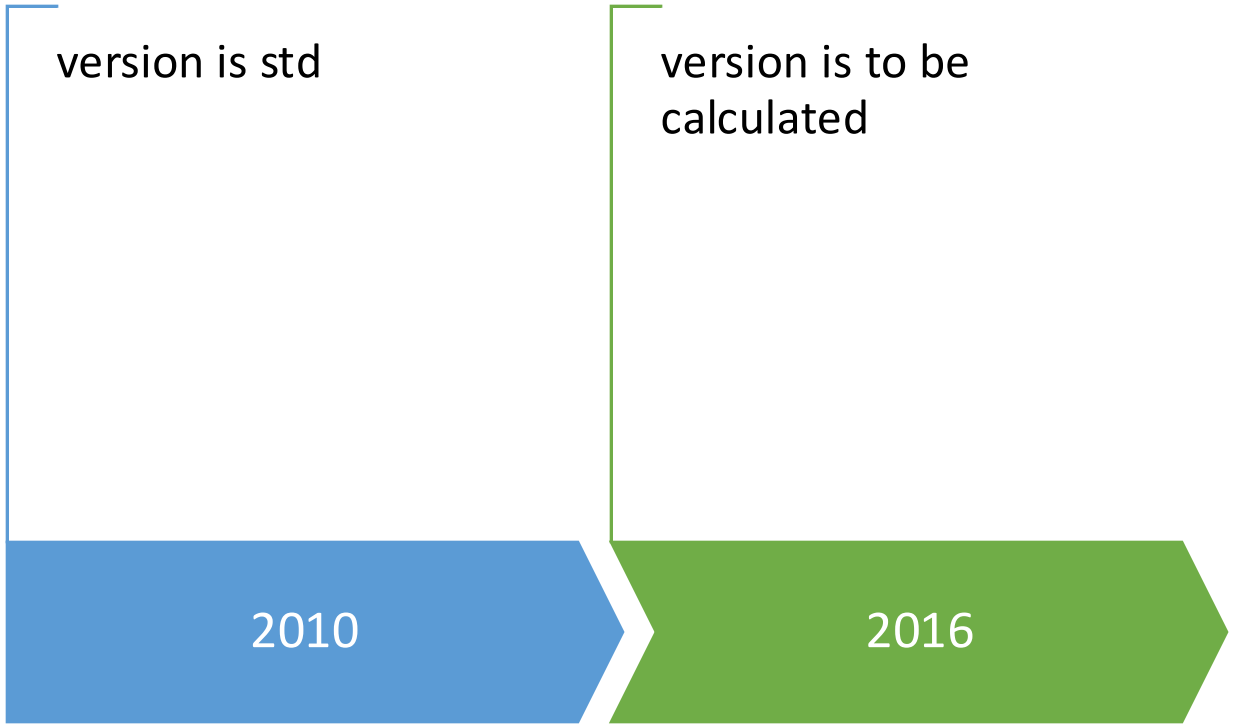
PLR_{fan} = fan part-load ratio (current L/s/design L/s).

Fan Part Load for VAV



Parichehr et al, *Comparison of actual supply air fan performance data to ashrae 90.1 standard-2010 and doe commercial reference buildings part load fan energy use formula, 2014 ASHRAE/IBPSA-USA Building Simulation Conference*

Infiltration



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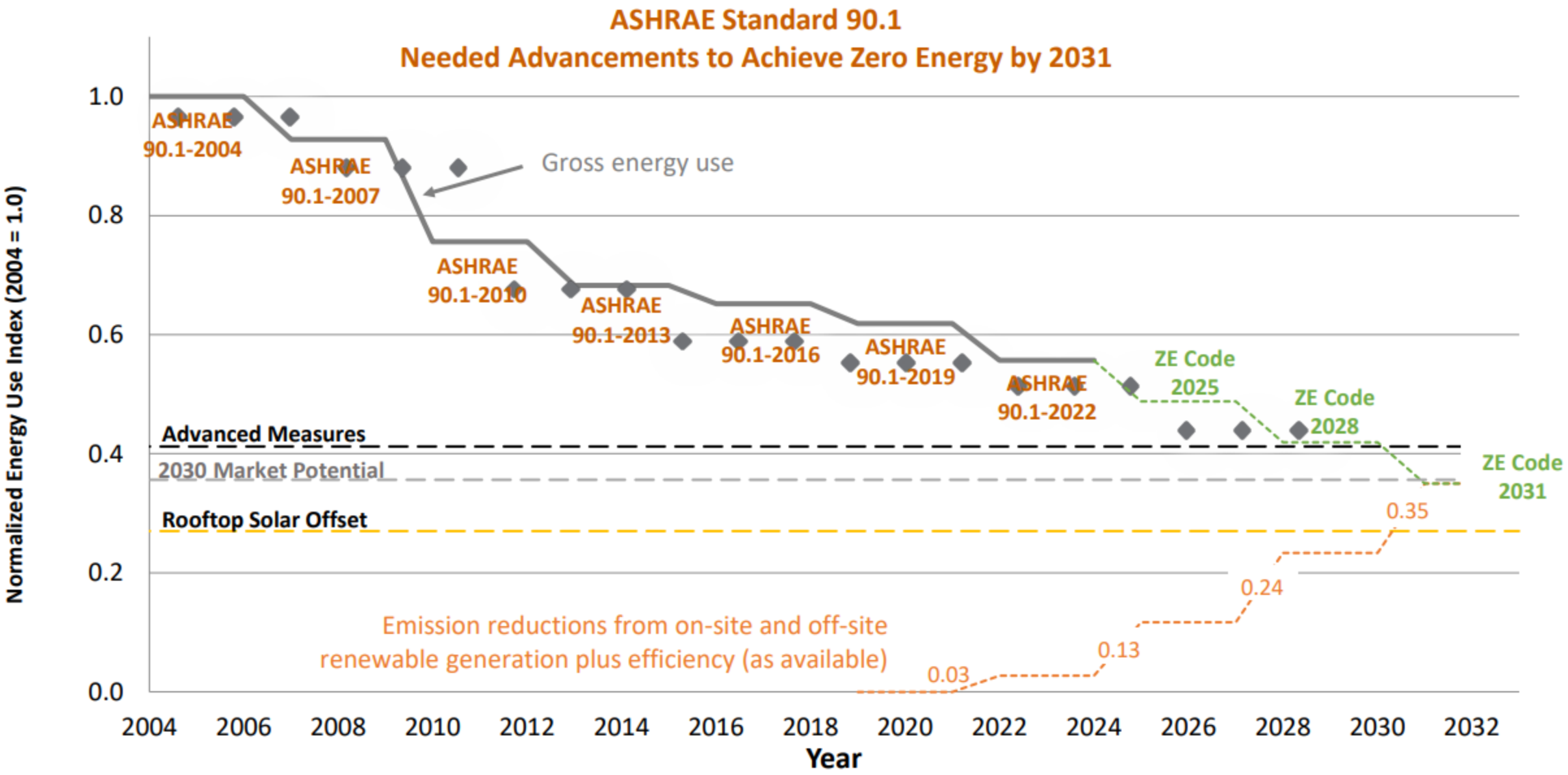
ASHRAE Standard 90.1/2019	*ASHRAE Standard 90.1/2022*



Michael Tillou, PNNL – The transition to Performance Based Codes, 2023 National Energy Codes Conference

LEED v5

AND….

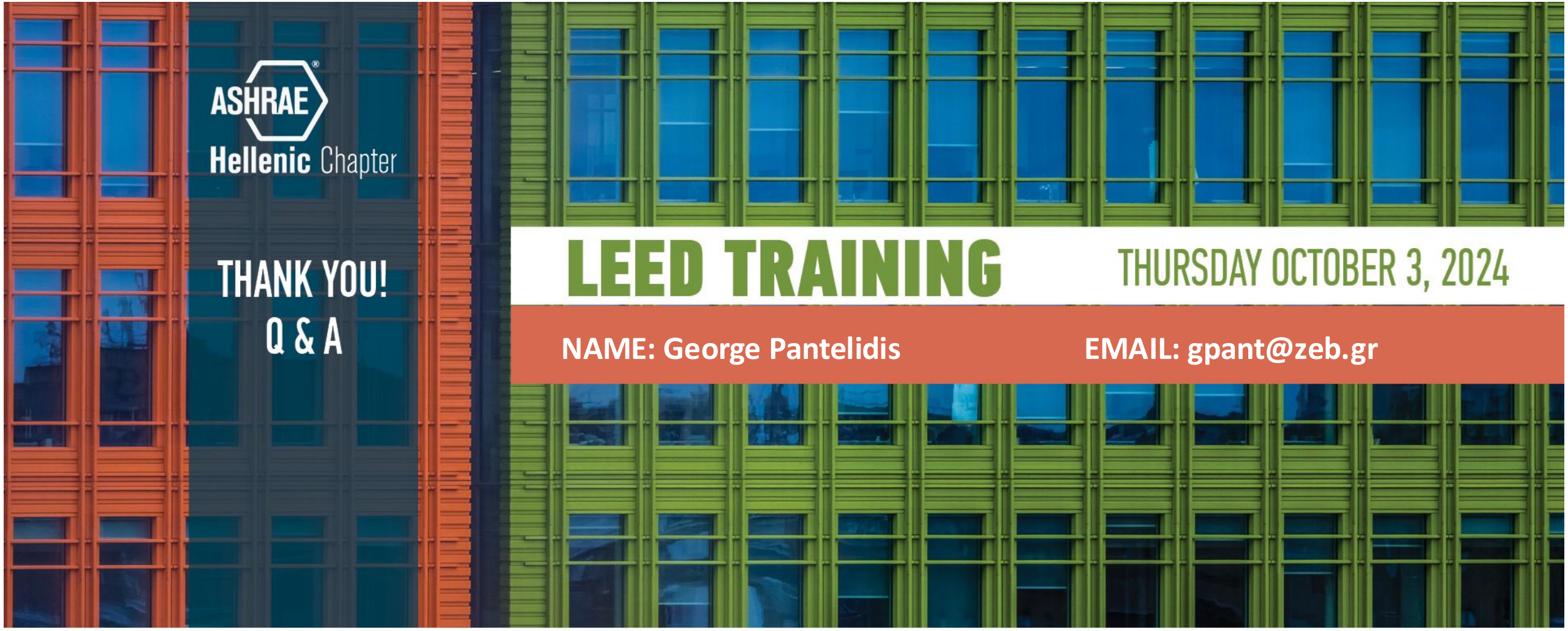
ASHRAE Standard 90.1 as option for Fundamental Commissioning

ASHRAE Standard 202-2018 for enhanced Commissioning

ASHRAE Standard 62.1-2022 for Fundamental and Enhanced Air Quality

ASHRAE Standard 55-2023 for Occupant Experience

ASHRAE Guideline 44 (Protecting Occupants from Smoke during Wildfires and Prescribed Burn Events) and ASHRAE Standard 241-2023 (Control of Infectious Aerosols) for Resilient Spaces



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