BESF September 8th 2021 Meeting

Energy modeling for compliance with 2021 Oregon Energy Efficiency Specialty Code

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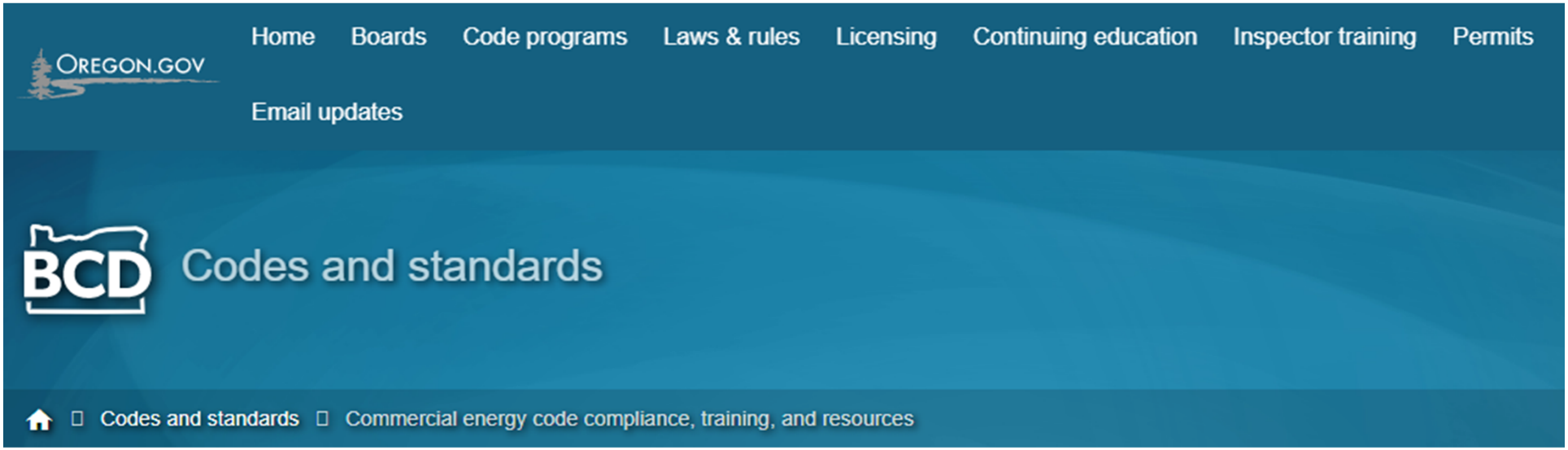
September 08, 2021

Agenda

- Current Oregon energy code overview
- Significant changes & Oregon amendments to 90.1
- Oregon documentation requirements
- Resources
- Compliance paths

Current Oregon Energy Code



2021 Oregon Energy Efficiency Specialty Code

Chapter 13 of the Oregon Structural Specialty Code

- Effective April 1, 2021
- Phase-in period ends Oct. 1, 2021
- Based on ASHRAE Standard 90.1-2019
- Significant changes summary

R-2,3,4 structures are subject to this code. The ORSC applies mainly to 1-2 family dwelling units & townhomes

- https://www.oregon.gov/bcd/codes-stand/Pages/energy-commercial-compliance.aspx
- Read only versions of 90.1 are available

Significant Changes & Amendments

Significant changes to ASHRAE Standard 90.1

No.	Section	Heading / Change summary
1	Tables 5.5-4 and -5	**Fenestration.** For vertical fenestration, the categories for "non-metal framed" and "metal framed" products were combined. Single U-factor requirement, regardless of frame construction material. Fixed frame metal requires better performance; non-metal frames have less restrictive requirement. Swinging door U-factor improved to 0.63.
2	5.4.3	**Building air leakage**. Air leakage test required for all structures. Exception from testing when air sealing design and field verification under Section 5.9.1. **Fiscal impact:** *Potential cost increase for testing.*
3	5.4.3.3	**Vestibules.** Air curtain exception added (2014 OEESC and 2018 IECC).
4	6.6	**ASHRAE 90.4 for Data Centers.** Alternate compliance path for use of 90.4 data center standard for HVAC systems. (See BCD modification to require use of 90.4 for new buildings with Data Centers).
5	Section 6	**Pump efficiency.** Federal efficiency standards brought into Section 6.
6	6.8.1 Efficiency Tables	**Expansion of tables.** New product types covered. Tables combined, added and deleted to align with latest federal regulations. Efficiency for specialty equipment clearly delineated, eliminating confusion from previous editions.

– https://www.oregon.gov/bcd/codes-stand/Documents/21oeesc-summary-matrix.pdf

Significant Changes & Amendments

7	6.5.3.1.3	**Fan Efficiency Grade.** New efficiency metric (FEI) for fans to replace "FEG". Unlike FEG, FEI considers motors and drives, not just fans.
8	6.5.6.1.1	**Dwelling unit heat recovery.** Apartments (nontransient dwelling) require 60% enthalpy recovery, heating mode only, in Oregon climate zones.
9	Tables 9.5.1 and 9.6.1	**Lighting power allowance:** Lowered power allowances for many building types (Building Area) and Space Types (Space-by-Space method). Updated to align with current (at time of review) LED lighting efficiencies. Calculations allowing for geometry of room.
10	9.3	**Simplified building compliance.** If office, retail and school occupancy comprises at least 80 percent of buildings under 25,000 sq. ft., then simplified compliance path is allowed. Aligns with HVAC simplified path.
11	9.4.1.1	**Daylight control.** Stepped control removed. Continuous dimming control for daylight zones.
12	9.4.1.2	**Parking garage automatic control.** Updated detection and control period.
13	9.4.1.1(e)	**Sidelight area.** Clarification to exceptions for distance and inclusion of natural obstructions.

– https://www.oregon.gov/bcd/codes-stand/Documents/21oeesc-summary-matrix.pdf

Oregon Specific Amendments

- **Section 5.1.2.3 Space Conditioning Categories**
  - A space with limited radiant heating system meeting the requirements of Section 6.5.8.3 shall be considered an unconditioned space.
    - » Can forego some envelope requirements

- **Section 6.5.8.3 Radiant Heating for Enclosed Unconditioned Spaces**
  - Overhead radiant heating systems shall be allowed in unconditioned spaces for spot heating of occupied areas. Spot heating shall be limited to 500 ft^2 (46 m^2) or 10 percent of the space floor area, whichever is greater. Control shall be automatic complying with either Section 6.4.3.3.1 (b) or 6.4.3.3.1 (c).
    - » Occ sensor to shut off after 30 mins or manual timer to allow 2 hours operation

- **Section 5.4.3.3 Vestibules and Revolving Doors**
  - Exception #11. Buildings under 25,000 ft^2 (2,322 m^2) meeting the requirements of Section 5.4.3.1.1 with a leakage rate less than 0.30 cfm/ft^2.
    - » i.e. 25% less than required by whole building leakage section

- **Section 6.4.3.4.5 Enclosed Parking Garage Ventilation**
  - Enclosed parking garage ventilation systems shall automatically detect contaminant levels and stage fans or modulate fan airflow rates per Section 404 of the *Mechanical Code* ~~to 50% or less of design capacity~~, provided acceptable contaminant levels are maintained.
    - » Exception 2. ~~Garages that have a garage area to ventilation system motor nameplate horsepower ratio that exceeds 1500 ft2 /hp and do not utilize mechanical cooling.~~

Oregon Specific Amendments

- **Section 6.4.3.5.1 Packaged HVAC Equipment with Electric Heat**
  - HVAC equipment for new buildings with a cooling capacity less than 241,000 Btu/h from Table 6.8.1-1 shall not have electric supplemental heat exceeding 21,500 Btu/h (6 kW). Equipment shall have heat pump operation for the first stage of heating and shall be selected from Table 6.8.1-2.

- **Section 8.4.2 Automated Receptacle Control**
  - Exception 3 The building complies with one of the following:
    a. Results of performance compliance under Section 11 or Appendix G are at least 5% better than the minimum.
    b. COMcheck envelope compliance report passes by minimum of 3%.
    c. COMcheck lighting report passes by a minimum of 5%.

- **Section 9.4.3 Dwelling Units**
  - Not less than ~~75%~~ 100% of the permanently installed lighting fixtures shall use lamps with an efficacy of at least 55 lm/W or have a total luminaire efficacy of at least 45 lm/W. No other provisions of Section 9 apply to dwelling units. Dwelling unit floor area shall be excluded from total building floor area under the Building Area Compliance Method (9.5.1).

- https://www.oregon.gov/bcd/codes-stand/Documents/2021oeesc.pdf

2021 OEESC
Construction Document Requirements

- **E104.2.1 Oregon Energy Compliance Form.** *Construction documents* for new buildings shall include the 2021 Oregon Energy Compliance Form, including a ZERO Code 2.0 Calculator report (See *ZERO-Code.org/energy-calculator/*)
  - https://zero-code.org/energy-calculator/

Commercial Energy Code Compliance

Yes, this still needs to be filled out when using Appendix G or Section 11.

COMcheck™

Only COMCheck-web has 90.1-2019 available currently.

Code Compliance Form

State of Oregon
Building Codes Division
Better Buildings for Oregon

Part I **COM*check* information**	
Compliance path: ☐ Performance path ☐ Prescriptive path	COM*check* (Standard 90.1-2019) results: ☐ Pass ☐ Fail *For performance path, submit the energy model report with this form.
Prepared by or under the supervision of:	Date:
Part II **Projected energy use**	
Enter the ZERO Code 2.0 Calculator results for projected energy use. Estimated building energy consumption: _____ MBtu/yr	
Part III **Estimated available renewables for the building**	
Enter the ZERO Code 2.0 Calculator results for offsets. Total renewable energy to achieve Net Zero: _____ MBtu/yr On-site PV generational potential: _____ MBtu/yr Remaining off-site renewable energy: _____ MBtu/yr	
CHECKLIST AND APPLICANT SIGNATURE	
COM*check* report and ZERO Code 2.0 Calculator report must be submitted with this form. ☐ COM*check* report is attached ☐ ZERO Code Calculator report is attached	☐ Energy model report is attached (if COM*check* failed) ☐ 2021 OEESC COM*check* supplement report is attached

https://www.oregon.gov/bcd/codes-stand/Documents/oeesc-compliance-form.pdf

9

OEESC Supplemental Form

COM*check* Supplement

2021 Oregon Energy Efficiency Specialty Code Compliance

SECTION 6: HVAC

6.4.3.5.1: Packaged HVAC Equipment with Electric Heat ☐ **Check if not applicable**

☐ Packaged HVAC systems with less than 241,000 Btu/h cooling capacity, with electric heating capacity of 21,500 Btu/h or greater have heat pump operation for first stage of heating

Plans and specs.:

6.5.8.3: Radiant Heating for Enclosed Unconditioned Spaces ☐ **Check if not applicable**

☐ Overhead radiant heating for occupied areas of the lesser of 500 ft^2 or 10% of floor area

☐ Automatic control: manual time switch or occupancy sensor

Plans and specs.:

SECTION 8: POWER

8.4.2: Receptacle Control Exception ☐ **Check if not applicable**

Building is not providing controlled receptacles required per Section 8.4.2. Additional efficiency provided with the following method (select one)

☐ Performance Compliance report showing minimum 5% better performance than minimum

☐ Section 11 ECB report included **or** ☐ Appendix G report included

☐ COMcheck Envelope Compliance report showing minimum 3% passing or higher

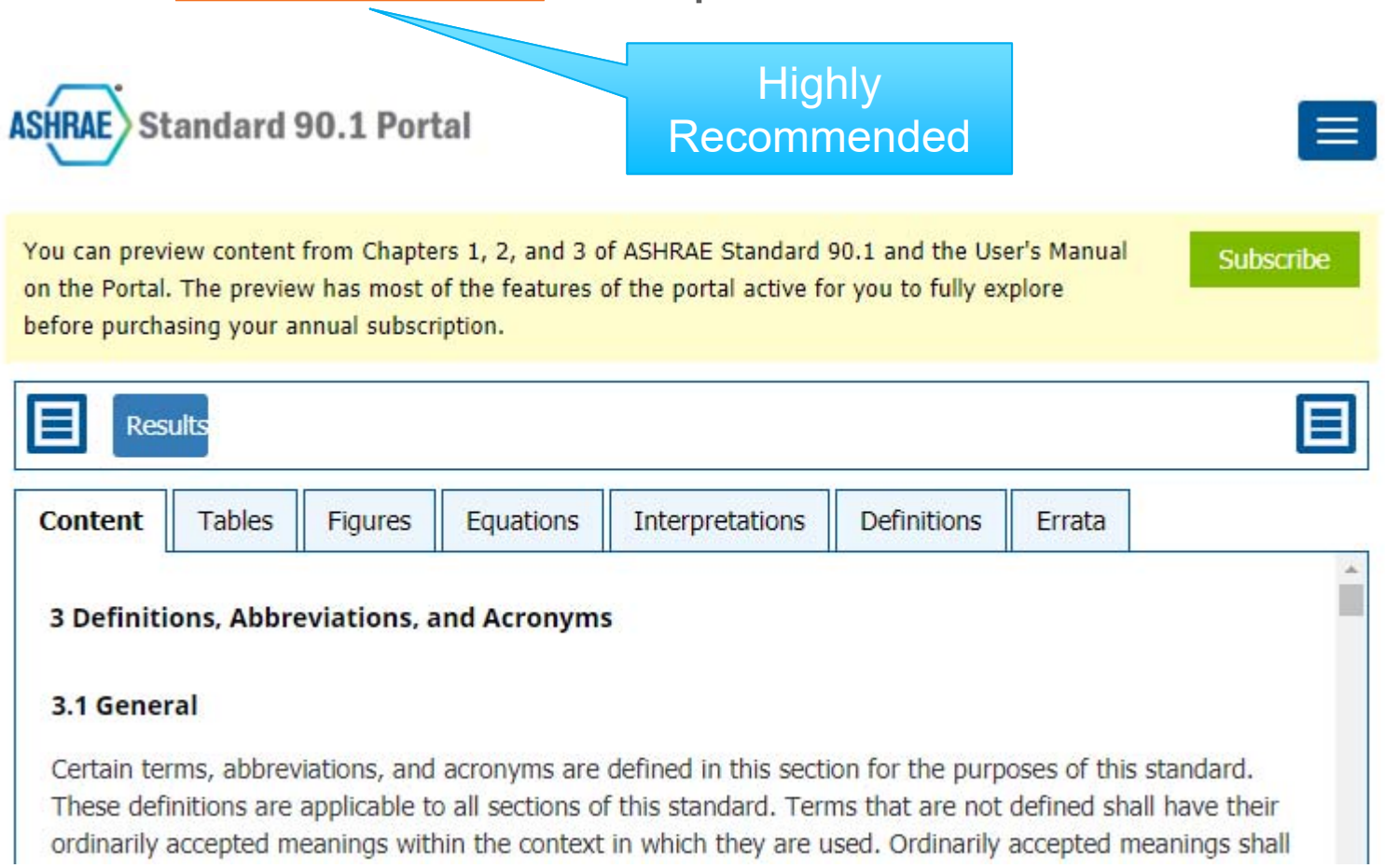
☐ ASHRAE 90.1-2019 COMcheck forms included

☐ COMcheck Lighting report showing minimum 5% passing or higher

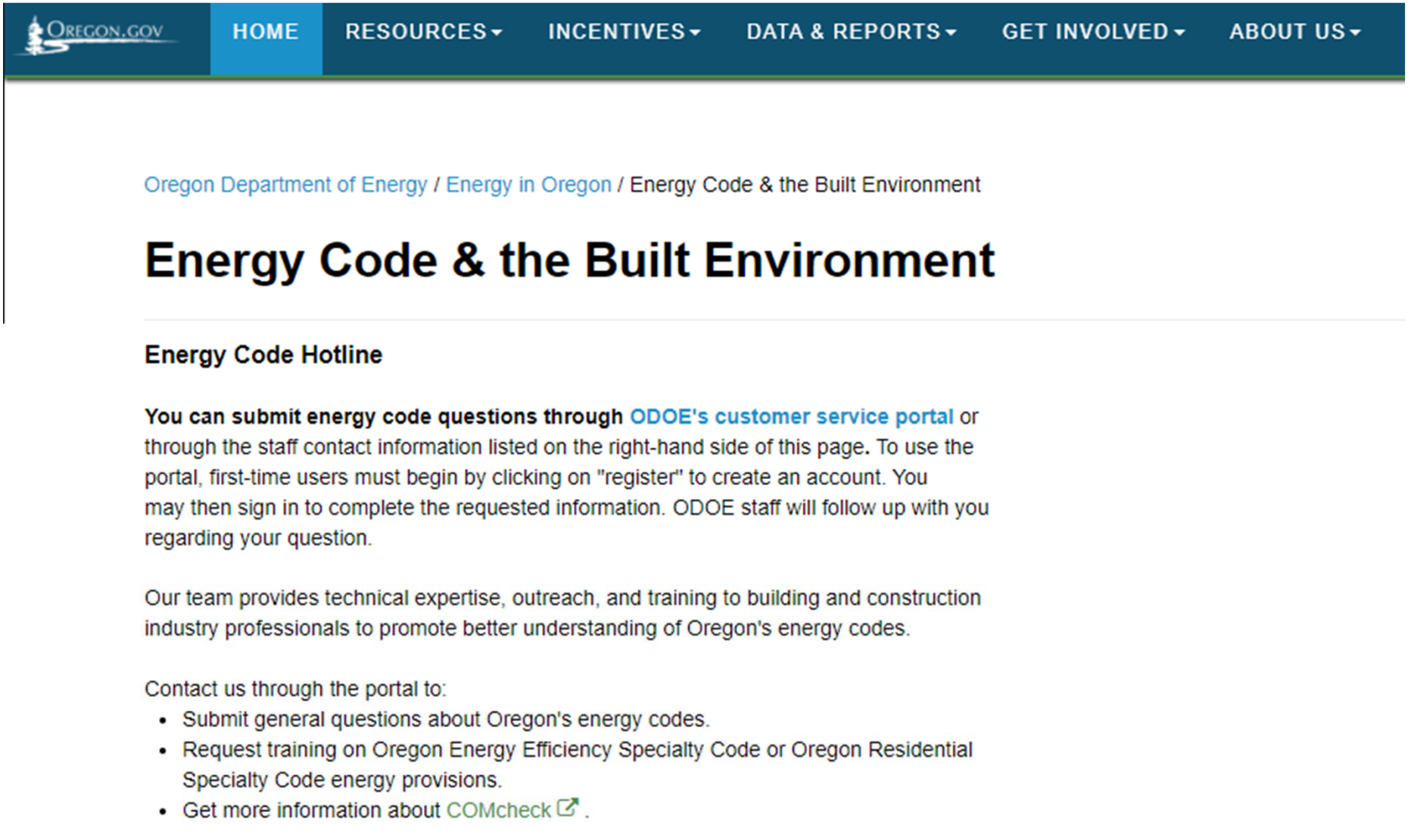
☐ ASHRAE 90.1-2019 COMcheck forms included

ASHRAE 90.1 Portal

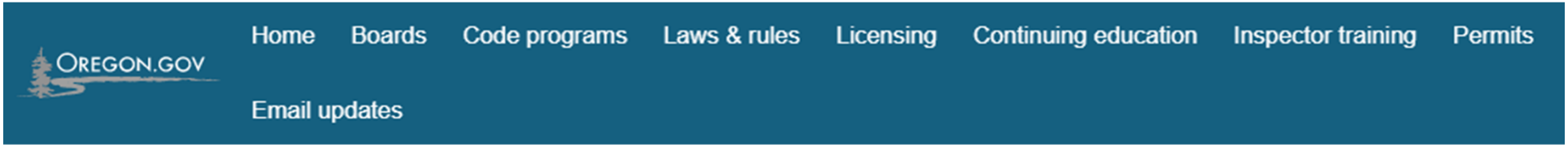
ASHRAE 90.1 online portal (annual subscription)
https://www.ashrae.org/technical-resources/90-1-portal
Includes user's manual, interpretations, redline & notes



Oregon Specific Resources



Oregon Specific Resources



Compliance forms and resources

To demonstrate compliance with the energy code, construction documents shall include the following where applicable:

- Oregon Energy Efficiency Compliance Form
- COM*check* supplement form

Use the following resources to complete the compliance form:

- Commercial compliance using COM*check*
- COM*check* web
- Zero Code calculator

Energy modeling / Cost of energy

Use the following for energy modeling / cost of energy:

- Cost-per-unit of energy: performance methods

Code update training

- 2021 OEESC update training video
- Significant changes summary
- Code adoption process and information

ASHRAE 90.1-2019 resources

- ANSI/ASHRAE/IES Standard 90.1-2019 Envelope
- ANSI/ASHRAE/IES Standard 90.1-2019 HVAC
- ANSI/ASHRAE/IES Standard 90.1-2019 Lighting
- US Department of Energy Building Energy Codes Training

https://www.oregon.gov/bcd/codes-stand/Pages/energy-commercial-compliance.aspx

Compliance Paths

Three Paths Through 90.1

Mandatory Requirements

Plus One

Prescriptive Requirements

Chapter 11 Performance (ECB)

Appendix G Performance (PRM)

Challenges with Prescriptive and Performance Paths

Prescriptive

- Fails to consider interactions between building components
- Limits design flexibility
- Reaching the physical limits of improvement for some components
- Overall HVAC system performance not prescribed
- Aggressive improvement targets not likely to be met

Whole Building Performance

- Resource intensive
- Trade-off between long-lasting envelope measures and shorter-lived measures like HVAC controls
- Requires simulation experts
- Difficult for building officials to verify compliance

Performance Path Resources

90.1-2016 Performance Rating Method Reference Manual

- https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26917.pdf
- Modelers: Use to build proposed design model
- Code Officials: Use to understand modeling requirements and interpretations

ASHRAE 90.1 Performance Based Compliance Form

- https://www.energycodes.gov/ashrae-standard-901-performance-based-compliance-form
- Modelers: Use to establish simulation inputs for baseline and proposed designs
- Code Officials: Simplifies submittal review process

Performance Pathways

2021 Oregon / ASHRAE 90.1-2019	2014 OEESC
Ch. 11, Appendix G	506

- Previous 2014 Oregon code contained Section 506 Whole Building Approach, based on 90.1 Ch. 11 Energy Cost Budget
- ASHRAE 90.1 includes two performance paths for code compliance, Ch.11 and Appendix G

KARPMAN CONSULTING

Performance-Based Compliance with ASHRAE Standard 90.1 2019

Section 11 Energy Cost Budget Method
Appendix G Performance Rating Method

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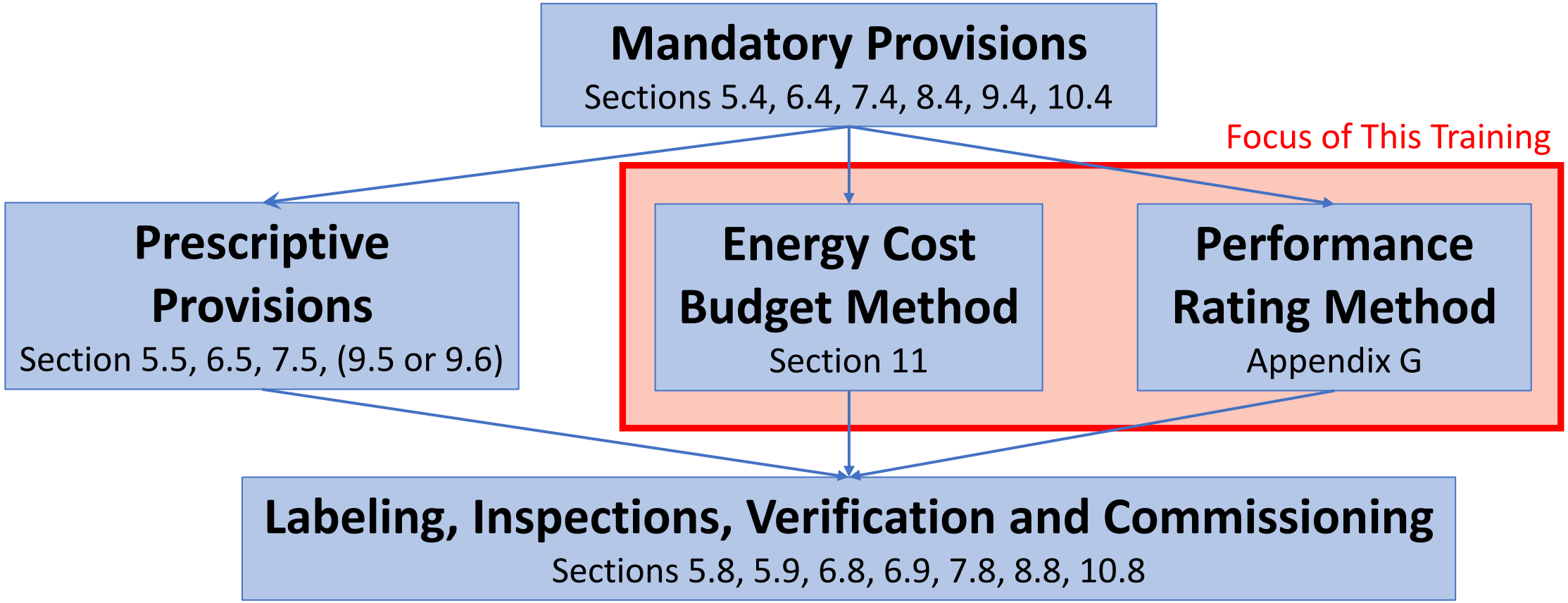
AGENDA

- General Concepts of Performance-based Compliance with ASHRAE Standard 90.1
- Modeling Requirements of 90.1 Section 11 and Appendix G
  - ✓ Building Envelope
  - ✓ HVAC
  - ✓ Interior Lighting
  - ✓ Other Loads (Exterior Lighting, Service Water Heating, Elevators, Refrigeration, Misc. Other Loads)
  - ✓ Service water heating
- Using Simulation Results to Establish Compliance
- Documentation Requirements

General Concepts of Performance-Based Compliance with ASHRAE Standard 90.1

ASHRAE Standard 90.1 Compliance Options

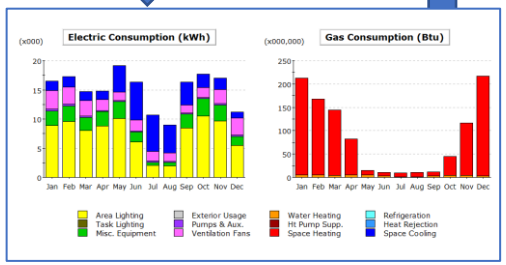


General Concept of Performance-based Compliance with 90.1

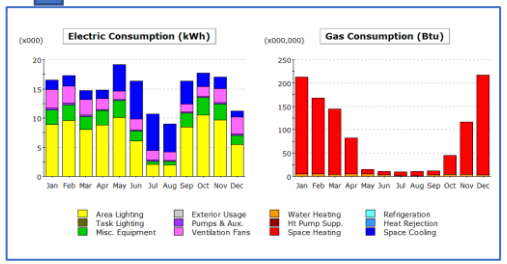
Proposed design: based on design documents

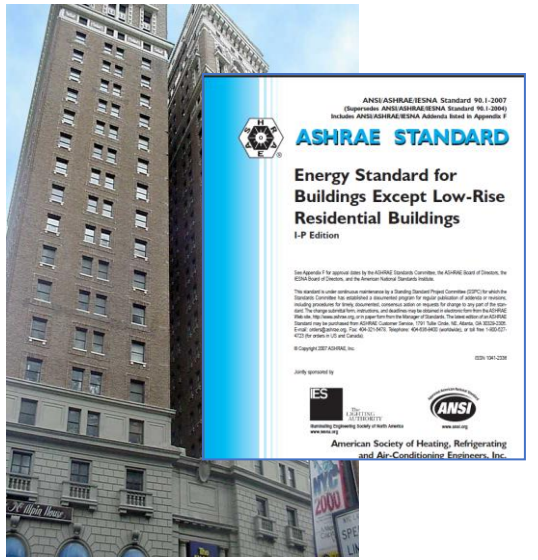
Reference design: virtual building used to evaluate proposed design

Simulation Tool



Simulation Tool





- Allow projects to not meet some of the prescriptive requirements and make up for the associated energy penalty by exceeding minimum requirements in other areas
- Configuration or both models is prescribed in ASHRAE Standard 90.1
- Energy use of both models is calculated using the same simulation tool, weather file and utility rates

Key Similarities Between Energy Cost Budget Method (ECB) and Performance Rating Method (PRM)

- May be used for new construction, alterations and additions to existing buildings except designs with no mechanical systems.
- Compliance is established based on the **relative annual energy cost of two models.**
- The **proposed design** model must reflect the specified systems, component and controls
- Proposed design must meet mandatory requirements of 90.1
- Except were specifically instructed, all building systems and equipment must be modeled identically in the two models.
- Operating schedules must be typical for the building type and identical in both models.
- Both models must be developed using the same simulation tool, weather and utility rates

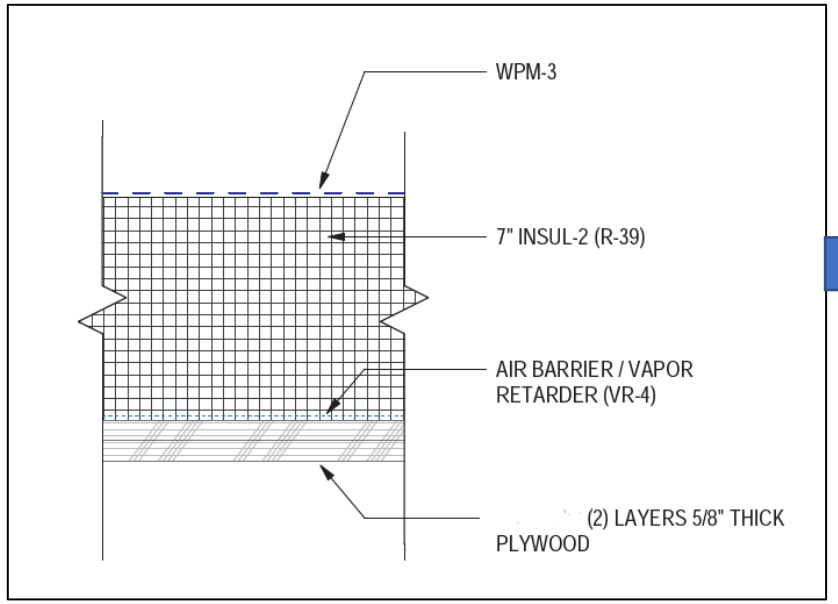
Key Differences between PRM and ECB

Energy Cost Budget Method	Performance Rating Method
Budget design has the same types of systems as the proposed design	Systems and components of the baseline design depend on project occupancy type and location but are otherwise largely independent of the proposed design
Budget design is minimally compliant with prescriptive requirements of 90.1 2019	Baseline design has efficiency levels approximately aligned with 90.1 2004
Project complies if the annual energy cost of the proposed design does not exceed the energy cost budget.	Project complies if the annual energy cost of the proposed design is below the baseline energy cost by a set margin.
Fewer opportunities for performance credit	More trade-off opportunities
Only systems submitted for the building permit together are subject to trade-offs	Baseline design is the same irrespective of permit scope
May be used only to document the minimum code compliance	May be used to document the minimum code compliance and beyond code performance

Modeling Requirements: Building Envelope

Proposed Design: Opaque Surfaces

Modeled opaque surface constructions must reflect design documents and account for thermal properties and thermal mass



Construction | Layers | Material

Currently Active Layers: EL1 Roof Cons Layers

Layers: EL1 Roof Cons Layers

Inside Film Resistance (R-val): 0.680

Material Layers (ordered from outside to inside):

	Material Name	Thickness (ft)	Conductivity (Btu/h-ft-°F)	Density (lb/ft3)	Spec. Heat (Btu/lb-°F)	R-Value (h-ft2-°F/Btu)
1	Blt-Up Roof 3/8in (BR01)	0.031	0.0939	70.00	0.350	n/a
2	Polyurethane 7in	0.583	0.0133	1.50	0.380	n/a
3	Plywd 5/8in (PW04)	0.104	0.0667	34.00	0.290	n/a
4	EL1 Roof Cons Mat 4 (2.8)	n/a	n/a	n/a	n/a	2.800

Proposed Design: Thermal Bridging

- Thermal resistance of surfaces that have sections with widely diverging conductivities, such as steel framed walls, must be de-rated in the simulation to account for thermal bridging
- If not explicitly modeled, de-rating must be based on ASHRAE 90.1 Appendix A

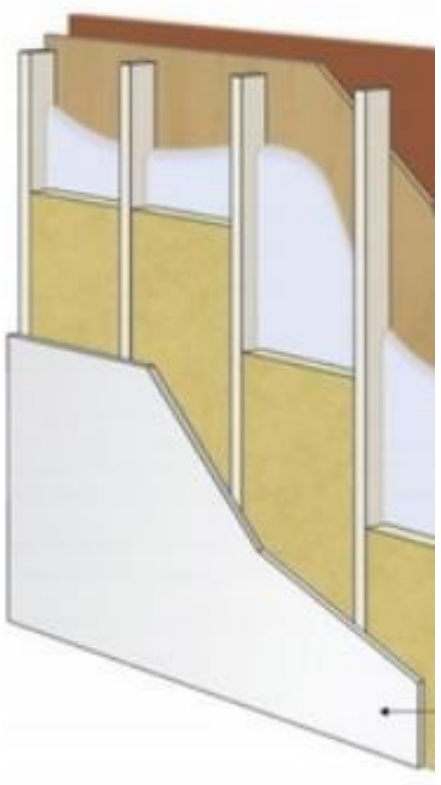


Table A9.2-2 Effective Insulation/Framing Layer *R-Values* for *Wall* Insulation Installed Between Steel Framing

Nominal Depth of Cavity, in.	Actual Depth of Cavity, in.	Rated *R-Value* of Air *Space* or Insulation	Effective Framing/Cavity *R-Value* at 16 in. on Center	Effective Framing/Cavity *R-Value* at 24 in. on Center
Empty Cavity, No Insulation				
4	3.5	R-0.91	0.79	0.91
Insulated Cavity				
4	3.5	R-11	5.5	6.6
4	3.5	R-13	6.0	7.2
4	3.5	R-15	6.4	7.8
6	6.0	R-19	7.1	8.6
6	6.0	R-21	7.4	9.0
8	8.0	R-25	7.8	9.6

ECB Budget vs PRM Baseline: Opaque Surfaces

	ECB Budget Design	PRM Baseline Design
Gross Area	Same as in the proposed design	
Construction Type	Same as in the proposed design	Prescribed, independent of the proposed design
Thermal Properties (U/F/C factors)	Based on construction type and space conditioning category (residential vs non-residential vs semi-heated)	
	Based on 90.1 2019 prescriptive requirements (Tables 5.5-1 to 5.5-8)	Baseline on 90.1 2004 requirements (Tables G3.4-1 to G3.4-8)

ECB Budget Design

Table 5.5-4 *Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

Opaque Elements	*Nonresidential*		*Residential*		Semiheated	
	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Insulation Min. *R-Value*	Assembly Maximum	Ins Mi
Roofs						
Insulation entirely above deck	U-0.032	R-30 c.i.	U-0.032	R-30 c.i.	U-0.093	R-
Metal building[a]	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.037	R-19 + R-11 *Ls* or R-25 + R-8 *Ls*	U-0.082	R-
Attic and other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-
Walls, above Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal building	U-0.060	R-0 + R-15.8 c.i.	U-0.050	R-0 + R-19 c.i.	U-0.162	R-
Steel-framed	U-0.064	R-13 + R-7.5 c.i.	U-0.064	R-13 + R-7.5 c.i	U-0.124	R-
Wood-framed and other	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.064	R-13 + R-3.8 c.i. or R-20	U-0.089	R-
Wall, below Grade						
Below-grade wall	C-0.119	R-7.5 c.i.	C-0.092	R-10 c.i.	C-1.140	NR
Floors						
Mass	U-0.057	R-14.6 c.i.	U-0.051	R-16.7 c.i.	U-0.107	R-
Steel joist	U-0.038	R-30	U-0.038	R-30	U-0.052	R-
Wood-framed and other	U-0.033	R-30	U-0.033	R-30	U-0.051	R-
Slab-on-Grade Floors						
Unheated	F-0.520	R-15 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.843	R-20 for 24 in.	F-0.688	R-20 for 48 in.	F-0.900	R-
Opaque Doors						
Swinging	U-0.370		U-0.370		U-0.370	
Nonswinging	U-0.310		U-0.310		U-0.360	

PRM Baseline Design

Table G3.4-4 *Performance Rating Method Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

Opaque Elements	Nonresidential	Residential	Semiheated
	Assembly Maximum	Assembly Maximum	Assembly Maximum
Roofs			
Insulation entirely above deck	U-0.063	U-0.063	U-0.218
Walls, Above-Grade			
Steel-framed	U-0.124	U-0.064	U-0.124
Wall, Below-Grade			
Below-grade wall	C-1.140	C-1.140	C-1.140
Floors			
Steel-joist	U-0.052	U-0.038	U-0.069
Slab-on-Grade Floors			
Unheated	F-0.730	F-0.730	F-0.730
Opaque Doors			
Swinging	U-0.700	U-0.700	U-0.700
Nonswinging	U-1.450	U-0.500	U-1.450

EXAMPLE

Multifamily building has walls made of CMU. The apartment walls are modeled as **U-0.09** in the ECB budget design and **U-0.064** wall in the PRM baseline design.

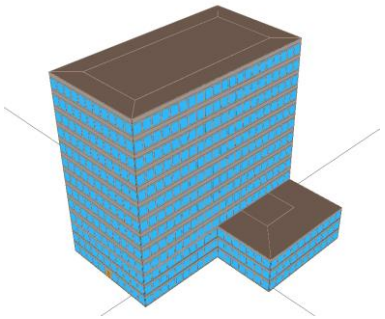
Vertical Fenestration Area

ECB Budget Design

- Same as in Proposed Design or 40% of the total area of exterior above and below grade walls of conditioned and semi-heated spaces
- If the specified fenestration area exceeds the 40% limit, the fenestration area in the budget design must be reduced proportionally until the limits are met.

New College Building Example

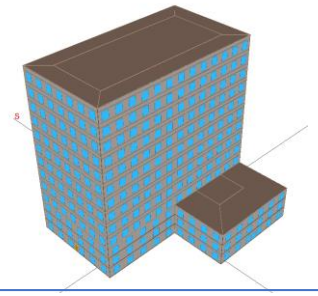
Proposed Design



Fenestration accounts for 60% of gross wall area

ECB Budget Design: Fenestration is **40%** of gross wall area.

PRM Baseline Design: Fenestration is **22%** of above grade wall area



PRM Baseline Design

- For many common building types, fenestration area is prescribed in Table G3.1.1-1 as percentage of gross above grade wall area including walls of conditioned and semiheated spaces
- For other building area types, vertical fenestration area is equal to the *proposed design* or 40% of gross *above-grade wall* area, whichever is less.

Table G3.1.1-1 Baseline *Building Vertical Fenestration* Percentage of Gross *Above-Grade-Wall* Area

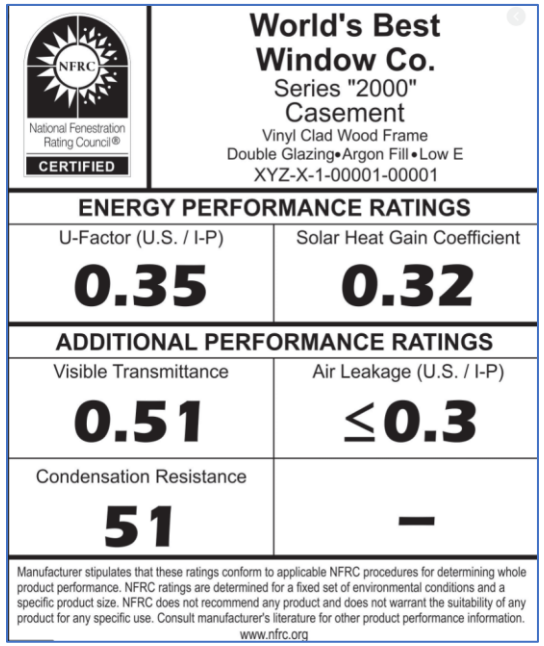
Building Area Types[a]	Baseline *Building* Gross *Above-Grade-Wall A*
Grocery store	7%
Healthcare (outpatient)	21%
Hospital	27%
Hotel/motel (≤75 rooms)	24%
Hotel/motel (>75 rooms)	34%
Office (≤5000 ft^2)	19%
Office (5000 to 50,000 ft^2)	31%
Office (>50,000 ft^2)	40%
Restaurant (quick *service*)	34%
Restaurant (full *service*)	24%
Retail (stand alone)	11%
Retail (strip mall)	20%
School (primary)	22%
School (secondary and university)	22%
Warehouse (nonrefrigerated)	6%

a. In cases where both a general *building* area type and a specific *building* area type are listed, the specific *building* area type shall apply.

Fenestration Properties: Proposed Design

- All manufactured and site-built fenestration and doors must have the rated U-factor, SHGC, VT and air leakage rate stated either on a label or a signed and dated manufacturer's certificate (90.1 Section 5.8.2.2)
- The rated performance must be determined by a laboratory accredited by the National Fenestration Rating Council (NFRC) or another nationally recognized rating authority, and **reflect performance of the entire fenestration assembly** including center of glass, edge of glass, sash and frame elements
- If NFRC rating is not available, defaults from 90.1 Tables A8.1 or A8.2 must be used.

OPTION 1: NFRC Rating



OPTION 2: Defaults from 90.1 Appendix A

Table A8.2 Assembly *U-Factors*, Assembly *SHGCs*, and Assembly Visible Transmittances (*VTs*) for Unlabeled *Vertical Fenestration*

Frame Type	Glazing Type	Unlabeled *Vertical Fenestration*					
		Clear Glass			*Tinted* Glass		
		U-Factor	*SHGC*	*VT*	*U-Factor*	*SHGC*	*VT*
All frame types	Single glazing	1.25	0.82	0.76	1.25	0.70	0.58
	Glass block	0.60	0.56	0.56	NA	NA	NA
Wood, vinyl, or fiberglass frames	Double glazing	0.60	0.59	0.64	0.60	0.42	0.39
	Triple glazing	0.45	0.52	0.57	0.45	0.34	0.21
Metal and other frame types	Double glazing	0.90	0.68	0.66	0.90	0.50	0.40
	Triple glazing	0.70	0.60	0.59	0.70	0.42	0.22

Fenestration Properties

ECB Budget Design

- Same type as in proposed design
- U-Factor, SHGC and VT from Tables 5.5-1 to 5.5-8

Table 5.5-4 *Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

	Nonresidential			Residential			Semiheated	
Fenestration	Assembly Max. U	Assembly Max. SHGC	Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC	Min. VT/SHGC	Assembly Max. U	Assembly Max. SHGC
Vertical Fenestration, 0% to 40% of *Wall*								
Fixed	0.36	0.36	1.10 (for all types)	0.36	0.36	1.10 (for all types)	0.50	NR (for all types)
Operable	0.45	0.33		0.45	0.33		0.65	
Entrance door	0.63	0.33		0.63	0.33		0.77	
Skylight, 0% to 3% of *Roof*								
All types	0.50	0.40	NR	0.50	0.40	NR	0.75	NR

PRM Baseline Design

- Type independent of the proposed design
- U-Factor, SHGC, VT from Table 3.4-1 to 3.4-8

Table G3.4-4 *Performance Rating Method Building Envelope* Requirements for Climate Zone 4 (A,B,C)*

	Nonresidential			Residential			Semiheated	
Fenestration	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance	Assembly Max. U	Assembly Max. SHGC	Visible Transmittance	Assembly Max. U	Assembly Max. SHGC
Vertical Glazing, % of *Wall*								
0% to 10.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40
10.1% to 20.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40
20.1% to 30.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40
30.1% to 40.0%	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.57	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-1.22	$SHGC_{all}$-0.40
Skylight All, % of *Roof*								
0% to 2.0%	U_{all}-0.69	$SHGC_{all}$-0.49	VT_{all}-0.54	U_{all}-0.58	$SHGC_{all}$-0.36	VT_{all}-0.40	U_{all}-1.36	$SHGC_{all}$-0.55
2.1%+	U_{all}-0.69	$SHGC_{all}$-0.39	VT_{all}-0.43	U_{all}-0.58	$SHGC_{all}$-0.19	VT_{all}-0.21	U_{all}-1.36	$SHGC_{all}$-0.55

EXAMPLE

College building has non-operable windows in the proposed design

- ECB Budget Design is modeled with **U-0.36 / SHGC 0.36**
- PRM Baseline Design will be modeled with **U-0.57/SHGC 0.39** windows

Envelope Air Leakage

Energy Cost Budget Method

- Same air leakage rate in the budget and in the proposed design

Performance Rating Method

Proposed Design	Baseline Design
• **0.6 cfm/ft²** @ 75PA if whole building air leakage testing was not performed • As measured if whole-building air leakage testing in accordance with ASTM E779 is specified during design and completed after construction	**1.0 cfm/ft²** of the *building envelope* at a fixed *building* pressure differential of 0.3 in. of water shall be

Modeling Requirements: HVAC

Proposed HVAC

Model must reflect the specified system type, capacity, efficiency, controls and ancillary features such as economizer and exhaust air energy recovery.

Exception: All conditioned spaces must be simulated as being both heated and cooled even if no cooling or heating system is specified.

- Where no heating system exists or is specified, the same heating system type must be modeled in the proposed design as in the budget/baseline design, and the modeled system efficiency must minimally comply with the requirements in Section 6.
- Where no cooling system exists or is specified, the modeled cooling system type must be as shown below; modeled cooling system efficiency must minimally comply with the requirements in Section 6.

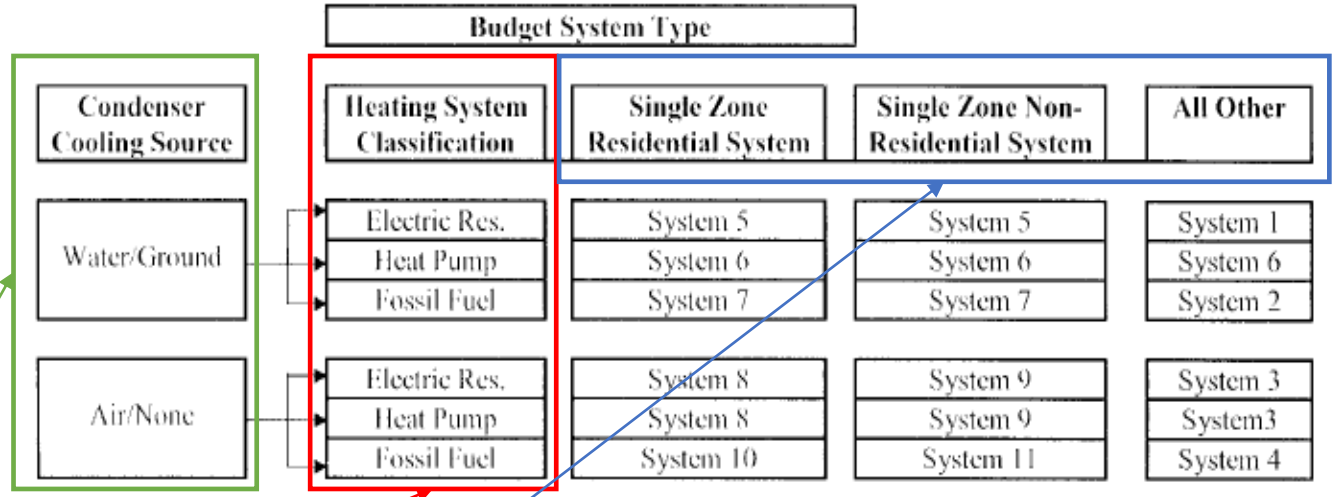
ECB Budget HVAC System Type (Section 11.5.2)

- Each proposed HVAC system has a corresponding budget HVAC system.
- Budget HVAC system type is established based on the parameters of the corresponding proposed system:

Step 1 Determine condenser cooling source: air cooled/no cooling /closed circuit dry cooler vs. water/ground cooled/district cooling.

Step 2 Determine the heating system classification: electric resistance vs. heat pump vs. fossil fuel/district system/none

Step 3 Determine system type category: single zone residential vs single zone nonresidential vs all other.



System No.	System Type	Fan Control	Cooling Type	Heating Type
1	VAV with parallel fan-powered boxes[a]	VAV[d]	Chilled water[e]	Electric resistance
2	VAV with reheat[b]	VAV[d]	Chilled water[e]	Hot-water fossil fuel boiler[f]
3	Packaged VAV with parallel fan-powered boxes[a]	VAV[d]	Direct expansion[c]	Electric resistance
4	Packaged VAV with reheat[b]	VAV[d]	Direct expansion[c]	Hot-water fossil fuel boiler[f]
5	Two-pipe fan-coil	Single- or two-speed fan [i,j]	Chilled water[e]	Electric resistance
6	Water-source heat pump	Single- or two-speed fan [i,j]	Direct expansion[c]	Electric heat pump and boiler[g]
7	Four-pipe fan-coil	Single- or two-speed fan [i,j]	Chilled water[e]	Hot-water fossil fuel boiler[f]
8	Packaged terminal heat pump	Single-speed fan[i]	Direct expansion[c]	Electric heat pump[h]
9	Packaged rooftop heat pump	Single- or two-speed fan [i,j]	Direct expansion[c]	Electric heat pump[h]
10	Packaged terminal air conditioner	Single-speed fan[i]	Direct expansion	Hot-water fossil fuel boiler[f]
11	Packaged rooftop air conditioner	Single- or two-speed fan [i,j]	Direct expansion	Fossil fuel furnace

PRM Baseline HVAC System Type (G3.1.1-3)

- Depends on the building location (climate zone) size, and occupancy type
- Does not depend on the specified HVAC system

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 <120,000 ft²	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Public assembly ≥120,000 ft²	*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 nonresidential and 3 *floors* or fewer and <25,000 ft²	*System* 3—PSZ-AC	*System* 4—PSZ-HP
Other nonresidential and 4 or 5 *floors* and <25,000 ft² or 5 *floors* or fewer and 25,000 ft² to 150,000 ft²	*System* 5—Packaged *VAV* with *reheat*	*System* 6—Packaged *VAV* with PFP boxes
Other nonresidential and more than 5 *floors* or >150,000 ft²	*System* 7—*VAV* with *reheat*	*System* 8—*VAV* with PFP boxes

PRM Additional Baseline HVAC System Types

- Use additional system types for non-predominant conditions (i.e., residential/ nonresidential) if those conditions apply to more than 20,000 ft^2 of conditioned floor area.

- If the baseline HVAC system type is 5, 6, 7 & 8, use System 3 or 4 (depending on climate zone) for thermal blocks with occupancy or process loads differing by 10 Btu/h·ft^2 or more from the average of other thermal blocks served by the same system, or schedules differing by more than 40 equivalent full-load hours per week.

- Use baseline systems 9 or 10, depending on climate zone, for thermal zones designed with heating-only systems serving storage rooms, stairwells, vestibules, mechanical rooms, and restrooms not exhausting or transferring air from mechanically cooled thermal zones in the proposed design.

- There are more exceptions….

Other Key HVAC System Rules

	ECB Budget Design	PRM Baseline Design
Capacity oversizing	Same as in proposed design	25% heating / 15% cooling
Heating/cooling efficiency	Min. efficiency required in Sections 6.4. Chillers must use Path A efficiencies from Table 6.8.1-3.	Tables G3.5.1 – G3.5.6, reflects 90.1 2004 requirements
Fan bhp per cfm of supply air	Same as proposed without exceeding the limits prescribed in Section 6.5.3.1.	Systems 1 and 2: *Pfan* = CFMs × 0.3 Systems 9 and 10: *Pfan* = CFMs × 0.3 (supply fan) Systems 3 - 8, and 11 – 13: *Pfan* = bhp × 746 /fan motor *effy*
Economizer	If cooling capacity >54,000 Btu/hr in OR climate zones (Table 6.5.1-1 and 6.5.1-3)	Not required in baseline Systems 1, 2, 9, and 10; for other baseline system types requirements depend on climate zone.

Mechanical Ventilation

	ECB Budget Design	PRM Baseline Design
Minimum Ventilation Rate	**Performance penalty** for ventilation exceeding 135% of minimum required	• **Performance penalty** for ventilation rates exceeding the minimum required • **Performance credit** for zone air distribution effectiveness (Ez) > 1.0 based on ASHRAE Std. 62.1
Demand controlled ventilation	Based on prescriptive requirements in 90.1 2019 Section 6.4.3.8	Based on prescriptive requirements in 90.1 2004
Exhaust air energy recovery	Based on prescriptive requirements in 90.1 2019 Section 6.5.6	Based on prescriptive requirements of 90.1 2004 (modeled on baseline systems with design flow >=5000 cfm AND min. OA fraction >=70%)

Modeling Requirements: Interior Lighting

Lighting Power

Proposed Design
General, task and furniture-mounted fixtures must be included in the lighting power calculations.
For each lighting fixture, all lighting system components shown or provided for on plans must be accounted for including lamps, ballasts, transformers and control devices
The maximum labeled lighting fixture wattage must be used, which may be different from wattage shown on lighting schedules.

	Energy Cost Budget	PRM Baseline
Lighting Power	Either Building Area Method (Table 9.5.1) or Space-by-space Method (Table 9.6.1)	Space-by-space method only, lighting power from Table G3.7 (based on 91.1 2004)
Additional Allowance	If using Space-by-space method: • 20% LPD increase for odd-shaped spaces. • Up to 0.75 W/SF for independently controlled decorative lighting and certain retail lighting	None

Interior Lighting Controls

Energy Cost Budget Method

- **Budget Design:** Automatic lighting controls minimally compliant with Section 9.4.1
- **Performance credit** for automatic lighting controls exceeding the minimum required in Section 9.4.1

Performance Rating Method

- **Baseline Design**: No automatic daylighting controls; no occupancy sensor except in employee lunch/break rooms, conference/meeting rooms, and certain classrooms
- **Proposed Design**: Performance credit for daylighting controls; performance credit for occupancy sensors modeled be reducing lighting runtime by the fractions specified in Table G 3.7

Common *Space* Types[a]	*Lighting Power Density*, W/ft^2	*Occupancy Sensor* Reduction[b]
Audience Seating Area		
Auditorium	0.90	10%
Convention center	0.70	10%
Exercise center	0.30	10%
Gymnasium	0.40	10%
Motion picture theater	1.20	10%

Modeling Requirements: Other Systems

Exterior Lighting

Proposed Design
All lighting system components shown or provided for on plans must be accounted for including lamps, ballasts, transformers and control devices
The maximum labeled lighting fixture wattage must be used

	Energy Cost Budget Design	PRM Baseline Design
Lighting Power	Same as in proposed design	Based on prescribed limits (Table G3.6); Trade-offs are allowed only for Tradeable lighting
Lighting Controls	Same as in proposed design	

Service Water Heating

Proposed Design
The service water-heating model must be consistent with design documents.

	Energy Cost Budget Design	PRM Baseline Design
System Type and Qty	Same as in proposed design	One central storage water heater per occupancy type
Fuel		Either gas or electric, prescribed based on building occupancy type
System Efficiency	Minimally compliant with efficiencies in Table 7.8	
Hot water load	Same as in proposed design	May demonstrate savings due to the following: • reducing the physical volume of service water required, e.g., with low-flow shower heads. • reducing the required temperature of service mixed water or increasing the temperature of the makeup water

Miscellaneous Other Loads

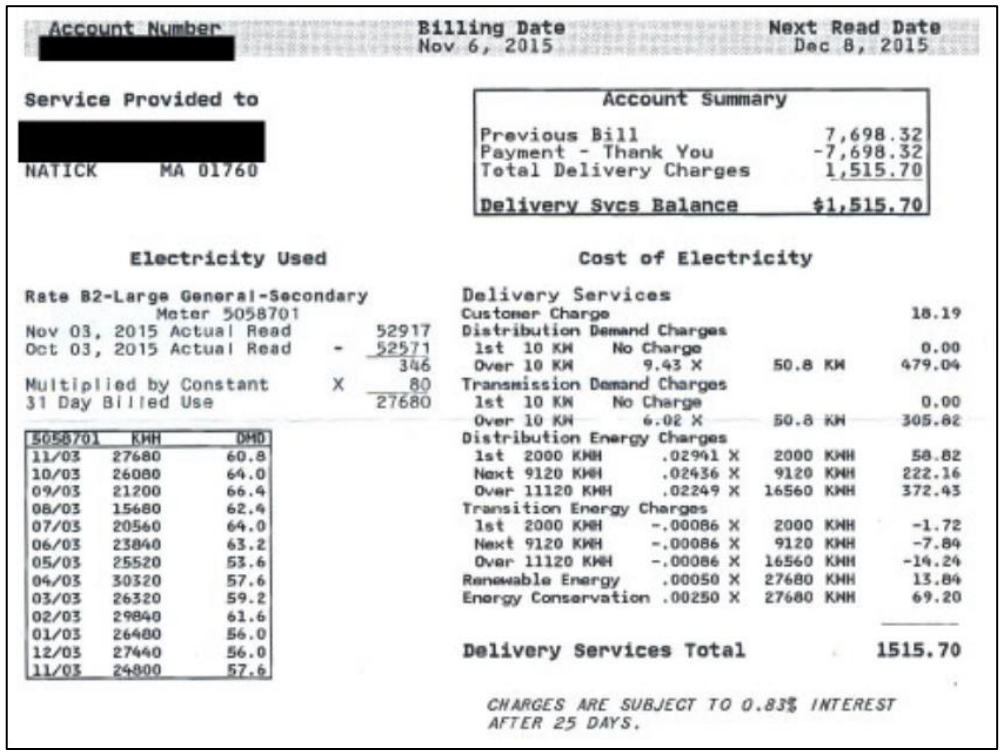
Proposed Design
Receptacle, motor, and process loads must be modeled and estimated based on the building area type or space type category.

	Energy Cost Budget	PRM Baseline
Elevators	Same as in proposed design	Performance credit may be claimed based on the prescribed baseline elevator type and efficiency
Non-HVAC Motors		Performance credit is available for motors >=1HP relative to prescribed baseline efficiency (Table G3.9.1)
Refrigeration Equipment		Performance credit for regulated systems may be claimed based on the baseline system efficiency prescribed in Tables G3.10.1 and G3.10.2
Other Plug and Process Loads		Performance credit for unregulated systems is available **only when using PRM to document beyond code performance**, if approved by the rating authority.

Using Simulation Results to Establish Compliance

Energy Prices

- The design energy cost and energy cost budget must be determined using rates for purchased energy (such as electricity, gas, oil, propane, steam, and chilled water) that are approved by the adopting authority.
- Common sources include actual utility rates for the facility or recent state averages posted on the Energy Information Administration website



Account Number [redacted]

Billing Date
Nov 6, 2015

Next Read Date
Dec 8, 2015

Service Provided to
[redacted]
NATICK MA 01760

Account Summary

Previous Bill	7,698.32
Payment - Thank You	-7,698.32
Total Delivery Charges	1,515.70
Delivery Svcs Balance	$1,515.70

Electricity Used

Rate B2-Large General-Secondary
Meter 5058701

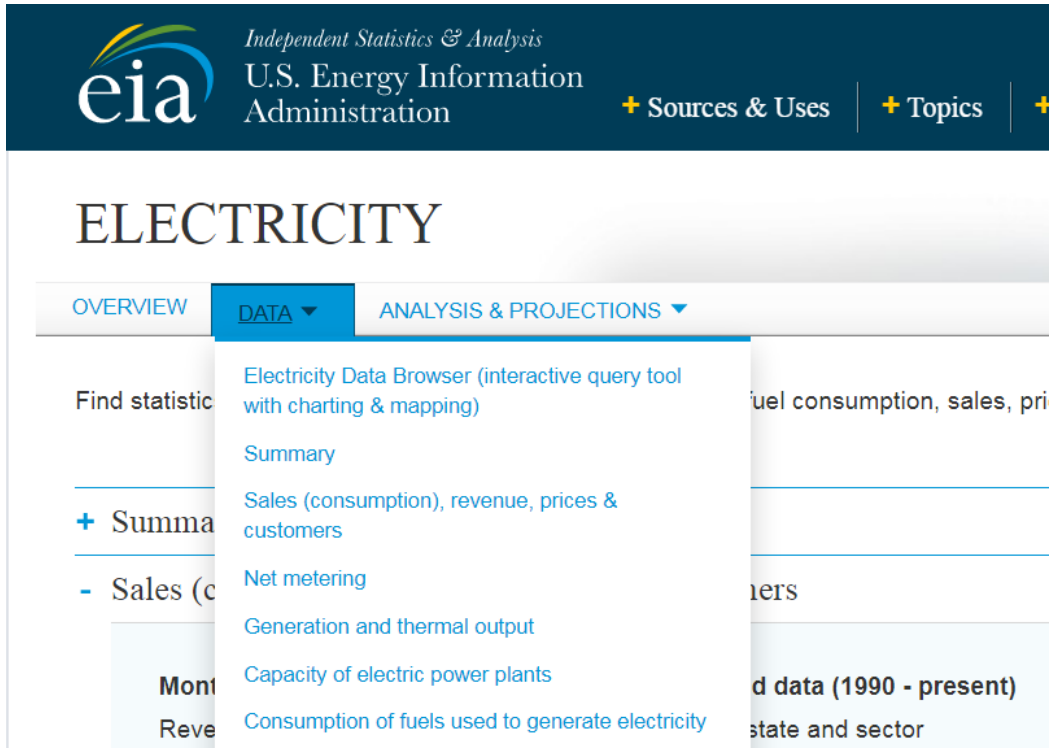
Nov 03, 2015 Actual Read		52917
Oct 03, 2015 Actual Read	-	52571
		346
Multiplied by Constant	X	80
31 Day Billed Use		27680

5058701	KWH	DMD
11/03	27680	60.8
10/03	26080	64.0
09/03	21200	66.4
08/03	15680	62.4
07/03	20560	64.0
06/03	23840	63.2
05/03	25520	53.6
04/03	30320	57.6
03/03	26320	59.2
02/03	29840	61.6
01/03	26480	56.0
12/03	27440	56.0
11/03	24800	57.6

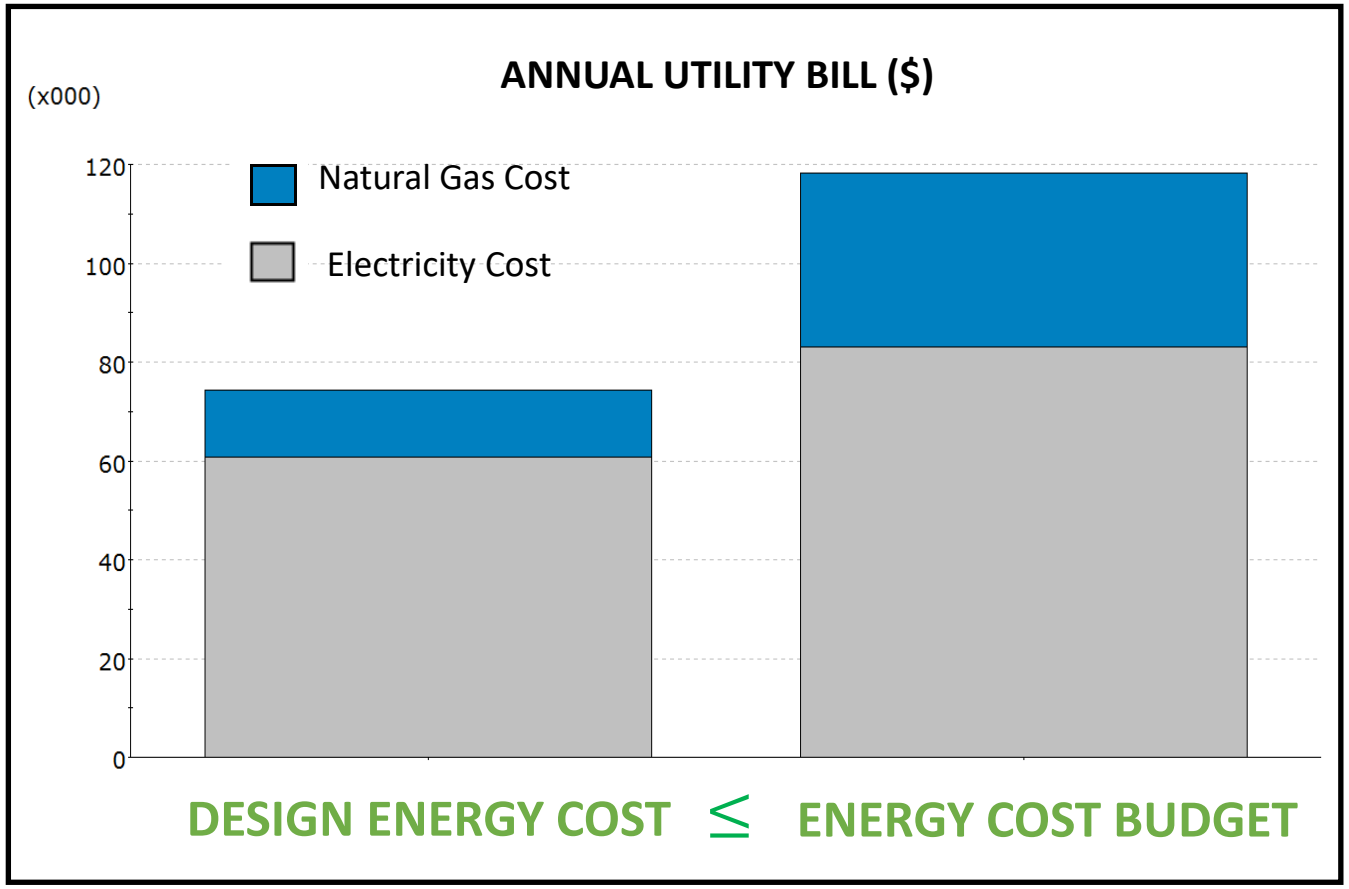
Cost of Electricity

Delivery Services				
Customer Charge				18.19
Distribution Demand Charges				
1st 10 KW	No Charge			0.00
Over 10 KW	9.43 X	50.8 KW		479.04
Transmission Demand Charges				
1st 10 KW	No Charge			0.00
Over 10 KW	6.02 X	50.8 KW		305.82
Distribution Energy Charges				
1st 2000 KWH	.02941 X	2000 KWH		58.82
Next 9120 KWH	.02436 X	9120 KWH		222.16
Over 11120 KWH	.02249 X	16560 KWH		372.43
Transition Energy Charges				
1st 2000 KWH	-.00086 X	2000 KWH		-1.72
Next 9120 KWH	-.00086 X	9120 KWH		-7.84
Over 11120 KWH	-.00086 X	16560 KWH		-14.24
Renewable Energy	.00050 X	27680 KWH		13.84
Energy Conservation	.00250 X	27680 KWH		69.20
Delivery Services Total				1515.70

CHARGES ARE SUBJECT TO 0.83% INTEREST AFTER 25 DAYS.



Energy Cost Budget Method Compliance



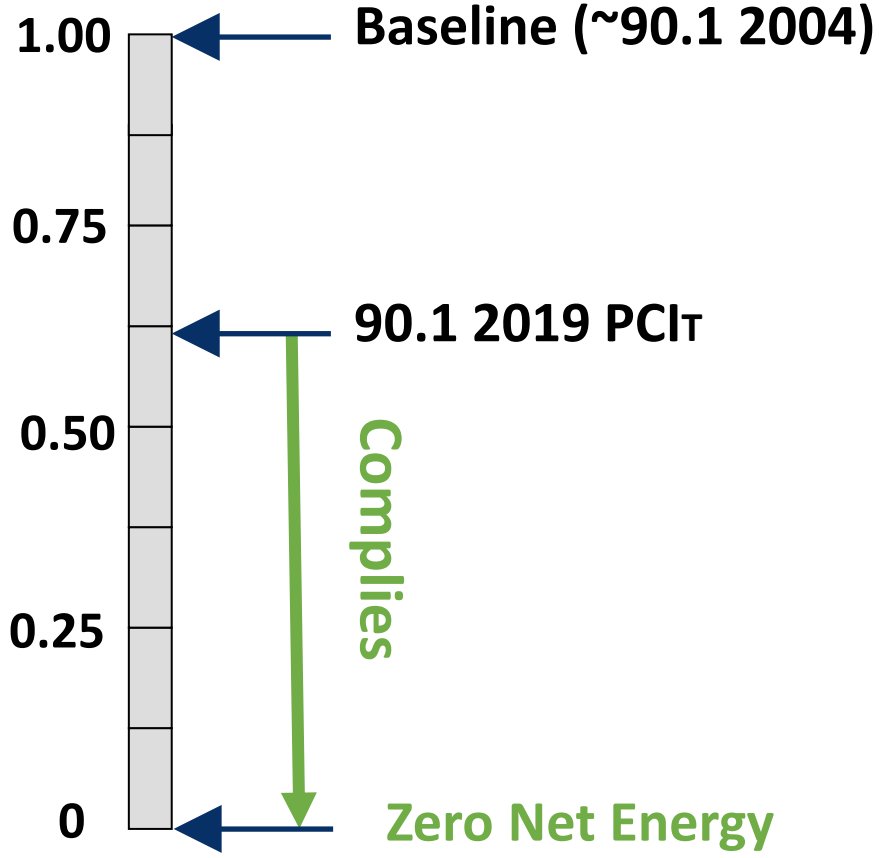
Performance Rating Method Compliance Calculations: Performance Cost Index

- Performance of the proposed design relative to the baseline is expressed as **Performance Cost Index (PCI)**

$$PCI = \frac{Proposed\ Building\ Energy\ Cost}{Baseline\ Building\ Energy\ Cost}$$

- Project meets code if the PCI is less than or equal to the Performance Cost Index Target (PCI_T)

$$PCI \leq PCI_T$$



Performance Cost Index Target

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

BBUEC=Baseline Building Unregulated Energy Consumption

Energy use of systems and components that have no requirements in 90.1 Sections 5 – 10 (kitchen appliances, consumer and office electronics; industrial process loads)

BBREC=Baseline Building Regulated Energy Consumption

Energy use of system and component with requirements prescribed in 90.1 Sections 5 through 10 (lighting, HVAC)

BBP = Baseline Building Performance; BBP=BBUEC+BBREC

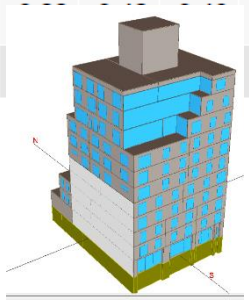
BPF=Building Performance Factor

Building Performance Factor (BPF)

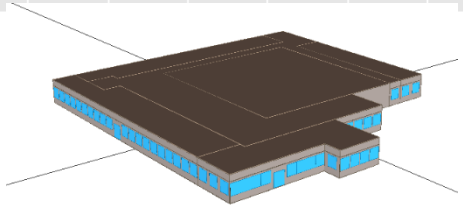
- Quantifies change in stringency between 90.1 2019 compared to 90.1 2004 which is used as the basis for the baseline model
- BPFs are provided in 90.1 Section 4 for different climate zones and building types
- The BPFs are updated for each new edition of 90.1

Table 4.2.1.1 *Building* Performance Factor (BPF)

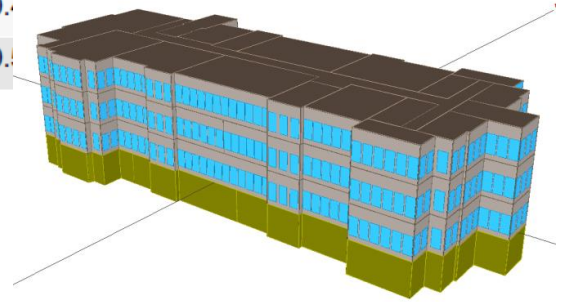
Building Area Type	Climate Zone																
	0A and 1A	0B and 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Multifamily	0.68	0.70	0.66	0.66	0.69	0.68	0.59	0.74	0.76	0.74	0.70	0.73	0.75	0.68	0.71	0.68	0.72
Healthcare/ hospital	0.60	0.60	0.58	0.54	0.56	0.55	0.55	0.55	0.54	0.54	0.57	0.52	0.54	0.57	0.52	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				0.42	0.43	0.44	0.43	0.44	0.43	0.46	0.49	0.					
All others				0.52	0.50	0.54	0.53	0.53	0.52	0.54	0.51	0.					



Multifamily, CZ 4C



Office, CZ 4C



School, CZ 4C

Documentation Requirements

90.1 Reporting Requirements

G1.3 Documentation Requirements

Simulated performance shall be documented, and documentation shall be submitted to the *rating authority*. The information shall be submitted in a report and shall include the following:

a. A brief description of the project, the key *energy efficiency* improvements compared with the requirements in Sections 5 through 10, the *simulation program* used, the *baseline building performance*, the *proposed building performance*, and the percentage improvement. This summary shall contain the calculated values for the *baseline building performance*, the *proposed building performance*, and the percentage improvement.

b. An overview of the project that includes the number of stories (above and below *grade*), the typical *building* use (e.g., office, cafeteria, retail, parking, etc.), the gross area of each use, and whether each use is *conditioned space*.

c. A list of the *energy*-related features that are included in the design and on which the performance rating is based. This list shall document all *energy* features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.

d. A list showing compliance for the *proposed design* with all the requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 (mandatory provisions).

e. A list identifying those aspects of the *proposed design* that are less stringent than the requirements of 5.5, 6.5, 7.5 9.5, and 9.6 (prescriptive provisions).

f. A table with a summary by end use of the *energy* cost savings in the *proposed building performance*.

g. A site plan showing all adjacent *buildings* and topography that may shade the proposed *building* (with estimated height or number of stories).

h. *Building* elevations and *floor* plans (schematic is acceptable).

i. A diagram showing the *thermal blocks* used in the computer simulation.

j. An explanation of any significant modeling assumptions.

k. Backup calculations and material to support data inputs (e.g., *U-factors* for *building envelope* assemblies, NFRC ratings for *fenestration*, end-uses identified in Table G3.1, "1. Design Model," paragraph [a]).

l. Input and output reports from the *simulation program* or compliance software, including a breakdown of *energy* use by at least the following components: lights, internal *equipment* loads, *service water-heating equipment*, *space*-heating *equipment*, *space*-cooling and heat rejection *equipment*, fans, and other HVAC *equipment* (such as pumps). The output reports shall also show the amount of *unmet load hours* for both the *proposed design* and *baseline building design*.

m. *Purchased energy rates* used in the simulations.

n. An explanation of any error messages noted in the *simulation program* output.

o. For any exceptional calculation methods employed, document the predicted *energy* savings by *energy* type, the *energy* cost savings, a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method.

p. The reduction in *proposed building performance* associated with *on-site renewable energy*.

Performance Rating Method documentation requirements (Section G1.3)

- The training covers PRM documentation requirements which are more extensive than those of ECB
- In 90.1 2019, ECB reporting requirements were updated to largely align with the PRM

11.7 Documentation Requirements

Compliance shall be documented and submitted to the *authority having jurisdiction*. The information submitted shall include the following:

a. The *energy cost budget* for the *budget building design* and the *design energy cost* for the *proposed design*.

b. A list of the *energy*-related features that are included in the design and on which compliance with the [illegible] is based. This list shall document all *energy* features that differ between the models used in the [illegible] and the *design energy cost* calculations.

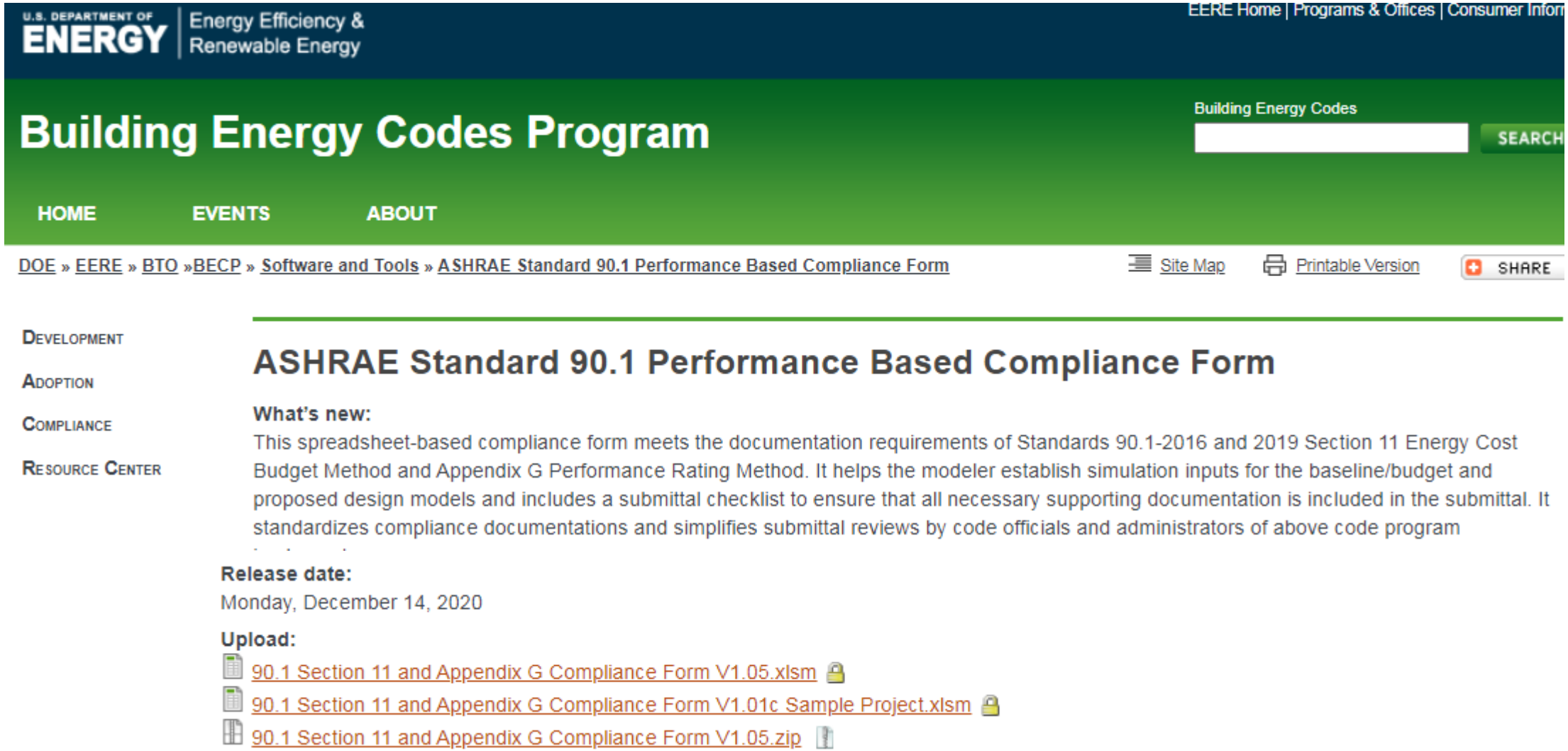
c. [illegible] breakdown of *energy* usage by at least the following components: lights, internal *equipment* loads, *service water-heating equipment*, *space*-heating *equipment*, *space* cooling and heat-rejection *equipment*, [illegible] *equipment* (such as pumps). The output reports shall also show the amount of time any loads are not met by the *HVAC system* for both the *proposed design* and *budget building design*.

d. An explanation of any error messages noted in the *simulation program* output.

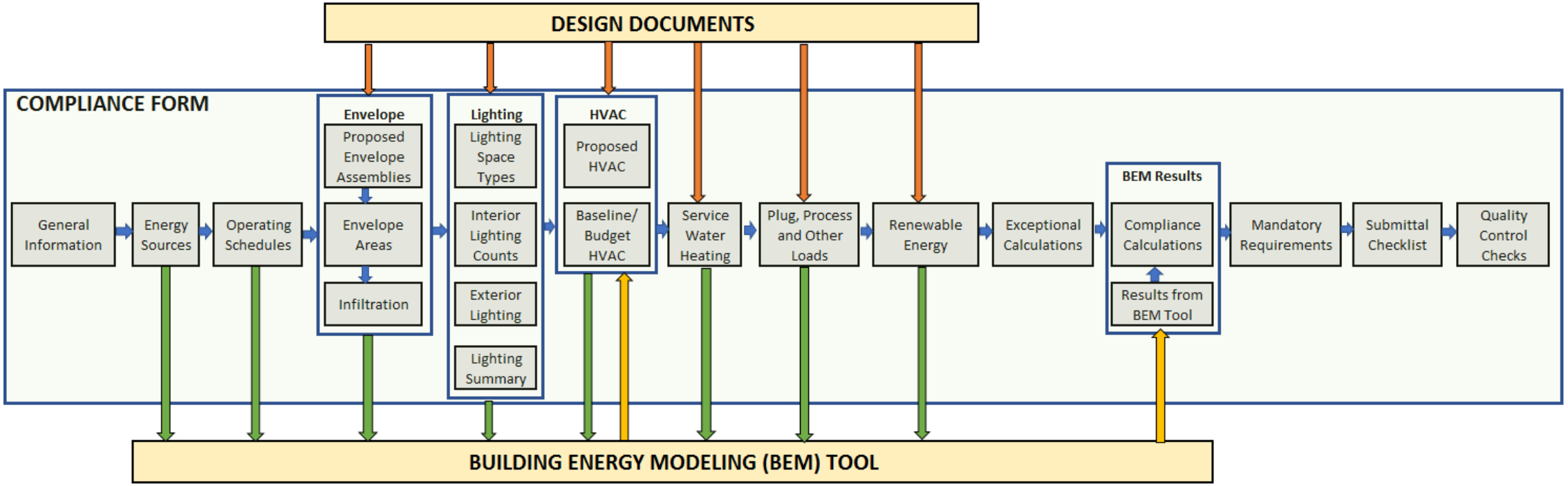
e. The reduction in *design energy cost* associated with *on-site renewable energy*.

Energy Cost Budget Method documentation requirements (Section 11.7)

DOE/PNNL 90.1 Performance Based Compliance Form

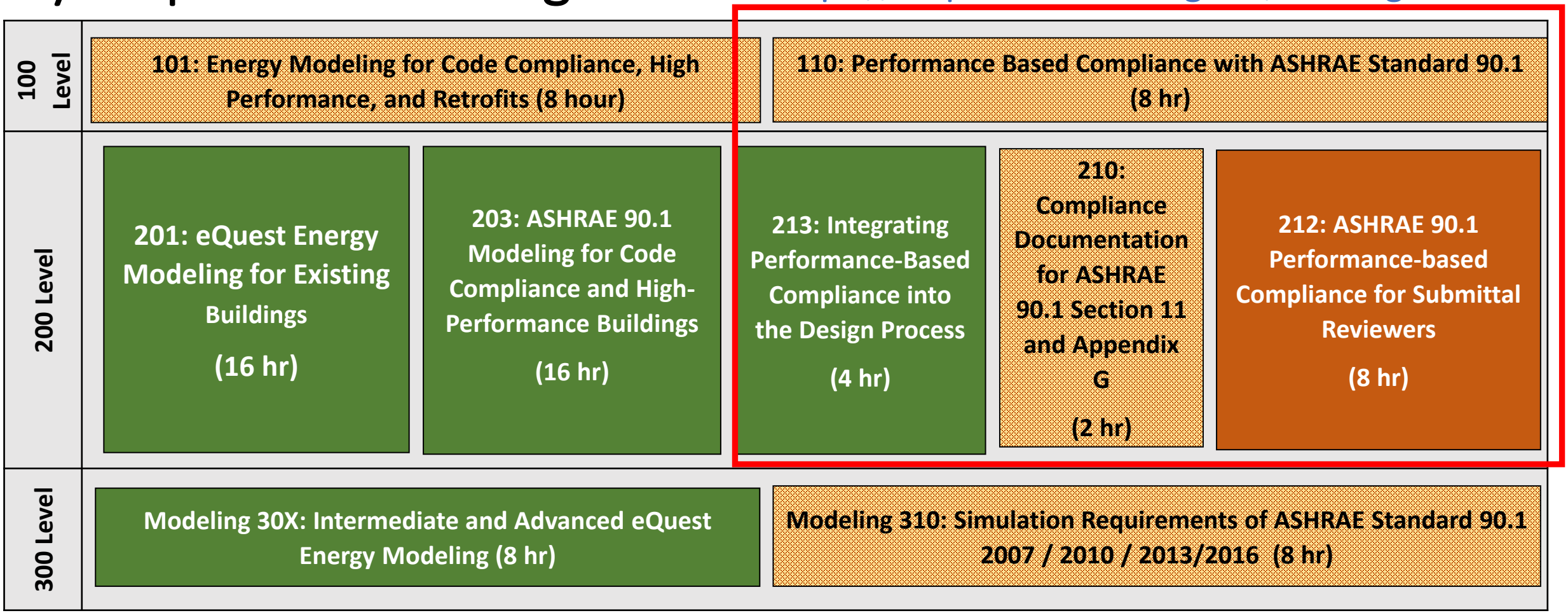
- 

DOE/PNNL Compliance Form Organization



Other 90.1 Performance-Based Compliance Trainings by Karpman Consulting

https://karpmanconsulting.net/trainings



LEGEND: primary target audience is…

energy modelers / design professionals

code officials / submittal reviewers / energy modelers

code officials / submittal reviewers

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