Normative Appendix C: Targeted Performance Simulation Guidelines

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1. Definitions and Acronyms

above grade floor: a *floor* of the *building thermal envelope* that is either above grade or is less than or equal to 24 in. below the final elevation of the nearest exterior grade.

above grade wall (from IECC 2021): a *wall* associated with the *building thermal envelope* that is more than 15 percent above grade and is on the exterior of the building or any *wall* this is associated with the *building thermal envelope* that is not on the exterior of the building. This includes, but is not limited to, between-*floor* spandrel, peripheral edge of *floors*, roof knee *walls*, dormer *walls*, gable end *walls*, *walls* enclosing a mansard *roof* and skylight shafts.

economizer, air (from 90.1 2019): a duct and damper arrangement and automatic control system that together allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather.

below grade wall (from IECC 2021): a *wall* associated with the basement or first story of the *building* that is part of the *building thermal envelope*, is not less than 85 percent below grade and is on the exterior of the building.

below grade floor: a *floor* of the *building thermal envelope* that is not an *above grade floor*.

building (from 90.1 2019): any structure used or intended for supporting or sheltering any use or occupancy.

building thermal envelope (from IECC 2021): the basement *walls*, *exterior walls*, *floors*, ceilings, *roofs* and any other building element assemblies that enclose *conditioned space* or provide a boundary between *conditioned space* and *unconditioned space*.

conditioned space (from IECC 2021): an area, room or space that is enclosed within the *building thermal envelope* and is directly or indirectly heated or cooled. *Spaces* are indirectly heated or cooled where they communicate through openings with *conditioned spaces*, where they are separated from *conditioned spaces* by uninsulated *walls*, *floors*, or ceilings, or where they contain uninsulated ducts, piping or other sources of heating or cooling.

COPnfcooling: full load cooling efficiency with fan power extracted from the rated efficiency.

COPnfheating: full load heating efficiency with fan power extracted from the rated efficiency.

daylighting: *the control of electric lighting by a device or system that provides automatic control of light levels based on the amount of daylight in a* space*.*

daylight area (from 90.1 2019): the floor area substantially illuminated by daylight.

door*: an operable opening area in the building thermal envelope that is not fenestration.*

demand control ventilation (from 90.1 2019): a ventilation system capability that provides for the automatic reduction of outdoor air intake below design rates when the actual occupancy of spaces served by the system is less than design occupancy.

enclosed space *(from 90.1 2019): a volume substantially surrounded* by solid surfaces, such as walls, floors, roofs, and openable devices, such as doors and operable windows.

exterior wall*:* walls *including both* above grade walls *and* below grade walls*.*

fenestration: an assembly, including the frame, that allows light to pass.

floor: includes *opaque* area and *fenestration*, that is horizontal or tilted at an angle of less than 60 degrees from horizontal.

floor area, gross (from 90.1 2019): the sum of the floor areas of the spaces within the *building*, including basements, mezzanine and intermediate-floored tiers, and penthouses with a headroom height of 7.5 ft or greater. It is measured from the exterior faces of walls or from the center-line of walls separating *buildings*, but excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features.

modeled floor area: the total enclosed floor area of the *building*, as reported by the *simulation program*, including *conditioned space* and excluding *unconditioned spaces.*

nonresidential *(from 90.1 2019):* all occupancies other than *residential*.

opaque: an assembly that does not allow light to pass and excludes openings such as vents and grilles.

orientation (from 90.1 2019): the direction an envelope element faces, i.e., the direction of a vector perpendicular to and pointing away from the surface outside of the element.

photosensor (from 90.1 2019): a device that detects the presence of visible light, infrared (IR) transmission, and/or ultraviolet (UV) energy.

residential: occupancies in a building that are used primarily for living and sleeping such as multifamily dwelling units and dormitory rooms

roof (from 90.1 2019): the upper portion of the *building thermal envelope*, including *opaque* areas and *fenestration*, that is horizontal or tilted at an angle of less than 60 degrees from horizontal.

simulation program*:* a computer program, including the simulation engine and the corresponding

user interface, that is capable of simulating the energy performance of *building* systems.

skylight (from 90.1 2019): a *fenestration* surface having a slope of less than 60 degrees from the horizontal plane. Other *fenestration*, even if mounted on the roof of a building, is considered *vertical fenestration*.

slab-on-grade floor *(from 90.1 2019):* that portion of a slab floor of the *building thermal envelope* that is in contact with the ground and that is either above grade or is less than or equal to 24 in. below the final elevation of the nearest exterior grade.

space (from 90.1 2019): an *enclosed space* within a *building*.

temperature control throttling range: the number of degrees that room temperature must change in order to go from full heating to no heating or from full cooling to no cooling.

thermal block: a collection of one or more *spaces* grouped together for simulation purposes. *Spaces* need not be contiguous to be combined within a single *thermal block*.

unconditioned space (from 90.1 2019): an *enclosed space* within a *building* that is not a *conditioned space*.

unmet load hour: an hour in which one or more zones is outside of the *thermostat set point* plus or minus one half of the *temperature control throttling range*. Any hour with one or more zones with an unmet cooling load or unmet heating load is defined as an *unmet load hour*.

***vertical fenestration* (from 90.1 2019)**: all *fenestration* other than *skylights*.

wall: an *opaque* area or *fenestration* area that is vertical or tilted at an angle of 60 degrees from horizontal or greater.

ACRONYMS

AHJ: Authority Having Jurisdiction

ASHP: Air Source Heat Pump

DCV: Demand Control Ventilation

DOAS: Dedicated Outdoor Air System

FCU: Fan Coil Unit

HVAC: Heating, Ventilation, And Air Conditioning

SHGC: Solar Heat Gain Coefficient

TEDI: Thermal Energy Demand Intensity

VT: Visible Transmittance

WSHP: Water Source Heat Pump

1. Purpose and Scope

These Simulation Guidelines are a companion to Section C407.1 and include the modeling requirements that must be followed when documenting compliance with the Targeted Performance path (Section C401.2.1, Part 2).

The purpose of these guidelines is to improve consistency in compliance outcomes across projects and preserve focus on minimizing *building* heating and cooling loads. The Guidelines include the following:

1. ~~Required simplifications to~~Default interior floor plan and thermal zoning, to streamline modeling
~~1.~~2. Default HVAC system type, efficiency, controls and fan and pump system efficiency and controls
~~2.~~3. Simulation inputs that are prescribed and must be used irrespective of specified systems and components. These inputs correspond to the design elements and *building* operating conditions that are not meant to impact Section C407.1 compliance. Examples of prescribed inputs include the following:
    a. Weather file
    ~~b. *HVAC* system type, efficiency, and controls~~
    ~~c. Fan and pump system efficiency and controls~~
    ~~d.~~b. Minimum mechanical ventilation rates, except when the specified ventilation rate exceeds

the prescribed value

~~e.~~c. Interior lighting system power and controls

~~f.~~d. Miscellaneous plug and process loads and schedules

~~g.~~e. Operating and occupancy schedules such as *building* operating hours, lighting runtime, thermostat setpoints, etc.

~~3.~~4. Systems and components that must be modeled as shown on construction documents or test results. Examples of such systems include the following:

a. *Opaque* envelope insulation accounting for thermal bridges and thermal mass effects
b. *Fenestration* area and orientation
c. Thermal and solar properties of windows and skylights
d. Shape of exterior envelope
e. Envelope air leakage
f. *Building* orientation
g. Fixed exterior shading (e.g., fenestration set back in envelope plane, side fins, and overhangs) and site shading (e.g., from surrounding *buildings*).
h. Mechanical ventilation rate when it exceeds the prescribed value
i. Exhaust air energy recovery efficiency and control

~~4.~~5. *Building* systems that do not interact with heating and cooling loads of the *building* or that are not permanent are excluded from the simulations.

The energy models developed for compliance with Section C407.1 are not predictive of actual energy consumption of the proposed design after construction for the two main reasons:

- Compliance with C407.1 uses prescriptive ~~*HVAC* systems,~~ weather files, internal gains, and other inputs as described herein which may vary from planned design to ensure compliance consistency and to facilitate design team focus on reducing heating and cooling thermal energy demands by normalizing other variables
- Variations in *building* operation and maintenance weather, and precision of the energy modelling tool.

2. Energy Modeler Qualifications

Energy models shall be created by persons qualified by education and training to perform such work. The modeling documentation submitted to *AHJ* shall be signed by a professional meeting qualification requirements outlined in Modeler_Quals_FINAL.pdf (energycodes.gov).

3. Simulation Program

The *simulation program* shall be a computer-based program for the analysis of *energy* consumption in *buildings.* Simulations shall be performed at an hourly timestep. The following *simulation programs* are pre-approved:

eQUEST version 3.65 or higher using DOE2.3 engine
Energy Plus version 9.3.0 or higher
IES Virtual Environment version TBD or higher

When the *simulation program* does not model a specified design, material or device, an external calculation shall be used as approved by the *AHJ*. The documentation submitted in support of the external calculations shall include a narrative explaining the methods, theoretical or empirical information supporting its accuracy, and documentation required in ASHRAE 90.1 2019 Section G2.5 (a) – (e).

4. Site and Climate Data

a. Projects shall use MAStretch2023 weather file included in the Schedules and Loads Guidelines Supplement Package.
b. Ground temperatures from the provided weather file shall be used.
c. The solar reflectance of the site ground surface = 0.2
d. Number of weekdays/weekends/holidays shall be based on the provided weather file.
e. Shading from adjacent structures, significant vegetation and topographical features shall be reflected in the simulation. All elements with height greater than their distance from a proposed *building* and whose width facing the proposed *building* is greater than one-third that of the proposed *building* shall be modeled.

5. TEDI Calculations

The heating *TEDI* shall be determined as a ratio of the annual heating energy delivered to the *spaces* and ventilation systems within the *building* to the *modeled floor area* $Heating\ TEDI\ [\frac{kBtu}{ft^2}] = \frac{\sum\text{Space and Ventilation Heating Output [kBtu]}}{Modeled\ Floor\ Area\ [ft^2]}$ (Equation 1~~(Equation 2~~)

$$Heating\ TEDI\ [\frac{kBtu}{ft^2}] = \frac{\sum\text{Space and Ventilation Heating Output [kBtu]}}{Modeled\ Floor\ Area\ [ft^2]} \quad \text{(Equation 1~~2~~)}$$

Where:

Σ*Space* and Ventilation Heating Output = the annual heating output of all systems in the *building* that maintain *space* temperature setpoints and heat ventilation air including the heating coils of the central air systems (e.g., make-up air units and air handling units) and terminal equipment (e.g., fan coils, heat pumps and unit heaters).

Modeled floor area = the total enclosed *floor* area of the *building*, as reported by the *simulation program*, including *conditioned* and excluding *unconditioned spaces*.

The cooling *TEDI* shall be determined as the ratio of the annual energy extracted from the *spaces* within the *building* and ventilation systems to maintain the thermostat setpoints to the *modeled floor area* ($Cooling\ TEDI\ [\frac{kBtu}{ft^2}] = \frac{\sum\text{Space and Ventilation Cooling Output [kBtu]}}{Modeled\ Floor\ Area\ [ft^2]}$ (Equation 2~~Equation 2~~).

$$Cooling\ TEDI\ [\frac{kBtu}{ft^2}] = \frac{\sum\text{Space and Ventilation Cooling Output [kBtu]}}{Modeled\ Floor\ Area\ [ft^2]} \quad \text{(Equation 2~~3~~)}$$

Where:

Σ*Space* and Ventilation Cooling Output = the annual cooling output of all *HVAC* systems that maintain space temperature setpoints and cool ventilation air, including but not limited to the cooling coils of the central air systems (e.g., make-up air units, air handling units.) and terminal equipment (e.g., fan coils and heat pumps).

Steps for extracting the simulation outputs necessary to calculate cooling and heating *TEDI* from the simulation reports generated by the approved energy modeling tools are included in Annex 1.

6. Unmet Loads

Unmet load hours shall not exceed 300 (of the 8760 hours simulated). U*nmet load hours* exceeding these limits shall be permitted to be accepted by the *AHJ*, provided that sufficient justification is given indicating that the accuracy of the simulation is not compromised by these unmet loads.

7. Systems Excluded from Simulation

The following systems and components shall be excluded from the simulation:

a. Exterior lighting system power and controls
b. Heating loads unrelated to maintaining occupant comfort such as swimming pool water heaters, outdoor comfort heating (e.g., patio heaters and exterior fireplaces), gas-fired appliances (stoves and dryers), heat tracing.
c. Renewable energy systems including but not limited to PV and solar thermal hot water collectors
d. Other electricity generation systems such as Combined Heat and Power.
e. Service water heating systems.

8. ~~Simplified~~ Thermal Blocks ~~Approach~~

8.1 General Approach

Thermal blocks shall be modeled as follows:

a. Buildings and areas within the buildings that are modeled with the default HVAC system following Section 13.2 shall be modeled with the default thermal blocks as prescribed in Sections 8.2 and 8.3.
b. Buildings and areas within the building that are modeled with as-designed HVAC system following Section 13.3 shall be modeled as prescribed in 90.1 2019 Appendix G Table G3.1, Proposed Building Performance column Row 9 for multifamily buildings and Row 7 for all other occupancy types.

8.2 Default Thermal Blocks

This section describes simplifications that shall be made to the interior floor plan and *HVAC* zoning ~~in a model developed for compliance with Section C407.1~~. These simplifications shall be used in all cases irrespective of project design state and the floor plan and zoning shown on design or construction documents. Section 0~~8.2~~ describes the types of *thermal blocks* that shall be modeled depending on the *building* use type. Section 8.3 describes criteria for further aggregating the *thermal blocks*.

~~*8.1*~~

8.2.1 Types of Thermal Blocks Depending on Building Use Type

The *building* shall be modeled using simplified *thermal blocks*. The following *thermal blocks* shall be modeled depending on the *building* use type:

a. Residential Buildings

i. *Residential thermal blocks* representing *spaces* that are used primarily for living and sleeping such as multifamily dwelling units and dormitory rooms.
ii. Supporting spaces *thermal blocks* representing corridors, stairs, trash rooms, lobbies and mechanical rooms.

iii. Nonresidential *thermal blocks* representing *spaces* such as lounges, laundry, leasing offices, fitness rooms, common bathrooms, community and conference rooms.

b. K-12 Schools

i. Cafeteria, including food preparation (i.e., kitchen) and dining areas

ii. Gymnasium, including locker rooms and showers

iii. Auditorium

iv. School *thermal blocks* representing classrooms, corridors, restrooms and offices.

c. Offices, fire stations, libraries, police stations, post offices, and town halls

i. Office *thermal blocks* representing variety of *spaces* found in office *buildings*.

The *modeled floor area* of *residential* and *nonresidential thermal blocks* in residential buildings and cafeteria, gymnasium and auditorium *thermal blocks* in K-12 schools shall be within 5% of the actual design shown on construction documents. The exterior envelope area of each *thermal block* shall reflect construction document.

Exception: Thermal blocks based on the specified HVAC zones may be used for the "supporting spaces" and "nonresidential" thermal blocks in residential buildings, "school" thermal blocks in K-12 schools and "office" thermal blocks in offices, fire stations, libraries, police stations, post offices, and town halls. When more detailed thermal blocks are modeled following this exception, these thermal blocks are subject to all rules in these guidelines that are applicable to the corresponding aggregated thermal blocks, including but not limited to the standardized assumptions for miscellaneous loads, lighting, occupancy and schedules.

Informative note: The simplifications described in this section are similar to those appropriate for the early design modeling cycles, such as the Load Reduction cycle, described in the ASHRAE Standard 209 Computer Simulation Aided Design. They allow evaluating compliance with Section C407.1 early in the design process before the *building* programming and *HVAC* zoning schemes are finalized.

8.3 Criteria for Aggregating Thermal Blocks

Thermal blocks of the same type shall be aggregated when they meet all of the following criteria:

a. Separate *thermal blocks* shall be assumed for interior and perimeter areas. Interior areas shall be those located greater than 15 ft from an *exterior wall*. Perimeter areas shall be those located within 15 ft of an *exterior wall* .

Exceptions:

1. *Residential*, *residential* supporting, cafeteria, gymnasium and auditorium *thermal blocks* shall not be split into perimeter and core *thermal blocks*.

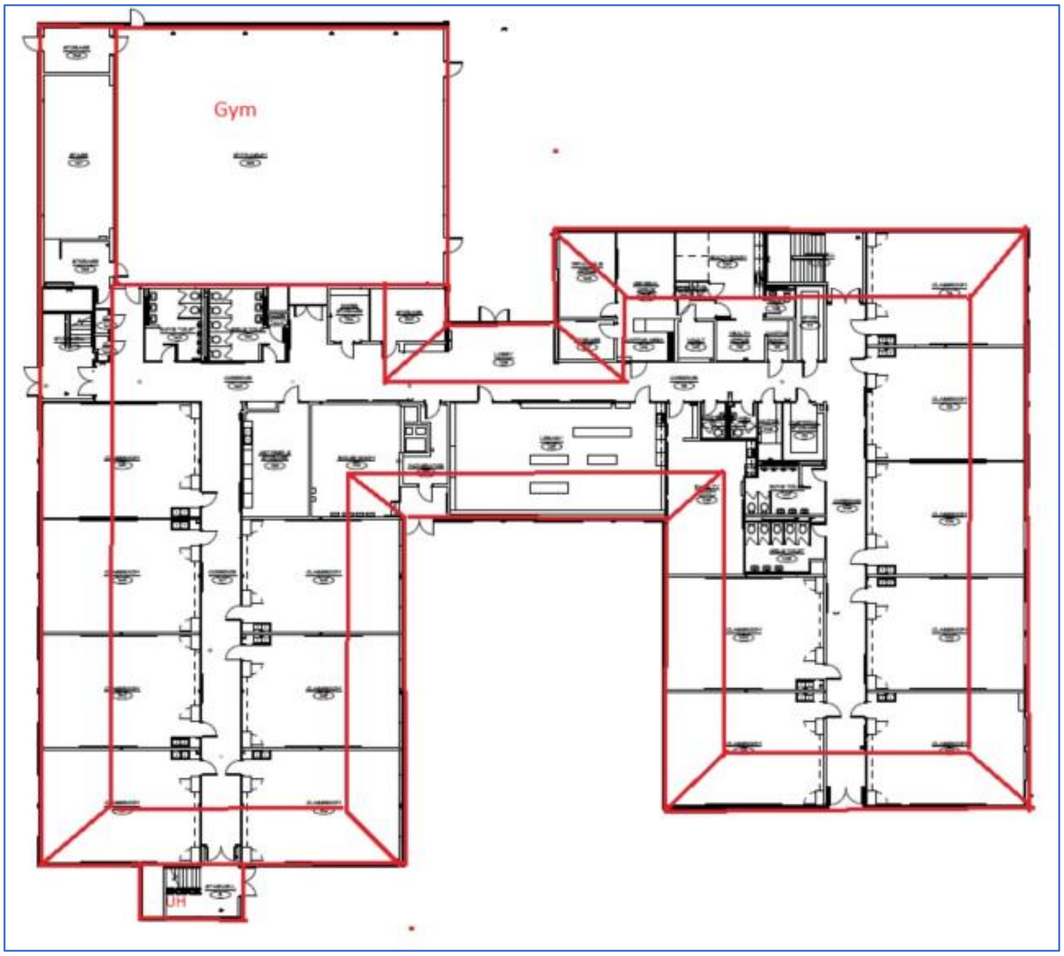
b. Separate *thermal blocks* shall be assumed for *spaces* adjacent to glazed *exterior walls*; a separate *thermal block* shall be provided for each *orientation*, except that *orientations* that differ by less than 45 degrees may be considered to be the same *orientation*. Each *thermal block* shall include all floor area that is 15 ft or less from a glazed perimeter *exterior wall*, except that *floor area* within 15 ft of glazed perimeter *exterior walls* having more than one *orientation* shall be divided proportionately between *thermal blocks*.

c. Separate *thermal blocks* shall be assumed for *spaces* having *floors* that are in contact with the ground or exposed to ambient conditions from zones that do not share these features.

d. Separate *thermal blocks* shall be assumed for *spaces* having exterior ceiling or *roof* assemblies from spaces that do not share these features.

e. *Spaces* served by mechanical systems with exhaust air energy recovery shall not be aggregated into the same *thermal block* with *spaces* served by mechanical systems that do not have exhaust air energy recovery.

Figure 1~~2~~: Simplified Thermal Blocks Example for a School Project



9. Building Envelope Shape and Areas

a. The modeled exterior envelope geometry shall be consistent with construction documents, including proper accounting of *fenestration* and *opaque* building envelope types and areas. Each modeled *thermal block* shall reflect the total area, type and orientation of *opaque* surfaces (i.e., *above and below-grade exterior walls, roof, above and below grade floors*) and *fenestration* associated with the spaces included in the block.

b. The total *modeled floor area* of *conditioned spaces* shall be within 5% of the *gross floor area* shown on the architectural drawings unless justification is provided to *AHJ*.

> **Informative Note:** Common reason for the deviation between the *modeled floor area* and the floor area reported on the construction documents include differences in accounting for area taken by interior partitions, mechanical chutes and stairwells and thickness of exterior walls.

10. Building Envelope Properties

10.1 General Requirements

a. All components of the *building* envelope shall be modeled as shown on architectural drawings and as described in this section.
b. Simulation shall account for thermal mass of the exterior surfaces.
c. Exterior surfaces whose azimuth *orientation* and tilt differ by less than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers.

10.2 Exterior walls

Exterior walls shall be modeled with the U-factors derated to account for thermal bridging using the derating methods described in Section C402.7.

10.3 Roof surfaces

Exterior *roof* surfaces shall be modeled using the aged solar reflectance and thermal emittance determined by testing in accordance with CRRC S100. Where aged test data are unavailable, the *roof* surface shall be modeled with a reflectance of 0.30 and a thermal emittance of 0.90.

10.4 Fenestration

a. Modeled *fenestration* properties shall reflect performance of the complete assembly including frame and glazing and reflect U-factor, *SHGC* and *VT* established by a laboratory accredited by a nationally recognized accreditation organization, such as the National Fenestration Rating Council (NFRC) and as described in Section C402.4.6. *Fenestration* products that do not have such rating shall be modeled with the default properties from 90.1 Table A8.1 for unlabeled *skylights* and Table A8.2 for unlabeled vertical *fenestration*.
b. Manual *fenestration* shading devices, such as blinds or shades, are allowed to be modeled in the *residential spaces*. In all other *space* types, manual *fenestration* shading devices shall not be modeled.
c. Automatically controlled *fenestration* shades or blinds shall not be modeled.
d. Permanent shading devices, such as fins, overhangs, and light shelves shall be modeled.
e. Shading due to setting *fenestration* faces back from surround *wall* faces shall be modeled.
f. Automatically controlled dynamic glazing may be modeled. Manually controlled dynamic glazing shall use the average of the minimum and maximum *SHGC* and *VT*.

Q: Why automatic interior shades cannot contribute to *TEDI* compliance?

A: *TEDI* focuses on the aspects of envelope design that are permanent and have long useful life such as insulation of *opaque* surfaces, mitigation of thermal bridging, efficient envelope aspect ratio and *orientation*, quality *fenestration*, aperture area and solar exposure, solar gains, and air leakage. While automatic shades cannot be modeled and used to contribute to *TEDI* compliance, they should still be considered by design team due to their potential to reduce *building* energy use and improve occupant comfort.

10.5 Air leakage

a. The modeled air leakage rate of the *building* envelope shall be based on air leakage testing completed following Section C402.5.2.
b. The air leakage rate of the *building envelope* shall be converted to appropriate units for the *simulation program* using one of the methods in 90.1 Section G3.1.1.4.

c. The infiltration flow shall be assigned to the *thermal blocks* in proportion to the area of surfaces adjacent to exterior.

Q: Project initiated *TEDI* modeling early in design process to ensure compliance of envelope design. However, air leakage testing can only be performed after construction is completed. What air leakage rate should be modeled?

A: *TEDI* models are typically created before air leakage testing is performed, so infiltration rate must be estimated. Since model will ultimately be updated to reflect the test results, it is recommended to avoid overly optimistic air leakage assumptions to ensure that *TEDI* compliance is not jeopardized. For example, 0.35cfm/ft^2 at 75Pa, the maximum allowed in Section C402.5.2, may be used as an early air leakage estimate.

Example
A 5 story office *building* has the following envelope dimensions:

- *Gross floor area*: 40,000 ft^2, including 30,000 ft^2 adjacent to exterior walls or roof.
- Gross *roof* area: 8,000 ft^2
- *Slab-on-grade floor* area: 8,000 ft^2
- Total gross *above grade exterior wall* area 17,117 ft^2

The air leakage rate measured following ASTM E3158 test is 0.30 cfm/ft^2 at a pressure differential of 0.3 inch water gauge (75 Pa). How should air leakage be modeled?

1. Calculate the *building* envelope area S as the sum of the *roof* area, *slab-on-grade floor* area and *above grade wall* area.

S= 8,000*2 + 17,117 =33,117 [ft^2]

Step 2: Calculate the air leakage flow rate at wind pressure following 90.1 Section G3.1.1.4

Q=0.112*0.30 [cfm/ft^2]* 33,117[ft^2] = 1,484 [cfm]

Step 3: Enter the calculated flow rate into simulation tool using the approved infiltration modeling algorithm and distributing air leakage in proportion to area of exterior surfaces within each *thermal block*.

d. Infiltration modeling algorithm selected within simulation tool shall include adjustment for weather.

- **eQuest** – model the Infiltration Method (keyword: INF-METHOD) as Air-Change and enter the infiltration value to be modeled for each space as A-C Air Change/hr (keyword: AIR-CHANGES/HR). Remember to zero out A-C Infiltration Flow (cfm/ft2) (keyword: INF-FLOW/AREA) to avoid over modeling infiltration. See the screenshot below for reference.

Display Mode: Infiltration

	Space Name	Parent Floor	Activity Desc.	Infiltration Method	Infiltration Schedule	A-C Air Changes/hr	A-C Infiltration Flow (cfm/ft2)	S-(R
99	36_Void 1	E8 Ground Flr	VOI	Air Change	LT_ON_Yrly	0.00	0.0000	
100	36_Elev	E8 Ground Flr	VOI	Air Change	LT_ON_Yrly	0.04	0.0000	
101	36_Void 2	E8 Ground Flr	VOI	Air Change	LT_ON_Yrly	0.00	0.0000	
102	36_Trash Room	E8 Ground Flr	STO	Air Change	LT_ON_Yrly	0.00	0.0000	
103	36_Apt A_0br	E8 Ground Flr	0br	Air Change	LT_ON_Yrly	0.11	0.0000	
104	36_Apt B_0br	E8 Ground Flr	0br	Air Change	LT_ON_Yrly	0.05	0.0000	

- **Energyplus** – model using the ZoneInfilration:DesignFlowRate object. Link to object details can be found here. Model the Design Flow Rate Calculation Method as Flow/ExteriorArea and the Velocity Term Coefficient as 0.224. See the screenshot below for reference.

Field	Units	Obj3
Name		Infiltration 1 cfm 3
Zone or ZoneList Name		SecondarySchool Classroom
Schedule Name		SchSec INFIL_SCH_PNNL
Design Flow Rate Calculation Method		Flow/ExteriorArea
Design Flow Rate	m3/s	
Flow per Zone Floor Area	m3/s-m2	
Flow per Exterior Surface Area	m3/s-m2	0.000227584
Air Changes per Hour	1/hr	
Constant Term Coefficient		0
Temperature Term Coefficient		
Velocity Term Coefficient		0.224
Velocity Squared Term Coefficient		

- **IESVE**- model based on a room/template level (Space Data) whereby a formula profile may be applied, referencing wind speed and/or wind direction.

e. Infiltration schedule shall be as specified in the Schedules and Loads Guidelines Supplement for the appropriate thermal block type.

11. Standardized Assumptions

The standardized assumptions prescribed in Table 1-6 in the Schedules and Loads Guidelines Supplement shall be modeled for each *thermal block* depending on the *building* use type, *gross floor area* and *thermal block* type.

12. Lighting

a. Interior lighting power shall be modeled based on *building* use type, *modeled floor area* and *thermal block* use type as prescribed in Tables 1-6 in the Schedules and Loads Guideline Supplement.

Informative Notes:

1. The prescribed lighting power density (LPD) for schools and *residential building* types are based on the assumed relative area of different space types within each thermal block type and the lighting power requirements for these space types in 90.1 2019 Table 9.6.1, Lighting Power Density Allowances Using the Space-by-Space Method.
2. For office, fire station, library, police station, post office, town hall, and other the prescribed lighting power density is based on the office *Building* Area Type allowance in 90.1 2019 Table 9.5.1. Prescribed schedules were established based on the occupancy controls that were assumed in the models used to establish the *TEDI* limits in Table C407.1.1.5.

b. *Daylighting* shall not be modeled in residential *thermal blocks*. In all other *thermal blocks* *daylighting* shall be modeled as follows:

i. For *thermal blocks* with *vertical fenestration*, the *daylight area* shall be modeled as directly adjacent to the *vertical fenestration* with a width equal to the width of the *vertical fenestration* and a depth equal to the head height of the *vertical fenestration*. A *photosensor* shall be modeled as located at the center of the width of the *daylight area*, at the depth of the *daylight area* and at a height of 3 ft.

ii. In each *nonresidential* zone associated with *skylights*, the *daylight area* under skylights shall be modeled as bounded, in each direction, by the edge of the *skylight* area plus 10 ft or the distance to the edge of the zone, whichever is less. A *photosensor* shall be modeled as located at the center of the horizontal plane of the *skylight* and at a height of 5 ft.

13. Heating, Ventilation and Air-conditioning Systems

13.1 General Approach

The heating, ventilation and air-conditioning systems, their components and controls shall be modeled as follows:

c. Buildings and areas within the building for which HVAC systems are not designed and are not shown on the construction documents shall be modeled with the default HVAC systems following Sections 13.2 and 13.4.

d. Buildings and areas within the building for which HVAC systems are designed shall be modeled following either of the following options:

i. with the specified systems following Sections 13.2 and 13.4

~~i.~~ ii. with the default HVAC systems following Section 13.1(a).

The selected approach shall be followed for the entire project.

~~Projects shall be modeled using the *HVAC* systems prescribed in this section regardless of planned and or designed *HVAC* systems.~~

13.2 Default HVAC System Configuration

13.2.1. Heating and Cooling System Type and Description

The modeled heating and cooling system types shall be determined using

Table **1**~~Table 1~~

Table 1Error! Reference source not found. based on the *building* type and the total *modeled floor area*.

Table **2**~~Table 2~~

Building Type	Heating/Cooling System Type
Office, fire station, library, police station, post office, town hall >= 125,000-sf	System 2 *FCU*
Office, fire station, library, police station, post office, town hall between 75,000 & 125,000-sf	System 2 *FCU*
Office, fire station, library, police station, post office, town hall <= 75,000-sf	System 1 *ASHP*
K-12 School >= 125,000-sf	System 2 *FCU*
K-12 School between 75,000 and 125,000-sf	System 2 *FCU*
K-12 School <= 75,000-sf	System 1 *ASHP*
Residential multifamily and dormitory >= 125,000-sf	System 3 *WSHP*
Residential multifamily and dormitory between 75,000 and 125,000-sf	System 1 *ASHP*
Residential multifamily and dormitory <= 75,000-sf	System 1 *ASHP*
All other >= 125,000-sf	System 2 *FCU*
All other between 75,000 and 125,0000-sf	System 2 *FCU*
All other <= 75,000-sf	System 1 *ASHP*

provides additional details for each system type.

Exceptions:

a. K-12 school cafeterias (including dining and food preparation areas), auditoriums, and gymnasiums shall be modeled with variable volume single zone system that has same heating and cooling type as the remainder of the *building*.

Table 1: Heating and Cooling System Types by Building Type

Building Type	Heating/Cooling System Type
Office, fire station, library, police station, post office, town hall >= 125,000-sf	System 2 *FCU*
Office, fire station, library, police station, post office, town hall between 75,000 & 125,000-sf	System 2 *FCU*
Office, fire station, library, police station, post office, town hall <= 75,000-sf	System 1 *ASHP*
K-12 School >= 125,000-sf	System 2 *FCU*
K-12 School between 75,000 and 125,000-sf	System 2 *FCU*
K-12 School <= 75,000-sf	System 1 *ASHP*
Residential multifamily and dormitory >= 125,000-sf	System 3 *WSHP*
Residential multifamily and dormitory between 75,000 and 125,000-sf	System 1 *ASHP*
Residential multifamily and dormitory <= 75,000-sf	System 1 *ASHP*
All other >= 125,000-sf	System 2 *FCU*
All other between 75,000 and 125,0000-sf	System 2 *FCU*
All other <= 75,000-sf	System 1 *ASHP*

Table 2: Heating and Cooling System Details

System Number	System Type	Fan Control	Cooling Type	Heating Type
System 1 *ASHP*	Air source heat pump	Constant volume	Direct expansion	Electric heat pump
System 2 *FCU*	4-Pipe fan coil units with CHW and HW		Chilled water	Hot-water electric boiler
System 3 *WSHP*	Water source heat pump		Direct expansion	Electric heat pump, condenser water loop served by electric boiler

Informative Note: The prescribed heating and cooling system types are **not** a design recommendation. They were selected to simplify energy modeling and ensure that *TEDI* compliance is not affected by the differences in the *HVAC* system design across projects to preserve the focus on *building* envelope performance. The prescribed systems are well supported by the *simulation programs* which simplifies the modeling, reducing modeling mistakes and effort of documenting *TEDI* compliance.

13.2.2 Air-side economizer

a. *Air economizer* shall be modeled for the single zone systems modeled following Section ~~13.1~~ 0 Exception (a).

b. *Air economizers* shall be modeled with a differential dry bulb temperature control to set the outdoor airflow to minimum ventilation requirements when the dry-bulb temperature of outdoor air is higher than the dry-bulb temperature of the return air with a low temperature minimum temperature setpoint cutoff of 45F. Modeled *air economizer* systems shall be capable of and configured to modulate outdoor air and return air dampers to provide up to 100% of the design supply air quantity as outdoor air for cooling.

c. The exhaust air recovery shall be locked out during *air economizer* operation if applicable.

13.2.2 Mechanical Ventilation System Type and Description

The modeled ventilation system(s) shall comply with the following:

a. Mechanical ventilation shall be provided by a dedicated outdoor air system (DOAS), de-coupled from the system that provides heating and cooling.

Exception: Single zone systems modeled following Section 0~~13.1~~ Exception (a) shall be modeled as also providing mechanical ventilation to the *thermal block*.

~~b.~~a. ~~The minimum ventilation flow rate shall be modeled using the greater of the following:~~

~~i. The value prescribed in Tables 1-6 of the Schedules and Loads Guidelines Supplement depending on the *building* use type and *gross floor area*.~~

~~ii.~~i. ~~The specified ventilation rate. The specified ventilation rate shall be documented in the same way as described in Section C103.2 #16.~~

~~**Informative Note**: The ventilation rates prescribed in Tables 1-6 in the Schedules and Loads Guidelines Supplement are based on assumed relative areas of different *space* types within each *thermal block* type and the minimum ventilation requirements for each space type in 62.1-2019 increased by up to 30%. If *space* allocation in the actual design is different, the up to 30% margin may not be available for the project.~~

~~c.~~b. *Demand control ventilation* shall not be modeled.

~~d.~~c. Exhaust air energy recovery effectiveness shall be modeled as specified. The modeled controls shall allow bypassing energy recovery to permit *air economizer* operation and allow free cooling when outdoor air conditions are favorable.

~~e.~~d. *DOAS* systems shall be modeled with preheating and precooling coils of the same type as are modeled for the space conditioning heating and cooling systems. The supply air temperature shall be maintained between 55F and 60F.

Q: What default heating, cooling, and ventilation systems should be modeled for a 320,000 ft^2 K-12 school with a 34,000 ft^2 gymnasium, a 10,600 ft^2 auditorium, and a 9,040 ft^2 cafeteria (which includes a kitchen and dining area)? Other *space* types include classrooms, lounges, corridors, restrooms, heated only storage rooms, mechanical rooms, and offices.

A: The following systems should be modeled:

Heating and cooling systems

- Based on
- Table **1**~~Table 1~~, all school *thermal blocks* (including heated-only spaces) are modeled with heating and cooling provided by constant volume fan coil units with hot water and chilled water coils. (K-12 schools over 125,000 ft^2)
- Based on Section 0~~13.1~~ Exception (a), the gymnasium, auditorium, and cafeteria are modeled with single zone variable volume units with hot water and chilled water coils

Ventilation systems

- Based on Section 0~~13.3~~ (a), school *thermal blocks* must be modeled with the dedicated outdoor air system (*DOAS*), de-coupled from the heating and cooling systems (i.e., OA provided to thermal zone separately from the heating and cooling system)
- Based on the exception to Section 0~~13.3~~ (a), the gymnasiums, cafeterias, and auditoriums shall

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Q: The as-designed *HVAC* systems in the previous example all include exhaust air energy recovery with an enthalpy recovery ratio of 75% except for the system serving heated only storage room. How should energy recovery be modeled?

A: Per Section0~~13.3~~.e exhaust air energy recovery must be modeled as specified. Therefore, exhaust air energy recovery with the 75% enthalpy recovery ratio is modeled for the *DOAS* system serving school *thermal blocks*, and for the single zone variable volume systems serving gymnasium, auditorium, and cafeteria.

Exhaust air energy recovery is not modeled for the heated only *thermal blocks* because it is not specified for these areas. Note that these are modeled as both heated and cooled as there are no provisions for heating-only *thermal blocks* for a school project in Section 0~~8.2~~. Also, following Section 8.3 (e) *thermal blocks* without energy recovery cannot be aggregated with *thermal block* with energy recovery specified.

13.2.3 Unitary Equipment Efficiency

a. Air source heat pumps shall be modeled with a cooling efficiency of 3.74 *COPnfcooling* and a heating efficiency of 3.66 *COPnfheating* at 47F DB.
b. Water source heat pumps shall be modeled with a cooling efficiency of 4.4 *COPnfcooling* at an entering water temperature of 86F and a heating efficiency of 5.0 *COPnfheating* at an entering water temperature of 68F.

13.2.4 Equipment Capacities and Sizing

Heating and cooling coil capacities shall be autosized based on sizing runs and shall be oversized by 15% for cooling and 25% for heating. The following design day conditions shall be used in the sizing runs:

a. Space temperature and humidity design setpoints
Summer: 75F DB, 55% RH maximum
Winter: 70F DB

b. Outdoor ambient design conditions
Summer: 87F DB; 71F WB
Winter: 7F DB

c. Design day schedules included in the Schedules and Loads Guidelines Supplement shall be used.

13.2.5 Design Airflow Rates

a. Supply airflow rates for system 1 through 3 shall be auto sized and based on a supply-air-to-room temperature set-point difference of 20°F, or the minimum outdoor airflow rate, whichever is greater.

13.2.6 *Fan System Operation*

a. Heating and cooling system fans that do not provide outside air to meet minimum ventilation requirements shall cycle on and off to meeting heating and cooling loads.
b. *DOAS* fans shall operate continuously during occupied hours and remain off during unoccupied hours.
c. Heating and cooling system fans in single zone systems modeled following Section 16.2 Exception a that provide outside air to meet minimum ventilation requirements (e.g., systems serving cafeterias, auditoriums, and gymnasiums) shall operate continuously during occupied hours and shall cycle to meet heating and cooling loads during unoccupied hours.

13.2.7 *System Fan Power*

a. Design fan power shall be modeled per Table 3~~Table 3~~ and
~~a.~~b. Table 4~~Table 4~~ based on the *building* type, areas served, and the system type.

Table 3: Fan Power Modeling Requirements for Heating and Cooling Equipment

Building **Type**	**Areas Served**	**Heating/Cooling System Type**	**Fan Power, kW/CFM**
Office, fire station, library, police station, post office, town hall, K-12 school, and all other	All except gyms, cafeterias, auditoriums	System 1 and System 2	0.00024
Residential multifamily and dormitory	All	System 1	0.00012
Residential multifamily and dormitory	All	System 3	0.00017
K-12 school	Gyms, cafeterias, and auditoriums only	System 1 and System 2	0.00050

Table 4: Fan Power Modeling Requirements for DOAS

Building **Type**	**Fan Power, kW/CFM**
Office, fire station, library, police station, post office, town hall, K-12 school, and all other	0.00063
Residential multifamily and dormitory	0.00035

~~b.~~c. Ventilation systems serving *thermal blocks* for which exhaust air energy recovery other than a coil runaround loop is specified in the proposed design shall be modeled with additional fan power determined as follows:

   i. For each airstream determine the pressure drop (PD) through the specified energy recovery device based on design documents and/or manufacturer specification.
   ii. Calculate the additional brake horsepower to be modeled
      (bhp) = sum of (PD × cfmD/4131)
      cfmD = the cfm of each applicable air stream
   iii. Convert bhp to kW = bhp × 0.746/fan motor efficiency
      Fan motor efficiency = the efficiency from ASHRAE 90.1 2019 Section 10 for the next motor size greater than the bhp.

~~*Piping and Ductwork Losses*~~

~~Piping and ductwork losses shall not be modeled.~~

13.2.8 System 2 Chilled and Hot Water Plant Description

a. Chilled water plant description
   i. Water cooled centrifugal chillers with a 6.6 COP shall be modeled.
   ii. Chilled-water design supply temperature shall be modeled at 44°F and return water temperature at 56°F. Chilled-water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 44°F at 80°F and above, 54°F at 60°F and below, and ramped linearly between 44°F and 54°F at temperatures between 80°F and 60°F.
   iii. Chilled-water systems shall be modeled as primary/secondary with a constant-flow primary loop and a variable-flow secondary loop. Pump power shall be 9.0 W/gpm for the primary loop and 13 W/gpm for the secondary loop at design conditions. The secondary pump shall be modeled with a variable-speed drive and a minimum flow of 25% of the design flow rate.
   iv. Heat-rejection system shall be an axial-fan open-circuit cooling tower with variable-speed fan control and an efficiency of 40.2 gpm/hp at an entering water temperature of 95F DB, a leaving water temperature of 85F DB, and an entering air temperature of 75F WB.
   v. The condenser-water design supply temperature for all system types shall be modeled using a cooling tower approach temperature of 7F and range of 10F.
   vi. The cooling tower shall be controlled to maintain a leaving water temperature of 70F, where weather permits, floating up to the design leaving water temperature for the cooling tower.
   vii. The condenser-water pump power shall be modeled as 19 W/gpm. The condenser water pumps shall be constant volume with each chiller modeled with separate condenser-water and chilled-water pumps interlocked to operate with the associated chiller.

b. Hot Water Plant Description
   i. Hot water shall be provided by 100% efficient electric resistance boilers.
   ii. Hot-water design supply temperature shall be 180°F; design return temperature shall be 130°F.
   iii. Hot-water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 180°F at 20°F and below, 150°F at 50°F and above, and ramped linearly between 180°F and 150°F at temperatures between 20°F and 50°F.
   iv. The pump system shall be modeled as primary-only with continuous variable flow and a minimum of 25% of the design flow rate.
   v. Modeled hot-water pump power shall be 19 W/gpm.

13.2.9 System 3 WSHP Description

a. Hot Water Plant Description

i. Condenser loop heat shall be provided by 100% efficient electric resistance boiler.
ii. Boilers shall maintain a condenser water temperature between 60F and 90F.

b. Heat Rejection System Description
   i. Heat-rejection system shall be an axial-fan open-circuit cooling tower with variable-speed fan control and shall have an efficiency of 40.2 gpm/hp at an entering water temperature of 95F DB, a leaving water temperature of 85F DB, and an entering air temperature of 75F WB.
   ii. The condenser-water design supply temperature shall be modeled using a cooling tower approach temperature of 7F and range of 10F.
   iii. The cooling tower shall be controlled to maintain leaving water temperatures between 60°F and 90°F.
   iv. The condenser-water pump power shall be modeled as 19 W/gpm and the variable speed drives. Condenser water loop flow shall be variable with flow shutoff at each heat pump when its compressor cycles OFF.

13.3 Modeling As-designed HVAC Systems

Where an *HVAC system* has been designed and submitted with design documents, the HVAC model shall be consistent with design documents. Where *efficiency* ratings include supply fan *energy*, the *efficiency* rating shall be adjusted to remove the supply fan *energy* from the *efficiency* rating. The systems shall be modeled using *manufacturers*' full- and part load data for the *HVAC system* without fan power.

13.4 Other HVAC Modeling Requirements

*13.4.*1 Minimum Ventilation Flow Rate

The minimum ventilation flow rate shall be modeled using the greater of the following:

i. The value prescribed in Tables 1-6 of the Schedules and Loads Guidelines Supplement depending on the *building* use type and *gross floor area*.

ii. The specified ventilation rate. The specified ventilation rate shall be documented in the same way as described in Section C103.2 #16.

> **Informative Note**: The ventilation rates prescribed in Tables 1-6 in the Schedules and Loads Guidelines Supplement are based on assumed relative areas of different *space* types within each *thermal block* type and the minimum ventilation requirements for each space type in 62.1 2019 increased by up to 30%. If *space* allocation in the actual design is different, the up to 30% margin may not be available for the project.

13.4.2 Piping and Ductwork Losses

Piping and ductwork losses shall not be modeled.

~~13.~~14. Special Cases

~~13.1~~14.1 Core and Shell and Initial Build-out

For projects in which systems and components that must be modeled as designed following these guidelines have not yet been designed, those yet-to-be-designed features shall be modeled to comply with but not exceed the requirements of the most current version of 225 CMR 23: Massachusetts Commercial Stretch Energy Code. Core and shell *buildings* where the details of the *building* occupancy is not known shall be categorized as an office *building*.

Q: Core and shell project has a complete envelope design but interior partitions and *HVAC* design will be completed by future tenant. How should thermal zoning be determined? Should energy recovery and an *air economizer* be modeled?

A: *Thermal blocks* must be modeled following Section 8, Simplified *Thermal Block* approach. Since *building* use type is unknown, office occupancy must be assumed. An *air economizer* must be included if required by Section C403.5 for any of the modeled *HVAC* systems. Energy recovery must be modeled as required in Section C403.7.4 for any of the modeled *HVAC* systems.

~~13.2~~14.2 *Additions*

Following C502.1, large additions which are either more than 100% of the size of the existing *building* or equal to or greater than 20,000-sf require conformance to C401.2. If the addition use type is office, dormitory, fire station, library, office, school, police station, post office, or town hall, the addition must show compliance with the Targeted Performance Compliance (C401.2 Part 2). In this scenario, the existing *building* shall be excluded from the model so that only the addition is modeled. Surfaces separating the addition from existing *building* shall be modeled as adiabatic.

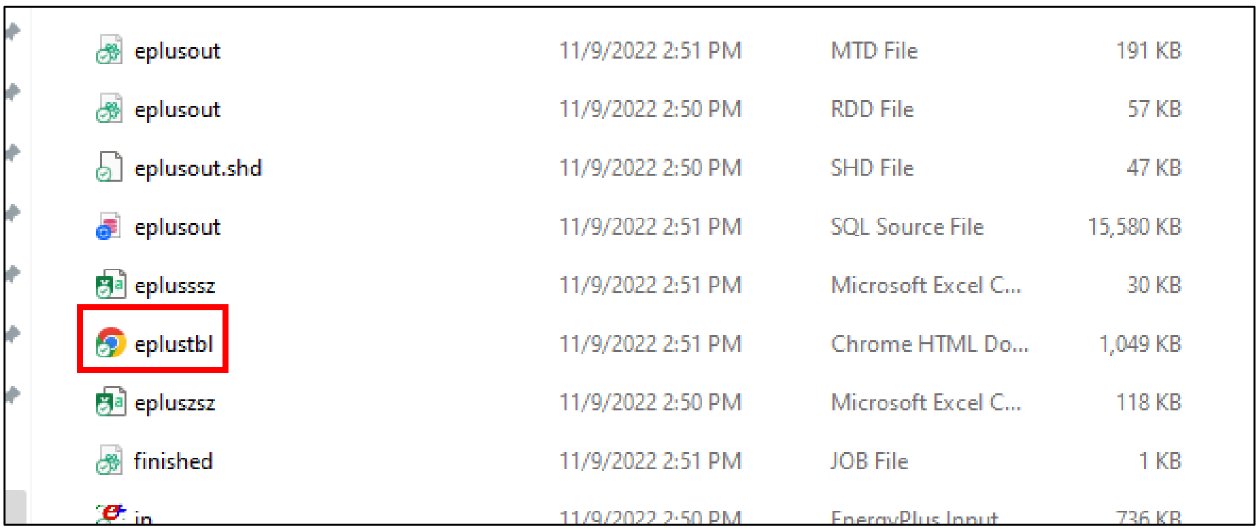
Annex 1: Extracting Simulation Results to Determine *TEDI*

This Appendix describes how to extract information necessary to calculate *TEDI* from the simulation reports generated by the approved *simulation programs* including OpenStudio, EnergyPlus, and IESVE.

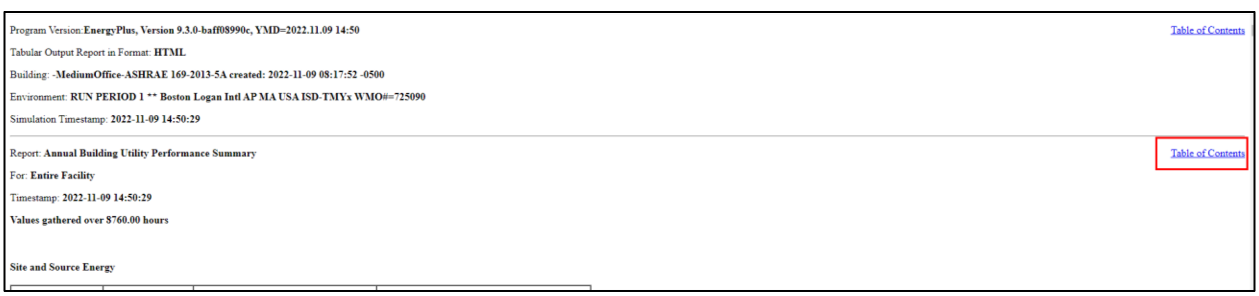
Openstudio/Energyplus

References to get E+/Openstudio to generate all summary output reports in html format: https://bigladdersoftware.com/epx/docs/8-6/input-output-reference/output-table-summaryreports.html and https://bigladdersoftware.com/epx/docs/8-0/input-output-reference/page-095.html

Step 1: Open the eplustbl html output document generated by E+/Openstudio



Step 2: Click the hyperlink to get to the Table of Contents



Step 3: Using the Table of Contents hyperlinks to navigate to the Energy Meters section

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Top
Annual Building Utility Performance Summary
Input Verification and Results Summary
Demand End Use Components Summary
Source Energy End Use Components Summary
Component Sizing Summary
Surface Shadowing Summary
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Initialization Summary
Annual Heat Emissions Summary
Climatic Data Summary
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Shading Summary
Lighting Summary
Equipment Summary
HVAC Sizing Summary
Coil Sizing Details
System Summary
Outdoor Air Summary
Object Count Summary
Energy Meters
Sensible Heat Gain Summary
Standard 62.1 Summary
LEED Summary

BUILDING ENERGY PERFORMANCE - ELECTRICITY

| Meter |

BUILDING ENERGY PERFORMANCE - NATURAL GAS

Step 4: Scroll down to the "Annual and Peak Values – Other" table.

Annual and Peak Values - Other

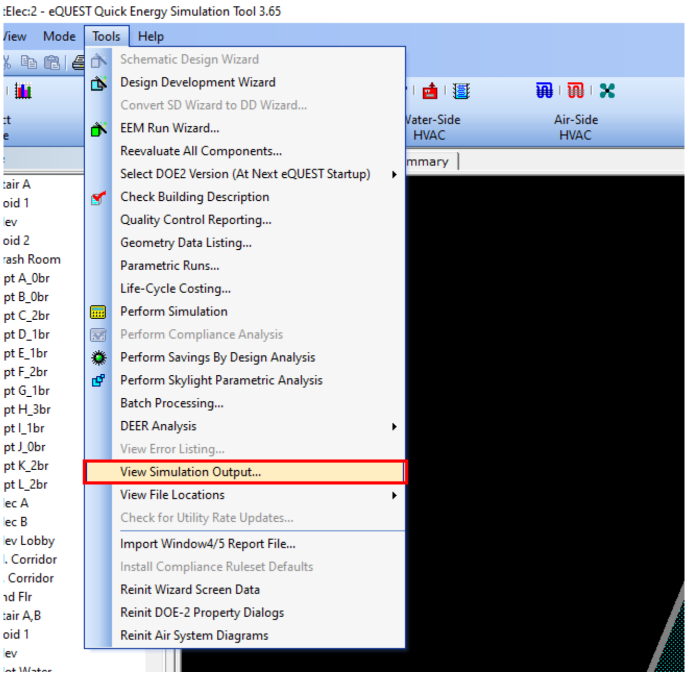
	Annual Value [kBtu]	Minimum Value [Btu/h]	Timestamp of Minimum {TIMESTAMP}	Maximum Value [Btu/h]	Timestamp of Maximum {TIMESTAMP}
EnergyTransfer:Facility	2548892.60	0.00	17-JAN-00:10	1489813.35	10-JUL-11:30
EnergyTransfer:Building	830472.04	0.00	04-JAN-22:10	530951.45	10-JUL-15:30
EnergyTransfer:Zone:CORE_BOTTOM ZN	282645.50	0.00	01-JAN-00:10	143790.80	24-JUL-07:20
Heating:EnergyTransfer	38940.71	0.00	04-JAN-22:10	340743.38	02-JAN-05:10
Heating:EnergyTransfer:Zone:CORE_BOTTOM ZN	14.68	0.00	01-JAN-00:10	16794.57	02-JAN-07:10
General:Heating:EnergyTransfer	38940.71	0.00	04-JAN-22:10	340743.38	02-JAN-05:10

Step 5: The CoolingCoils:EnergyTransfer and HeatingCoils:EnergyTransfer rows are the modeled total cooling and heating loads to use to calculate *TEDI*. If the html report was generated in imperial units, then these numbers will be in units of kBtu. Divide each by *modeled floor area* to arrive at the modeled cooling and heating *TEDI* values.

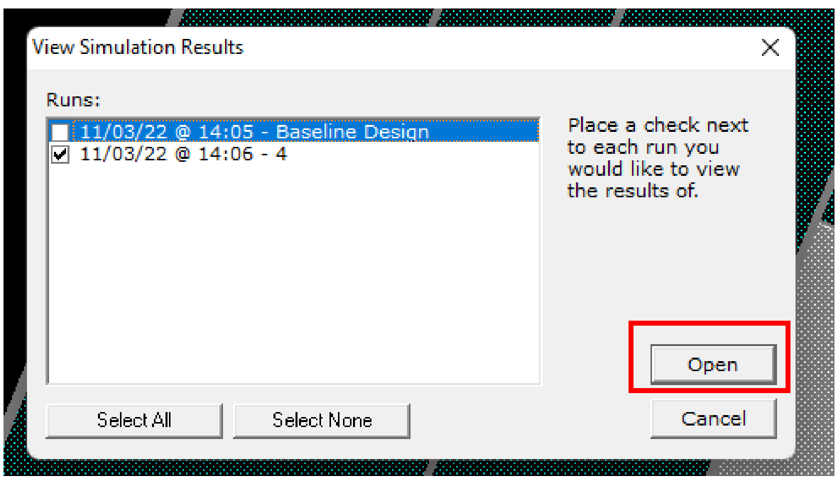
	CoolingCoils:EnergyTransfer	968493.29
	HeatingCoils:EnergyTransfer	85068.42

eQuest

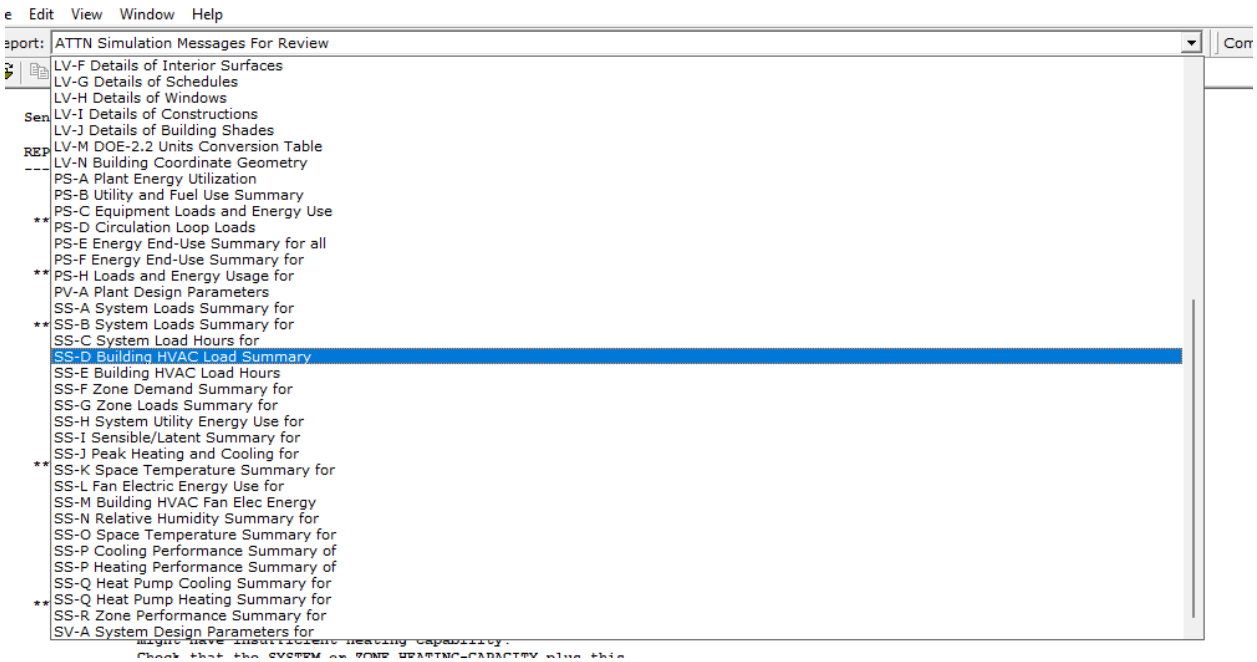
Step 1: After running the simulation to Tool→ View Simulation Output…



Step 2: Open the output for the simulation



Step 3: Navigate to the SS-D report



Step 4: Find the heating and cooling loads at the locations shown below in the SS-D report. Multiply each number by 1,000 to convert to kBtu and then divide each by the *modeled floor area* to arrive at the modeled cooling and heating *TEDI* values.

REPORT- SS-D Building HVAC Load Summary WEATHER FILE- EPW Boston Logan Int

	COOLING						HEATING						ELEC	
MONTH	COOLING ENERGY (MBTU)	TIME OF MAX DY	TIME OF MAX HR	DRY-BULB TEMP	WET-BULB TEMP	MAXIMUM COOLING LOAD (KBTU/HR)	HEATING ENERGY (MBTU)	TIME OF MAX DY	TIME OF MAX HR	DRY-BULB TEMP	WET-BULB TEMP	MAXIMUM HEATING LOAD (KBTU/HR)	ELEC-TRICAL ENERGY (KWH)	MAXIMUM ELEC LOAD (KW)
JAN	8.28206	16	16	47.F	38.F	116.240	-72.487	29	8	13.F	10.F	-320.675	45039.	104.137
FEB	10.74596	14	16	38.F	33.F	187.800	-56.175	9	8	18.F	17.F	-304.401	39612.	103.935
MAR	20.94034	27	18	57.F	43.F	266.033	-31.774	18	8	29.F	24.F	-195.751	39712.	84.883
APR	56.42065	15	18	63.F	44.F	453.741	-9.837	9	8	34.F	34.F	-126.982	37126.	94.250
MAY	107.72193	11	19	78.F	53.F	593.573	-2.363	29	5	44.F	42.F	-13.430	39651.	105.436
JUN	171.29518	1	19	86.F	71.F	690.363	-0.703	14	9	54.F	52.F	-3.765	42092.	115.613
JUL	217.24588	10	18	89.F	73.F	697.254	-0.331	1	2	74.F	71.F	-0.755	45726.	113.710
AUG	204.94670	19	18	86.F	72.F	676.035	-0.102	1	2	71.F	62.F	-0.334	44855.	111.483
SEP	140.12317	4	18	82.F	73.F	593.638	-0.152	17	9	51.F	45.F	-5.844	39823.	101.677
OCT	67.20216	2	18	67.F	52.F	429.798	-2.817	23	8	42.F	37.F	-29.458	37469.	85.553
NOV	29.55248	5	16	54.F	43.F	322.117	-13.440	23	8	33.F	28.F	-166.833	36112.	82.523
DEC	10.91148	4	16	55.F	47.F	212.691	-36.534	31	8	29.F	26.F	-222.003	39857.	89.294
TOTAL	$\boxed{1045.388}$						$\boxed{-226.715}$						487074.	
MAX						697.254						-320.675		115.613

IESVE

Please visit the IESVE frequently asked questions (FAQ) page for instructions for determining heating and cooling *TEDI*s from the IESVE energy model. The instructions on the web page are for generating the heating *TEDI*, to generate the cooling *TEDI* just replace “heating” with “cooling” for both cases of the variables referenced on the FAQs page. Please use the definition in Section 1 for *modeled floor area* for determining the floor area that needs to be manually entered per the instructions on the FAQ page.

Link: https://www.iesve.com/support/ve/knowledgebase_faq/faq/tedi/13803

If the *TEDI*s generated by IESVE following the instructions on the web page are in units of $kWh/m^2/yr$ they will need to be converted to units of $kBtu/ft^2/yr$ by multiplying by 0.317.

Appendix D Relative Performance Simulation Guidelines

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1. Purpose

The purpose of the Simulation Guidelines is to improve the accuracy and technical integrity of building energy models used to establish compliance with Section C407.2 Relative Performance by meeting the following objectives:

a. Clarify areas where the Relative Performance Path deviates from ANSI/ASHRAE/IESNA Standard 90.1 2019 (90.1) Appendix G Performance Rating Method (PRM) due to MA Stretch Code amendments.
b. Provide requirements for areas that are either not directly addressed by the PRM or are ambiguous. In most cases, such requirements are based on addenda to 90.1 2019, which is directly referenced.
c. Explain PRM rules that are often misapplied or misinterpreted.
d. Provide examples to illustrate all of the above.

The Simulation Guidelines are not a standalone document and must be used in conjunction with the modeling requirements in ASHRAE 90.1 2019 Appendix G and MA Stretch Code 2022 Section C407.2.

2. Additional Reference Materials

The following additional reference materials are available:

a. ASHRAE 90.1 2019 Users' Manual
b. ASHRAE 90.1 Section 11 and Appendix G Submittal Review Manual is a comprehensive reference for reviewing modeling-based submittals. The Manual is a companion to the DOE/PNNL 90.1 Section 11 and Appendix G Compliance Form and supports 2016 and 2019 editions of ANSI/ASHRAE Standard 90.1. The document was developed to help code officials review modeling-based submittals and should also be used energy modelers to self-check the models before submitting compliance documentation to code official.
c. ASHRAE Standard 90.1 Performance Based Compliance Form is spreadsheet-based and meets the documentation requirements of Standards 90.1-2016 and 2019 Section 11 Energy Cost Budget Method and Appendix G Performance Rating Method. It helps the modeler establish simulation inputs for the baseline/budget and proposed design models and includes a submittal checklist to ensure that all necessary supporting documentation is included in the submittal. It standardizes compliance documentations and simplifies submittal reviews by code officials and administrators of above code program implementers.

3. General Modeling Approach

Compliance is established based on the relative site energy use of two models – *baseline design* model and *proposed design* model.
The *proposed design model* reflects building systems, components and controls specified in the construction documents. The modeled operating conditions and schedules must reflect the expected operation of the building or typical for the given building use type.

The following systems must be excluded from the proposed design model (MA Stretch amendments to 90.1 G2.4.1):

- Energy used to recharge vehicles that are used for on-road and off-site transportation purposes, or energy losses from use of behind-the-meter energy storage
- On-site renewable energy systems

The *baseline design model* is a virtual building that has the following characteristics:

- The same building use type, programming, envelope shape, HVAC zoning and operating schedules as the *proposed design model*.
- Most other systems and components such as envelope construction, fenestration area, HVAC system type and controls, SWH system type and lighting power and controls are prescribed in 90.1 Appendix G and are independent and different from the systems in the proposed design.
- All systems are modeled at the efficiency levels approximately aligned with requirements of ASHARE 90.1 2004.
- Parameters of the baseline model that are not explicitly defined in 90.1 PRM must be modeled the same as in the *proposed design*.
- The end uses that are not included in the proposed design must not be modeled in the baseline. For example, if the project includes a parking lot for which no exerior lighting is specified, the parking lot lighting power allowance cannot be modeled in the baseline. The only exception to this rule is that certain conditioned spaces must be modeled as both heated and cooled even if no cooling is specified (90.1 PRM Table G3.1 Proposed Building Performance column #1 (b)).
- Baseline energy use is calculated as an average of four alternative orientations of the *baseline design model*. There are two exceptions that allow using the same orientation for the baseline as specified for the proposed design:
    i. projects where fenestration area across different exposures in the proposed design differs by less than 5%
    ii. projects where exposure is dictated by the building site. The second exception may apply to retrofits and additions, and also new construction projects in urban areas where orientation is dictated by street frontage.

3. Compliance Calculations

Compliance is established by calculating the Performance Energy Index (PEI) as the ratio of the site energy use of the proposed design model to the baseline model and comparing the PEI to the Performance Energy Index target (PEIt) determined as described in Section C407.2.2.1.
In order to calculate PEIt, simulation results for the baseline must be separated into baseline building unregulated site energy (BBUE) and baseline building regulated site energy (BBRE).

- Regulated energy use is associated with building systems and components with requirements prescribed in 90.1 Sections 5-10 such as interior and exterior lighting, space heating and cooling, heat rejections, ventilation and parking garage fans, pumps, service water heating, refrigeration, elevators and escalators.
- Unregulated end uses are limited to interior lighting designed to comply with health or life safety regulations (90. Section 9.1.1 Exception 2), industrial process equipment, and systems installed by tenants that are not shown on construction documents such as miscellaneous plug loads.

4. Approved Building Energy Modeling Tools and Calculation Methods

Simulation software must comply with the software requirements outlined in Appendix G Section G2.2. The following software tools are pre-approved:

- eQUEST

- EnergyPlus
- IESVE

Other software tools may be approved by MA DOER on a case-by-case basis.
If an approved simulation tool used on a project does not have the capability to calculate energy usage/savings for a design feature allowed by 90.1 PRM, supplemental calculations may be used. Such calculations, referred to as exceptional calculation methods in 90.1, must be documented following requirements of Section G2.5 summarized below, and are subject to AHJ approval:

a. Step-by-step documentation of the Exceptional Calculation Method performed detailed enough to reproduce the results
b. Copies of all spreadsheets used to perform the calculations
c. A sensitivity analysis of energy consumption when each of the input parameters is varied from half to double the assumed value
d. The calculations shall be performed on an hourly time step basis
e. The Performance Energy Use calculated with and without the Exceptional Calculation Method
f. The total savings documented using the Exceptional Calculation Methods cannot account for more than half of the difference between the *baseline building performance* and the *proposed building performance*. This cap is incorporated in the DOE/PNNL Compliance Form.

5. Energy Modeler Qualifications

Energy models shall be created by persons qualified by education and training to perform such work. The modeling documentation submitted to AHJ shall be signed by a professional meeting qualification requirements outlined in Modeler_Quals_FINAL.pdf (energycodes.gov).

6. Reporting Requirements

Compliance documentation must meet requirements of 90.1 2019 Section G1.3.2. To meet these requirements, projects must submit the filled out DOE/PNNL ASHRAE Standard 90.1 Performance Based Compliance Form | Building Energy Codes Program. The Compliance Form includes the submittal checklist, a list of simulation reports and other supporting documentation that must be provided to the code official.

7. District Energy Systems

Projects with space heating, cooling or service water heating provided by a district plant in lieu of on-site systems must be modeled as using the purchased energy (chilled water, hot water, and/or steam) in both the baseline and proposed models, as described in 90.1 G3.1.1.1, G3.1.1.2, G3.1.1.3. This results in a slight penalty for such projects compared to projects with on-site systems. District systems cannot contribute toward compliance with C407.2 irrespective of their efficiency.

8. Electricity Generation Systems

a. Contribution of renewable electricity generation systems toward compliance with Section C407.2 is not allowed following MA Stretch amendments to 90.1 Section G2.4.1. Such systems should not be modeled in either the *proposed design* or *baseline design*.
b. The Combined Heat and Power systems must be modeled the same in the baseline and proposed design, except the baseline design must be modeled without waste heat recovery (90.1 G2.4.2).

Example 1
Q: A hospital project includes a combined heat and power (CHP) system that uses natural gas to generate electricity. The waste heat from the CHP is recovered and used for service water heating. How should the CHP be modeled in the baseline and proposed design?
A: In the proposed design, the CHP would be modeled as part of the whole building simulation, reflecting the specified system electric and thermal efficiency and controls.
In the baseline design, the CHP would be modeled as part of the whole building simulation reflecting the electricity generation efficiency but without accounting for the recovered heat. Service hot water would be supplies by the gas storage water heater (90.1 Table G3.1.1-2).

9. Simulated Schedules

Modeled occupancy, HVAC, and other schedules should reflect expected building operation based on information provided by building owner and design team. Where the details of building operation are unknown, typical schedules for the building use type should be used, such as the standardized schedules prescribed for Section C407.1. For residential occupancies, schedules prescribed in the [ENERGY STAR Multifamily New Construction Program Simulation Guidelines] should be used. When modeled schedules deviate significantly from typical, AHJ may request supporting documentation to justify the modeled schedules. Examples of acceptable documentation include but are not limited to a statement from the owner with anticipated project's operating hours, or operating hours of a similar franchise.
Schedules must be modeled identically in the baseline and proposed design models, unless otherwise permitted by 90. Appendix G Table G3.1 #4, Baseline Building Performance column or as documented in an exceptional calculation method.

10. Building Envelope

Proposed Design

a. Areas that are not classified as *enclosed spaces* per 90.1 definition including ventilated attics, ventilated crawlspaces and parking garages that are mechanically or naturally ventilated may be explicitly modeled or excluded from the model. Whichever approach is selected, it must be applied to both the baseline and proposed design models. If excluded, the associated surfaces that are not part of the *building envelope* must also be excluded from the model, and surfaces that are part of the *building envelope* must be modeled as having direct exterior exposure.

> ***Example 2***
> **Q:** Building has a mechanically ventilated parking garage on the first floor and hotel occupancy on floors 2-6. How should the parking garage be modeled?
> **A:** Parking garage may be modeled explicitly as show on construction documents or omitted from the model. If omitted, the floor of the hotel above the parking garage must be modeled as adjacent to exterior. The selected modeling approach must be used for both the baseline and proposed design. Irrespective of the selected approach, parking garage loads such as lighting and ventilation must be modeled

b. Modeled envelope properties must reflect materials and constructions included in design documents.
c. Modeled thermal transmittance of wall assemblies must be derated to account for *clear field*, *linear* and *point thermal bridges* as described in C402.7. Any derating method allowed in Section C402.7 may be used.
d. When the total area of penetrations from mechanical equipment, such as through-wall AC sleeves and PTAC/PTHP, exceeds 1% of the opaque above-grade wall area, the area of the penetrations must be modeled in the Proposed Design with a default U-factor of 0.5. When mechanical equipment has been tested in accordance with approved testing standards, the mechanical equipment penetration area may be calculated as a separate wall assembly with the U-factor as determined by such test. Insulated covers for the through-wall AC units must not be modeled even when specified.
e. Fenestration must be modeled to reflect whole window assembly U-factors (including framing) and not the center-of-glass U-factor. Acceptable sources for overall fenestration U-factors include the

following:

- NFRC rating from the window manufacturer for the entire fenestration unit. (This is usually only available for standard window sizes.)
- LBNL WINDOW software (http://windows.lbl.gov/software/window/window.html)
- Modeling the framing and glazing explicitly in the whole building simulation tool used for the project based on known thermal properties and dimensions of the framing and glazing
- ASHRAE Fundamentals 2021, Chapter 15 Table 4.
- If both summer and winter U-factors are available, winter U-factor must be modeled as it reflects the testing conditions of NFRC 100 referenced in 90.1 Section 5.8.2.3.

f. The same infiltration modeling algorithm and schedule must be used for baseline and proposed design models. f. Modeled air leakage must be based on testing as required by Section C402.5.2. The test results must be converted to simulation inputs as prescribed in 90.1 Section G3.1.1.4. Infiltration must be modeled at 100% (i.e. with schedule fraction of 1) during un-occupied hours when HVAC systems are off, and at 25% during occupied hours (i.e. with schedule fraction of 0.25). If simulation tool restricts changes to infiltration schedule, infiltration can be ignored during occupied hours by modeling infiltration schedule fraction of 0 when fans are on

Baseline Design

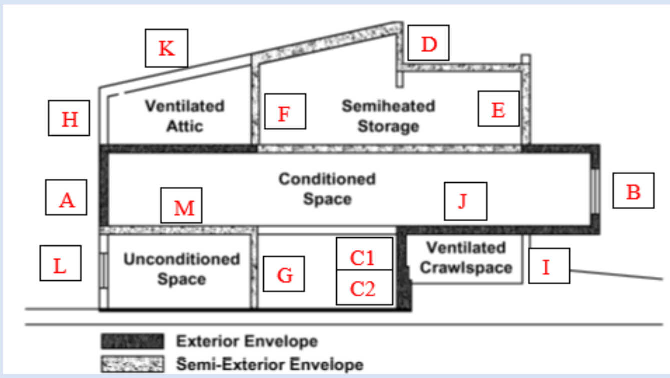
a. The opaque envelope and fenestration properties must be modeled as prescribed in Table G3.1 #5 based on occupancy type (residential/nonresidential) and space conditioning category (conditioned/semiheated/unconditioned). Space conditioning category must be determined using the criteria in 90.1 Section 3 definition of *space*.

b. The vertical fenestration areas for new buildings and additions must be determined as follows:
   - For building types included in Table G3.1.1-1, based on the percentage of the above-grade wall area specified in the table. For building types not shown in Table G3.1.1-1, vertical fenestration areas must equal that in the proposed design or 40% of gross above-grade wall area, whichever is smaller. Doors that are more than one-half glass are considered fenestration, per Section 3 of ASHRAE 90.1, and must be modeled with properties required for vertical glazing from ASHRAE 90.1 Table G3.4-5. The entire surface area of such doors counts as fenestration area.
   - MA Stretch amended table G3.1.1.-1 to require that multifamily buildings are modeled with the vertical fenestration area equal to 24% of the above grade wall area.
   - The fenestration area for existing buildings must equal the existing fenestration area prior to the proposed work

   Wall area used to determine fenestration area includes all walls that are part of the *exterior* and *semi-exterior* building envelope (per 90.1 2019 addendum ct).

Example 3

Q: The figure below shows an elevation view of an office building. Which of the walls must be included in the fenestration area calculation?



A: Area of walls F, D, E, B, A, C1 and G must be included when calculating baseline fenestration area in accordance with Table G3.1 part 5 item c.

c. Fenestration must be distributed on each face of the building in the same proportions as in the proposed design.

d. The modeled air leakage rate must be based on 1.0 cfm/ft^2 of the building thermal envelope at 0.3" water gauge (75 Pa). The surface area must include the above- and blow-grade *conditioned* and *semi-heated* walls, ceiling/roof and floors. Simulation inputs must be determined following 90.1 Section G3.1.1.4 which prescribes conversion to the equivalent air leakage at wind pressure and procedures for normalizing the infiltration rate by appropriate surface area based on simulation program input requirements.

11. Interior Lighting

Proposed Design

a. All specified fixtures including general, task, decorative and furniture-mounted fixtures must be included in the lighting power calculations.

b. 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

c. Modeled lighting power must be based on the maximum rated fixture wattage and may be higher than the wattage of the specified bulb and ballast combination (Table G3.1 #6 b, Proposed Building Performance column).

Example 4

Q: Corridor in a hotel has recessed ceiling fixtures and wall sconces. Wall sconces are specified with 18W LED bulb but are rated for 60 Watt based on incandescent bulb. How should wall sconces be modeled in the proposed design?

A: Wall sconces must be modeled based on their rated wattage of 60W. If the manufacturer labels the fixtures shipped to the project with the 18W rated wattage, this lower wattage may be used in the proposed design model. The requirement to use the labeled rated fixture wattage when determining compliance ensures that the maintenance staff will use the LED replacement bulb, ensuring persistence of modeled performance.

d. For track lighting, the modeled wattage must not be less than 30 W/lin. ft. See Section 9.1.4 for other rules applicable to track lighting.

e. In spaces where lighting is connected via receptacles and not shown on design documents, lighting power used in the simulation must be equal to the lighting power allowance in Table 9.6.1 for the appropriate space type or as designed, whichever is greater. For the dwelling units, lighting power used in the simulation must be equal to 0.60 W/ft2 or as designed, whichever is greater. This provision in Table G3.1 #6 (e), Proposed Building Performance column was added in 90.1 2019 to ensure that spaces were lighting is not specified or only partially specified do not contribute to lighting power savings. Partially specified lighting is common for dwelling units, hotel/motel guestrooms and dormitory living quarters.

Example 5

Q: Specified lighting in a 400 ft^2 hotel guest room includes a bathroom fixture rated at 18 Watt and a hallway fixture rated at 22 Watt. No other lighting is shown on drawings. What lighting power should be modeled in the proposed design?

A: The specified lighting is (18+22)/400=0.1 W/ ft^2 does not served the entire guest room, and is meant to be supplemented by plug-in table, floor and night stand lamps. The guest room lighting of 0.41 W/ ft^2 must be modeled in the proposed design based on the guest room allowance in 90.1 Table 9.6.1.

f. Lighting exempt from 90.1
Section 9.1.1 Exception 2 excludes from the scope of the Standard 90.1 any lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation. With AHJ approval, such lighting, as well as other exempt lighting, may be modeled as an unregulated load, the same in the baseline and proposed design.

g. Temporary Lighting
Where temporary or partial lighting is specified for core and shell spaces, lighting power in the proposed design must be equal to the allowance in Table 9.6.1, Space-by-Space method where space types are known and using Table 9.5.1 Building Area Method when space types are not known as for core and shell projects.

Example 6: Temporary Lighting

Q. Core and shell project includes a 3,000 ft^2 area that will be a retail store. There area has a temporary lighting with a total power of 1,000 W. The permanent lighting system will be designed and installed by the future tenant. What lighting power should be modeled in the baseline and proposed design?

A. The baseline must be modeled with 1.50 W/ft^2 lighting power density based on 90.1 Table G3.8. Lighting power allowance for retail building area type in Section 9 is 0.84 W/ft^2 (Table 9.5.1). The specified temporary lighting is 1,000/3,000=0.33 W/ft^2 which is lower than this allowance. The retail area must be modeled with 0.84 W/ft^2 lighting power density in the proposed design.

h. Lighting controls other than daylighting

Automatic lighting controls are required by Standard 90.1 in most space types (90.1 Section 9.4.1 and Table 9.6.1). Since these provisions are mandatory, where such controls are required (if exceptions to these sections do not apply), they must be specified in the proposed design. Lighting controls other than daylighting must be modeled by reducing the lighting schedule each hour by the occupancy sensor reduction factors in 90.1 Table G3.7 Occupancy Sensor Reduction column. Based on the footnotes below the table, the occupancy sensor reduction factor must be multiplied by 1.25 for manual-on or partial-auto-on occupancy sensors; for occupancy sensors controlling individual workstation lighting, occupancy sensor reduction factor of 30% must be used. Projects following MA Stretch may also document credit for the following automatic lighting controls included in the proposed design that are not required by Section 9.4.1 and Table 9.6.1:

- F*or luminaire* that meet requirements of C406.4 (enhanced digital lighting controls) the *occupancy sensor* reduction factor may be increased by 7.5%.
- For lighting in the *dwelling units* that have controls meeting all of the following requirements, the *occupancy senor* reduction factor of 10% may be used.
  - i. Each *dwelling unit* has a main control by the main entrance that turns off all the lights and all switched receptacles in the *dwelling unit*.
  - ii. The main control may have two controls, one for permanently wired lighting and one for switched receptacles.
  - iii. Where controls are divided the main controls must be clearly identified as "lights master off" and "outlets master off."

i. Daylighting Controls
- Automatic daylight responsive controls are required for most spaces with vertical fenestration and skylights following 90.1 Section 9.4.1 and Table 9.6.1. These controls must be specified in the proposed design and either modeled directly in the whole building simulation tool used for the project or through a schedule adjustment determined by a separate approved analysis. If a separate analysis was performed, such as using a specialized daylighting software, the summary outputs from such software and explanation of how the results were incorporated into the whole building simulation must be included in the submittal.
- Schedule adjustments must be applied only to the fixtures for which daylight controls are specified.
- Visual light transmittance (VT) of the specified windows affects daylighting savings and must be captured in the tool used to calculate savings.

Baseline Design

a. Lighting power must be determined using Table G3.7 Space-by-Space Method and assigned to each modeled thermal block based on space use types within the block. Table G3.8, Building Area Method, may only be used for portions of the building where lighting is not specified and space types are unknown, as with core-and-shell projects.
b. Lighting power cannot be increased to account for decorative lighting. Where specified, such lighting will be modeled in the proposed design but not in the baseline design, resulting in a performance penalty.
c. Where retail display lighting is included in the proposed building design in accordance with Section 9.6.2b, the baseline building design retail display lighting additional power should be equal to the limits established by Section 9.6.2b or same as proposed which ever less (90.1 2019 addendum af).
d. Lighting must be modeled with automatic shutoff controls in buildings >5000 ft^2 and occupancy sensors in employee lunch and break rooms, conference/meeting rooms, and classrooms (not

including shop classrooms, laboratory classrooms, and preschool through 12th-grade classrooms).
e. Daylighting controls must not be modeled in the baseline design model.

12. Exterior Lighting

Proposed Design

a. Exterior lighting power allowances and control requirements are mandatory in 90.1. Thus, the specified exterior lighting may improve over the allowances in 90.1 Table 9.4.2-2 but must not exceed it.
b. The allowances in Table 9.4.2-2 depend on the Exterior Lighting Zones that are based on project location. All projects in MA are expected to use either Zone 2 or Zone 3 allowances based on zone description in 90.1 Table 9.4.2-1:
   Zone 2: Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed-use areas
   Zone 3: All other areas excluding exterior lighting in national state parks, forest land and rural areas and high activity commercial districts in major metropolitan areas as designated by the local jurisdiction
c. Table 9.4.2-2 categorizes lighting applications into tradable and non-tradable. Tradable applications include uncovered parking areas, building grounds, building entrances and exits, sales canopies, and outdoor sales areas. The specified lighting for all tradable applications must not exceed the combined lighting allowance for such applications in Table 9.4.2-2.
d. Non-tradable exterior lighting applications includes building façades, automated teller machines, night depositories, etc. Non-tradable lighting allowances are use-it-or-lose-it caps that must be met individually by each corresponding exterior lighting application in the proposed design.
e. Following Section 9.4.1.4, the exterior lighting must be controlled to turn off when sufficient lighting is available and turned off, or operate at wattage reduced by at least 30%, during non-business hours. These controls are mandatory and must be specified on all projects. Following these requirements, the modeled exterior lighting runtime may be up to 12 hours / day (4,380 hours per year) for facilities opened 24/7, such as hospitals. Lower runtime (e.g., 6 hours per day) is expected for other building types due to lighting control requirements in 90.1 Section 9.4.1.4.

Baseline Design

a. The lighting allowances in Table 9.4.2-2 for all tradable applications must be multiplied by the associated area or length to determine the total baseline power allowance. Only illuminated areas can be included in the calculations of the baseline wattage.
b. The baseline power for the non-tradable lighting applications must be the same as in the proposed design.
c. Exterior lighting runtime hours must be modeled the same as in the proposed design.

Example 7: Common Mistakes When Calculating Baseline Exterior Lighting Power

1. Including areas of the proposed design that are not illuminated, or incorrectly accounting for partially illuminated areas, when calculating the baseline exterior lighting power. For example, if proposed design has an uncovered parking lot that has no lighting specified, the exterior lighting allowance for the uncovered parking areas in 90.1 Table G3.6 cannot be included in the baseline.
2. Double-counting areas when calculating the baseline exterior lighting power allowance. For example, the baseline lighting allowance for the walkway that crosses an illuminated parking lot can be determined based on the parking lot allowance, or walkway allowance in 90.1 Table G3.6, but not both. If walkway allowance is used, the walkway area calculated as described in #3 above must be subtracted from the parking lot area used to calculate the parking lot baseline lighting allowance.
3. Modeling baseline lighting for non-tradeable surfaces based on the full allowance in 90.1 Table G3.6. The baseline non-tradeable lighting must be modeled the same as in the proposed design.

13. Process and Plug Loads

The process and plug loads category includes systems and equipment that impact building energy use but are not regulated by ASHRAE Standard 90.1, such as consumer appliances, miscellaneous plug-in systems, IT equipment, etc. These systems contribute to internal heat gains which impact heating and cooling loads on the HVAC systems. Modeled process and plug loads must be as expected for the particular project or representative for the building use type. Typical plug and process loads for common building use types are included in

Annex . Process and plug loads must be the same in the baseline and proposed design models.

Example 8 Common Mistakes in Categorizing Process and Plug Loads

1. Elevators are regulated by 90.1 and must be modeled as prescribed in Table G3.1 #16.
2. Commercial refrigeration equipment is regulated by 90.1 and must be modeled as prescribed in Table G3.1 #17.

14. Commercial Refrigeration Equipment

a. Commercial refrigerators and freezers that have the baseline efficiency prescribed in 90.1 Table G3.10.1 and the refrigerated cases with the baseline efficiency prescribed in 90.1 Table G3.10.2 must be modeled as described in the following bullets. For all other types of refrigeration equipment, the same energy use must be modeled in the baseline and proposed design.
   - Baseline energy use (kWh/day) must be as prescribed in 90.1 Table G3.10.1 and G3.10.2 for the specified equipment type and size.
   - Proposed energy use must reflect the AHRI 1200 kWh/day rating for the specified equipment from equipment manufacturer.

b. The hourly refrigeration load (RL) entered into simulation tool must be determined as follows, assuming uniform year-round operation:

   RL = RP/24

   Where:

   RL [kW/hr] = refrigeration load,

   RP [kWh/day] =rated performance, based on Tabled G3.10.1 or G3.10.2 for the baseline and based on AHRI 1200 rating of the specified equipment for the proposed design.

c. The schedules used in the baseline and proposed design in conjunction with the refrigeration load must have hourly fractions of 1 for all hours of the year.

d. If the specified refrigeration equipment has remote condensers, the internal gains to the spaces where equipment is located must be adjusted to reflect amount of heat extracted from the space as appropriate for the specified equipment. The same internal gains adjustment must be used for the baseline design as for the proposed design.

15. Heating, Ventilation and Air Conditioning Systems

HVAC System Type and Efficiency

Proposed Design

a. HVAC system types and efficiencies must be modeled as specified

b. If the HVAC system efficiency for the proposed design is given as SEER or HSPF and the EER or COP ratings are not available from the manufacturer, the equivalent system efficiency excluding fan power must be calculated using the following relationships, based on 90.1 Section 11.5.2 (c):

$$COPnfcooling = -0.0076 \times SEER^2 + 0.3796 \times SEER \quad (Equation\ 1)$$

$$COPnfheating = -0.0296 \times HSPF^2 + 0.7134 \times HSPF \quad (Equation\ 2)$$

Where:

COPnfcooling = Coefficient of Performance (COP) cooling efficiency excluding AHIR rating fan power

c. COPnfheating = Coefficient of Performance (COP) heating efficiency excluding AHIR rating fan power Based on Appendix G section G3.1.2.1, where efficiency ratings, such as EER and COP, include fan energy, the descriptor must be broken down into its components so that supply fan energy can be modeled separately. Manufacturers often publish both gross and net AHRI capacities, and the difference between these two figures is equal to the fan power. The following calculation must be used to extract fan power from the rated efficiency of the specified equipment:

$$EER_{ADJ} = \frac{Q_{T,RATED} + BHP_{SUPPLY} * 2.545}{\frac{Q_{T,RATED}}{EER} - BHP_{SUPPLY} * .7457} \qquad \text{(Equation 3)}$$

Where:

EER$_{ADJ}$ = the adjusted Energy Efficiency Ratio with fan power removed, to be used for simulation purposes

EER = the rated Energy Efficiency Ratio, at AHRI conditions

Q$_{T,RATED}$ = the AHRI rated total cooling capacity of the unit (net capacity) in kbtu/h

BHP$_{SUPPLY}$ = the supply fan brake horsepower (bhp) at AHRI rating conditions. For the purposes of these calculations, BHP includes losses of the fan motor and drive.

For heat pumps, the following equation should be used for extracting supply fan power from heating COP when AHRI supply fan BHP is available:

$$COP_{ADJ} = \frac{Q_{T,RATED} - BHP_{SUPPLY} * 2.545}{\frac{Q_{T,RATED}}{COP} - BHP_{SUPPLY} * 2.545} \qquad \text{(Equation 4)}$$

Where:

COP$_{ADJ}$ = the adjusted COP with fan power removed, to be used for simulation purposes

COP = the rated COP, at ARI conditions

Q$_{T,RATED}$ = the ARI rated total heating capacity of the unit (net capacity) in kbtu/h

BHP$_{SUPPLY}$ the supply fan brake horsepower (bhp) at AHRI rating conditions. For the purposes of these calculations, BHP includes losses of the fan motor and drive

If the actual supply fan BHP is not available from the manufacturer, then fan power must be extracted from the proposed systems using 90.1 11.5.2 (c) for the analogous system type.

Baseline Design

a. HVAC System Type

90.1 2019 addendum ab clarified and streamlined the process of determining the baseline HVAC system types. These updated requirements must be followed when documenting compliance with Section C407.2. Below is a summary of the process based on amended Section G3.1.1.1:

1. Determine the combined gross conditioned and semi-heated floor area for each of the following building area types in the proposed design:
    - residential and residential-associated zones
    - public assembly
    - heating-only storage

- retail
- hospitals
- other nonresidential

2. Classify the nonresidential building area type with the largest combined area as the predominant nonresidential building area type. Add the combined area of any remaining nonresidential building area types with less than 20,000 ft2 to the combined area of the predominant nonresidential building area type.
3. Select a baseline HVAC system type from Table G3.1.1-3 for each of the following building area types included in the proposed design based on the size of the building as a whole and not an individual occupancy: 1. Residential + residential associated 2. Predominant nonresidential 3. Each additional nonresidential building area type with more than 20,000 ft2 of combined area based on G3.1.1.1.

The amended section G3.1.1.2 includes requirements for determining additional and adjusted baseline HVAC System Types.

Example 9 Baseline System Type for a Mixed-Use Building

Q. New construction project involves a 5 story 100,000 ft^2 building with a retail store on the first floor (25,000 ft^2) and hotel on floors 2-5. The retail store includes the sales floor, offices, restrooms and heated-only storage space. Hotel floors include guest rooms, corridors, heated only stairwells, conference rooms and management offices. What HVAC systems should be modeled in the baseline?

A. The baseline HVAC systems are established using a two-step process:

Step 1: Determine the baseline HVAC system types based on building area types following 90.1 addendum ab Section G3.1.1.1
Based on 90.1 2019 Addendum ab definition, any HVAC zone that primarily includes nonresidential spaces designed to serve occupants of residential spaces on a floor where over 75% of the gross conditioned floor area are residential spaces is considered residential-associated. On floors 2-5, hotel guest rooms account for more than 75% of conditioned and semi heated floor area, and all non-residential spaces on these floors are used for the hotel function. Thus, the entire area of floors 2-5 is considered residential and would have baseline System 1 – PTAC following Table G3.1.1-3.

The entire area of the first floor is considered retail and would map to baseline System 5 – Packaged VAV with reheat following Table G3.1.1-3 based on the number of floors and floor area of the entire building.

Step 2: Determine additional and adjusted baseline HVAC system types following 90.1 addendum ab Section G3.1.1.2
Heated only stairwells on the hotel floors and heated only storage on the retail floor are subject to addendum ab Section G3.1.1.2 Exception (c) and will be modeled with System 9 – Heating and Ventilation

b. Air-side System Efficiency
   - Baseline air-side HVAC system efficiency ($COP_{NFCOOLING}$ and $COP_{NFHEATING}$) is determined based on 90.1 Tables G3.5.1, G3.5.2, and G3.5.5.
   - The values provided in the tables depend on the baseline system capacity which must be determined using the simulation sizing runs following Section G3.1.2.2.1.
   - Table G3.1 #7-9 allow modeling multiple HVAC zones that meet the specified criteria as a single thermal block to simplify modeling. To avoid impact of these modeling simplifications on the baseline system efficiency, the baseline efficiencies must be based on the load of individual HVAC zones prior to aggregation into thermal blocks as is allowed in 90.1 Table G3.1 #7 Thermal Blocks – HVAC Zones Designed. When identical floors are grouped in accordance with Section G3.1.1(a)(4), efficiencies in G3.5.1 for the Baseline HVAC System Types 5 or 6 must be based on the cooling equipment capacity of equipment serving a single floor.

Mechanical Ventilation

Proposed Design

Mechanical ventilation must be modeled as specified, including ventilation delivery method such as via the space conditioning system or a Dedicated Outdoor Air System (DOAS), ventilation controls such as Demand Control Ventilation (DCV), and exhaust air energy recovery.

90.1 Section 6.4.2.4 includes mandatory requirements for ventilation system controls that must be met by the ventilation system design. Below are several common examples:

- Automatic controls to shut off fans when outdoor air not required (6.4.3.4.4)
- Garage ventilation capable to automatically stage fans or modulate airflow rates to 50% or less of design capacity based on contaminant levels (6.4.3.4.5)
- DCV for spaces over 500 SF with design occupancy equal or greater than 25 people per 1000 SF (6.4.3.8). If the occupant density in spaces that are typically subject to the DCV requirement is less than the default occupant density listed in ASHRAE 62.1 Table 6-1, making DCV not required, the source for the assumed occupant density must be documented.

Baseline Design: Ventilation Rate

As a general rule, the minimum outdoor air ventilation rate must be modeled the same in the baseline design as in the proposed design except when the following conditions apply:

a. Following 90.1 Section G3.1.2.6 exception (c), if the minimum outdoor air intake flow in the proposed design exceeds the amount required by the applicable code, then the baseline building design must be modeled to reflect the minimum required ventilation rate and will be less than in the proposed design. There is no over-ventilation penalty for healthcare facilities following ventilation requirements of ASHRAE Standard 170, as Section 7 of the standard allows higher rates if deemed necessary by the owner.
b. Zones with air distribution effectiveness Ez>1.0 may be modeled with lower ventilation rate in the proposed design compared to the baseline as described in 90.1 Section G3.1.2.5 Exception (2). This performance credit may apply to designs with displacement ventilation or other techniques that result in ventilation effectiveness greater than 1.0. Projects must use Ventilation Rate Procedures described in ASHRAE Standard 62.1, Section 6.2 to demonstrate the savings.

Baseline Design: Demand Control Ventilation

a. Section 90.1 G3.1.2.5 Exception 1 requires that demand control ventilation (DCV) is modeled in the baseline design for systems serving areas with a design occupancy greater than 100 people per 1,000 ft^2 of floor area and a design outdoor airflow greater than 3000 CFM. In all other cases, DCV is not modeled in the baseline.
b. DCV can be modeled for performance credit when it is not already required to be modeled per ASHRAE 90.1 2019 Appendix G. Minimum code-required ventilation rates must be used in the baseline model for systems in the proposed design claiming credit for using DCV.

Fan Systems

Proposed Design

Fan systems that provide outside air to the building must operate continuously whenever the building is occupied, and cycle on and off to maintain the setback temperature when the building is unoccupied, per 90.1 G3.1.2.4 and Table G3.1 #4. In unoccupied mode, outside air must not be provided unless required by applicable health and safety mandated minimum ventilation requirements.

Baseline Design

a. The system baseline fan power must be calculated according to Appendix G section G3.1.2.9 and represents the total fan power allowance including supply, return, and exhaust fans, central and zonal.
b. Baseline fan power allowance must be allocated to supply, return and exhaust in the same proportion as in the proposed design.
c. Baseline fan power allowance may be increased to account for air filtration (based on MERV rating) and sound attenuation when specified for the proposed design. Exhaust air energy recovery adjustment may be used only when energy recovery is modeled in the baseline. Fully ducted return adjustment may only be used when the proposed design is required by code or accreditation standards to be fully ducted is required by applicable code
d. The preferred method for modeling baseline fan power is by specifying Watt per CFM of air flow in the model, as this avoids the need to adjust fan power whenever flow rates change when evaluating ECMs. However, if a software tool does not allow inputting power per unit flow, the same purpose can be achieved by defining the total static pressure drop (TSP) and overall fan efficiency fraction (including motor, drive, and mechanical efficiencies). If TSP and/or overall fan efficiency are unknown, use equation 7-7 to convert from kW/cfm (power per unit flow).

$$Power_{kW/CFM} = \frac{TSP_{in.wg}}{8520 \times \eta_{overall}} \qquad \textit{(Equation 5)}$$

If overall fan efficiency fraction $\eta_{overall}$ is unknown, 0.55 default may be used. The accuracy of this estimate does not affect the results of the simulation, since adjusting the efficiency fraction when using $\mathrm{Power}kW/\mathrm{CFM} = \frac{\mathrm{TSP_{in.wg}}}{8520 \times \eta_{\mathrm{overall}}}$ (Equation 5 will cause an offsetting adjustment in the total static pressure.

***Example 10:* Fan Power and Cooling Efficiency**

Q. A 10,000 square foot office building has three thermal blocks, each served by a packaged rooftop unit with a gas furnace. The rooftop units have fully ducted return, MERV 13 filters, exhaust air energy recovery and sound attenuation sections. Each unit is identical and has a design supply flow of 4,500 CFM, an AHRI net cooling capacity 144,000 btu/h, and an EER of 11.5. Gross capacity at AHRI conditions listed by the manufacturer is 151,000 btu/h. Supply and return fan BHP at design conditions for each unit are 2.8 and 1.1 respectively. Flow rate across the return fan is 90% of supply flow. Each thermal block also includes a restroom with a 200 CFM continuously running exhaust fan with a 75W motor (~1/10 HP). What should be the baseline and proposed fan power and cooling efficiency?

A. The baseline will be modeled as follows:
According to Table G3.1.1-3, the baseline is System 3, Packaged Single Zone with Fossil Fuel Furnace.
Baseline thermal blocks are the same as in the Proposed Design.
Based on the sizing runs, the baseline systems have capacity of 160 kBtu/hr and the design flow rate of 4,850 CFM each.
The baseline system efficiency from ASHRAE 90.1 Table G3.5.1 for 135 kBtu/hr – 240 kBtu/hr capacity bracket is COPnfcooling=3.4.
To calculate baseline fan power, first determine the total baseline fan power allowance according to section G3.1.2.9. The specified units include MERV 13 filters, exhaust air energy recovery, fully ducted return and sound attenuation that each have fan power pressure drop adjustments available in 90.1 Table 6.5.3.1-2. The return is not required by code to be fully ducted, thus the associated pressure drop adjustment cannot be used for the baseline. Exhaust air energy recovery pressure drop adjustment also cannot be used because the baseline system is modeled without exhaust air energy recovery following G3.1.2.10. Only the MERV 13 adjustment (0.9) and sound attenuation adjustments (0.15) are used as follows:

$$A = (0.9 + 0.15) \times 4{,}850 \div 4{,}131 = 1.23$$

$$BHP = 0.00094 \times CFM + A = 0.00094 \times 4850 + 1.23 = 5.8 \text{ bhp}$$

Fan motor efficiency for the next available motor size in Table G3.9.1 is 89.5%. Based on this, the fan power is calculated as follows:

$$P_{FAN} = BHP \times 746 \div Fan\ Motor\ Efficiency = 5.8 \times 746 \div 0.895 = 3{,}872\ W$$

The final step in determining baseline fan power is to apportion the total system P_{FAN} to supply, return, and exhaust fans in the same proportion as in the Proposed Design. For this example, total proposed fan BHP for each system is 2.8 + 1.1 + 75 / 746 = 4 HP. Total baseline fan power = 5,207 W. Application ratios and their usage in calculating power per unit flow for this example are listed in the table below.

	% of Total Fan Power in Proposed Design	Total Baseline Fan Power W	Baseline Fan Power kW
Supply Fan	2.8 / 4 = 0.7	3,872	0.7 * 3,872 = 2.71
Return Fan	1.1 / 4 = 0.275		0.275 * 3,872 = 1.06
Bathroom Exhaust	(75 / 746) / 4 = 0.025		0.025 * 3,872 = 0.10

The baseline kW/CFM should either be entered directly into the modeling tool, or first converted into TSP and efficiency fraction inputs using

$$\text{Power}kW/\text{CFM} = \frac{\text{TSP}_{\text{in.wg}}}{8520 \times \eta_{\text{overall}}}$$

(Equation 5. There is no additional allowance for individual exhaust fan – the calculated baseline fan power allowance covers all applications.

Proposed Model: To extract proposed fan power, use equation 7-1. For BHP_{SUPPLY}, take the difference between gross and net cooling capacities and convert to HP using

$$\text{COP}ADJ = \frac{Q_{T,RATED} - BHP_{SUPPLY} * 2.545}{\frac{Q_{T,RATED}}{COP} - BHP_{SUPPLY} * 2.545}$$

(Equation 4.:

$$144 + \frac{151{,}000 - 144{,}000}{\ldots} * 2.545 \quad 151$$

Special Rules for Laboratory Exhaust Systems

The requirements of 90.1 Appendix G for modeling the baseline laboratory exhaust systems are summarized below.

- Following Addendum ab Section G3.1.1.2 (b), laboratory spaces in buildings having a total laboratory exhaust rate greater than 15,000 CFM must be modeled with baseline systems of type 5 or 7 serving all such spaces. The lab exhaust fan must modeled as constant horsepower (kilowatts) reflecting constant-volume stack discharge with outdoor air bypass.
- Following the exception to Section G3.1.3.13, the baseline systems serving laboratory spaces shall be modeled to reduce the exhaust and makeup air volume during unoccupied periods to the largest of 50% of zone peak air flow, the minimum outdoor air flow rate, or the air flow rate required to comply with applicable codes or accreditation standards. If project has a minimum flow rate above 50% due to the applicable codes and standards, and this higher rate is modeled in the baseline, the flow cannot be reduced below this required minimum the proposed design.

- Following Section G3.1.2.10 Exception 2, exhaust air energy recovery does not have to be modeled in the baseline unless it is specified for the proposed design.
- Following 90.1 2019 Addendum i, HVAC systems serving laboratory HVAC zones with a total laboratory exhaust volume greater than 15,000 cfm should not be modeled with exhaust air energy recovery. Prior to the addendum, a proposed laboratory design with variable flow exhaust and energy recovery would be required to model both heat recovery and variable exhaust in the baseline HVAC system, which misrepresents 90.1 2004 requirements

Chiller Performance Curves

Table G3.5.2 prescribes full load efficiency (FL) and part load efficiency (IPLV) for the baseline chillers depending on chiller type and capacity. Similarly, construction documents provide FL and IPLV of the specified equipment. Commonly used simulation tools allow entering chiller full load efficiency and performance curves that determine chiller operation at lower loads, but do not the IPLV input. Previously, performance curves corresponding to the prescribed baseline chiller IPLV were not provided in 90.1. As a result, modelers often used default curves that differed between simulation tools and did not reflect the intended performance of the baseline chillers. The issue was addressed by 90.1 2019 addendum bd which prescribed the performance curves that must be used for the baseline chillers. The addendum also requires that where the performance curves for the chillers specified in the proposed design are not available, the provided default performance curves are used based on the specified chiller type. The addendum also prescribes chiller minimum part-load ratio (ratio of load to available capacity at a given simulation time step) and minimum compressor unloading ratio (part-load ratio below which the chiller capacity cannot be reduced by unloading and chiller is false loaded) of 0.25. Chiller performance must be modeled as required in 90.1 2019 addendum bd.

Boiler Performance Curves

Condensing boiler performance is dependent on return water temperature and variations in load. In general, the efficiency of a condensing boiler increases as return water temperature and part load ratio decreases. Condensing boiler efficiency drops considerably when return water temperature is greater than 130°F.

Where baseline HVAC system types include boilers, boilers must be natural draft with efficiency determined based on Table G3.5.6. Number of boilers depends on the building area served by the hot water plant (Section G3.1.3.2). Boilers must be stages as required by load and modeled with 180°F supply and 130°F return water temperature (G3.1.3.3).

For projects with boiler system(s) in the proposed design, modeling parameters must reflect mechanical drawings. Design supply and return water temperatures must be explicitly entered into the simulation tool if the tool can automatically capture their impact on boiler efficiency through performance curves. If the tool is not capable of automatically adjusting efficiency based on entered loop temperatures (such as TRACE 700), efficiency input must be adjusted manually to reflect manufacturer's performance data for the boiler at actual operating conditions. Atmospheric boiler performance curves included in Annex must be modeled for the baseline design. For the proposed design, either the default performance curves included in Annex or the actual performance curves for the specified boilers should be used.

16. Water Heating

Baseline Design

a. The service hot-water system in the baseline building design is prescribed in Table G3.1.1-2 and is either gas or electric resistance storage central water heater. In mixed use buildings, baseline water heater type must be established separately for each occupancy.
b. Hot water demand in the Baseline Building Design must be typical for building occupancy type.
c. Table 1 provides typical hot water use for various types of buildings that should be used to establish baseline hot water energy use. 2019 ASHRAE Applications Handbook also provides hot water demand per fixture for various types of buildings which may be used to establish appropriate assumptions.

Proposed Design

a. Hot water heater type and efficiency must be modeled as specified.
b. How water demand may be lower than in the baseline if the following technologies are specified (Exceptions 1-3 to Table G3.1 #11 (g), Baseline Building Performance column):
    i. Measures that reduce the physical volume of service water required blow the maximum flow rates allowed by applicable code, such as low-flow shower heads and dishwashers.
    ii. Measures that reduce the required temperature of service mixed water, by increasing the temperature, or by increasing the temperature of the entering makeup water. Examples include alternative sanitizing technologies for dishwashing and heat recovery to entering makeup water.
    iii. Reducing the hot fraction of mixed water to achieve required operational temperature. Examples include shower or laundry heat recovery to incoming cold-water supply, reducing the hot-water fraction required to meet required mixed-water temperature.

In all cases, the supporting calculations justifying the modeled reduction in hot water demand must be included in submittal and are subject to AHJ approval.

Technologies demonstrating a reduction in hot water usage should be modeled as reduced hot water demand in the Proposed Design based on $\mathrm{HWD}PROP = \mathrm{HWD}_{\mathrm{BASE}}*(1\text{-R})$ (Equation 6.

$$HWD_{PROP} = HWD_{BASE} * (1 - R) \qquad \textit{(Equation 6)}$$

$$R = \sum(R_A * F_A) \qquad \textit{(Equation 7)}$$

where

HWD_{BASE}	baseline consumption [gal/day]
R	% reduction from baseline to proposed.
R_A	% reduction in hot water usage for a particular hot water application
F_A	hot water usage for the particular application as a fraction of total usage.

Table 2 shows R_A and F_A values for common building types and technologies. Values for other technologies must be documented in the modeling submittal. F_A values must reflect realistic run-time based on the number of fixtures specified for the project. See Example 8-1.

*Table 1 Sample Hot-Water Demands and Use for Various Types of Buildings[1] **

Type of Building	**Average Daily Usage**
Dormitories**	12.7 Gal/Student
Motels***	
20 units or less	20 Gal/Unit
20-100 units	14 Gal/Unit
100 units or more	10 Gal/Unit
Nursing Homes	18.4 Gal/Bed
Office Buildings	1.0 Gal/Person
Food Service Establishments	
Type A: Full Meal Restaurants and Cafeterias	2.4 Gal/Average meals/day
Type B: Drive-ins, Grills, Luncheonettes, Sandwich, and Snack Shops	0.7 Gal/Average meals/day
Apartments****	39 Gal/Apartment
Elementary schools	0.6 gal/student
Junior and senior high school	1.8 gal/student

*Data predates modern low-flow fixtures and appliances, and may be reduced by projects
**Average of men's and women's dormitories

***Categories changed to ranges to avoid the need for interpolation
****Average for different size apartment buildings

Table 2: F_A and R_A values for calculating reductions in hot water usage

Load Type	**F_A***	**R_A**	**Notes**
Low flow faucets	Residential: 10% Commercial: estimate	1-FR/MAF	FR = average flow rate of installed faucets (GPM); MAF= maximum allows flow rate based on [2021 International Plumbing Code Table 604.3] MAF=0.8 for private lavatories MAF=0.5 for public lavatories MAF=1.75 for other residential sinks (e.g. kitchen) MAF=3 for service sinks
Low flow showerheads	Residential: 54% Commercial: estimate	1-FR/2.5	FR = average flow rate of installed showerheads (GPM); 2.5 GPM = From Table 604.3
Energy Star Appliances	$\frac{APPL_{BASE}}{HWD_{BASE}}$	WS	$APPL_{BASE}$ = Baseline water usage for the appliance from the Energy Star Calculator, in the same units as HWD_{BASE}; WS = % Water Savings from the Energy Star Calculator

*sum of all F_A values must not exceed 100%

[1] Based on 2019 ASHRAE Applications Handbook, Section 51, Table 6

17. Special Cases

Core and Shell Projects

Systems and components that are not specified on construction documents must be modeled as minimally complying with ASHRAE Standard 90.1 2019 in the proposed design. The baseline design must be modeled following the same rules as when all components are fully specified.

Example 11 : Core and Shell Project

Q. Construction documents for a 180,000 ft^2 core and shell project include exterior envelope and central heating and cooling plants that are designed to serve the entire building. The air-side systems and lighting design is completed only for common spaces that will be shared by future tenants. Lighting, service water heating and air-side HVAC system design in tenant spaces is not included in the permit and will be completed by future tenants under a separate permit. How should the project be modeled?

A. The following systems and components would be modeled:

Proposed Design	Baseline Design
1. Thermal Blocks	
a. Thermal blocks in the common areas where air-side HVAC system design is completed will be based on specified HVAC zones and requirements in Table G3.1.#7, Thermal Blocks – HVAC Zones Designed. b. In tenant spaces where air-side HVAC systems are not yet designed, thermal blocks will be modeled using perimeter/core approach as described in Table G3.1 #8, Thermal Blocks – HVAC Zones Not Designed.	
2. Building Envelope	
Envelope will be modeled following the rules described in the Building Envelope section, Proposed Design subsection of these guidelines – i.e., thermal properties of opaque surfaces will be derated to account for thermal bridging, air leakage rate will be as measured, etc.	Envelope will be modeled following the rules described in the Building Envelope section, Baseline Design subsection of these guidelines – i.e., the same rules apply as for projects with the fully completed designs
3. Lighting in Common Spaces with Completed Lighting Design	
Lighting power and controls will be modeled as shown on design documents and as described in the Interior Lighting section, Proposed Design subsection of these guidelines.	Lighting power and controls will be modeled as described in the Interior Lighting section, Baseline Design subsection of these guidelines – i.e., using space-by-space method and otherwise following the rules for projects with the completed lighting designs.
4. **Lighting in Tenant Spaces with No Lighting Design**	
Lighting power and controls will be modeled as minimally compliant with the allowances in Table 9.5.1, Building Area Method (Table G3.1 #6 (c), Proposed Building Performance column.	Lighting power and controls will be modeled following Table G3.8, Performance Rating Method Lighting Power Densities Using the Building Area Method (90.1 2019 Addendum af). If use type of future tenant spaces is unknown, office occupancy must be assumed (Table G3.1#1 (c), Proposed Building Performance).
5. HVAC in Common Spaces with Completed HVAC Design	
HVAC systems and controls must be modeled as shown on construction documents, including central heating and cooling plants and air-side systems, and as described in the Heating, Ventilation and Air Conditioning Systems section, Proposed Design subsection of these guidelines	Baseline System 7 is modeled following the same requirements as for projects with completed HVAC design and as described in the Heating, Ventilation and Air Conditioning Systems section, Baseline Design subsection of these guidelines
6. **HVAC in Tenant Spaces with No HVAC Design Other than Central Heating and Cooling Plants**	
Systems in tenant spaces will be modeled with the same configuration as in the baseline (System 7, one per floor) but with efficiency and controls minimally compliant with the applicable prescriptive requirements of 90.1 2019.	Baseline System 7 is modeled following the same requirements as for projects with completed HVAC design and as described in the Heating, Ventilation and Air Conditioning Systems section, Baseline Design subsection of these guidelines
7. Service Water Heating System	
System type and hot water demand should be modeled the same as in the baseline. SWH system efficiency should be modeled to minimally comply with the requirements in 90.1 Section 7.	Baseline is modeled the same as for projects with completed Service Water Heating system design and as described in the Water Heating section, Baseline Design subsection of these guidelines

Tenant Space Fit Out Zones

Tenants space fit out zones include portions of a building in which only the envelope is completed, and the mechanical, lighting, and other interior systems are either incomplete or partially complete at the time of building permitting. When such areas are leased out for the first time and design documents for mechanical, lighting and other systems are submitted for building permit, the project must meet the same requirements as a new construction projects (C401.2). The proposed design models for tenant space fit out zones must reflect systems, components and controls shown on the construction documents for the tenant zone and previously designed systems included in the core-and-shell project housing the tenant area. The baseline shall be modeled the same as for new construction projects.

Example 12: Tenant Space Fit-out Zone Project

Q. *A 30,000 ft² tenant space in the building described in **Error! Reference source not found.** is leased to a retail tenant. The tenant designs lighting system and air-side HVAC and uses Relative Performance approach to document compliance with the MA Stretch Code. How should the project be modeled?*

A. Model may include the full building or just the tenant space, as allowed in Table G3.1 #2, Additions and Alterations, Proposed Design column. If only the tenant portion of the building is modeled, the modeled capacity of the central heating and cooling plat should be prorated based on the modeled conditioned floor area. If the entire building is modeled, all areas except for the tenant space subject to the current permit should be modeled as described in **Error! Reference source not found.**. The tenant area should be modeled as described in the following table.

Proposed Design	**Baseline Design**
1. Thermal Blocks	
Thermal blocks will be based on specified HVAC zones and requirements in Table G3.1.#7, Thermal Blocks – HVAC Zones Designed.	
2. Building Envelope	
Envelope will be modeled as described in **Error! Reference source not found.** reflecting core-and-shell envelope design.	Envelope will be modeled as described in **Error! Reference source not found.**, Baseline column.
3. Lighting System	
Lighting power and controls will be modeled as shown on design documents and as described in the Interior Lighting section, Proposed Design subsection of these guidelines.	Lighting power and controls will be modeled as described in the Interior Lighting section, Baseline Design subsection of these guidelines – i.e., using space-by-space method.
4. HVAC System	
HVAC systems and controls must be modeled as shown on construction documents, including central heating and cooling plants and air-side systems, and as described in the Heating, Ventilation and Air Conditioning Systems section, Proposed Design subsection of these guidelines	Baseline System 7 is modeled following the same requirements as for projects with completed HVAC design and as described in the Heating, Ventilation and Air Conditioning Systems section, Baseline Design subsection of these guidelines
5. Service Water Heating System	
System type efficiency and hot water demand should be modeled as specified and as described in the Water Heating section, Proposed Design subsection of these guidelines	Baseline is modeled as described in the Water Heating section, Baseline Design subsection of these guidelines

Annex 1: Reference Site EUI by End Use

These tables are provided for reference and are based on the energy consumption by end use of the PNNL prototype models[2] in Climate Zone 5A minimally compliant with 90.1 2004 (analogous to 90.1 Appendix G baseline) and 90.1 2019 (analogous but less efficient than design minimally compliant with the MA Stretch Code.

Table 1.1: Site EUI [kBtu/SF] of Designs Minimally Compliant with ASHRAE 90.1 2004 in CZ5A

Building Type	Interior Lighting	Exterior Lighting	SHW	Heating	Cooling	Fans	Pumps	Refrigeration	Elevators	Transformers	Process & Plug	Total
Highrise Apt	3.8	2.4	13.8	30.2	1.9	3.0	0.7	0.0	1.8	0.4	11.0	69.0
Midrise Apt	3.9	2.0	11.9	22.7	2.3	2.5	0.0	0.0	3.6	0.0	10.9	59.9
Hospital	16.4	1.0	5.3	64.5	12.4	17.2	4.2	1.0	10.0	0.7	38.6	171.3
Large Hotel	11.3	2.4	17.9	32.5	9.6	13.8	1.4	0.8	7.6	0.4	27.2	125.0
Small Hotel	10.9	2.1	14.3	15.7	5.9	6.8	0.0	0.0	5.7	0.0	16.8	78.2
Large Office	9.8	1.9	1.2	16.4	8.7	4.5	1.3	0.0	3.7	0.3	28.9	76.7
Medium Office	9.8	4.0	1.6	16.9	3.9	1.7	0.0	0.0	3.1	0.6	11.3	53.0
Small Office	12.2	4.3	3.1	9.5	2.9	4.0	0.0	0.0	0.0	0.0	9.1	45.0
Outpatient Healthcare	14.2	5.3	5.9	50.3	14.8	12.7	0.1	0.0	15.1	0.0	32.2	150.6
Standalone Retail	18.9	4.4	3.8	32.9	6.3	18.0	0.0	0.0	0.0	0.0	7.5	91.8
Strip Mall	26.6	7.0	3.0	45.5	5.2	10.5	0.0	0.0	0.0	0.0	5.4	103.2
Primary School	15.5	1.1	2.0	26.6	6.1	9.9	0.1	1.7	0.0	0.6	20.6	84.3
Secondary School	14.8	1.0	3.1	15.7	7.0	11.0	0.5	0.9	0.3	0.4	13.6	68.3
Warehouse	8.8	2.2	0.5	26.7	0.3	1.1	0.0	0.0	0.0	0.0	2.5	42.2

[2] https://www.energycodes.gov/sites/default/files/documents/2019EndUseTables.zip

Table 1.2: Site EUI [kBtu/SF] of Designs Minimally Compliant with ASHRAE 90.1 2019 in CZ5A

Building Type	Interior Lighting	Exterior Lighting	SHW	Heating	Cooling	Fans	Pumps	Refrigeration	Elevators	Transformers	Process & Plug	Total
Highrise Apt	2.3	1.3	13.8	11.1	1.6	2.2	0.4	0.0	1.8	0.2	10.9	45.5
Midrise Apt	2.3	0.7	11.9	6.6	1.7	1.9	0.0	0.0	3.5	0.0	10.8	39.6
Hospital	12.9	0.6	5.2	18.9	8.0	12.2	1.1	0.5	9.8	0.3	37.9	107.4
Large Hotel	4.1	1.4	17.9	4.6	4.7	5.9	0.4	0.5	7.4	0.2	26.6	73.5
Small Hotel	4.0	1.0	14.2	5.8	4.1	3.4	0.0	0.0	5.5	0.0	16.0	54.0
Large Office	4.9	0.7	1.2	4.0	5.2	3.9	0.5	0.0	3.6	0.1	27.9	51.9
Medium Office	4.4	0.8	1.6	7.2	2.5	1.1	0.0	0.0	2.9	0.2	10.3	31.1
Small Office	4.4	1.0	3.1	5.2	1.6	2.7	0.0	0.0	0.0	0.0	8.3	26.2
Outpatient Healthcare	8.8	1.3	5.3	24.6	10.1	7.8	0.1	0.0	14.8	0.0	31.9	104.7
Standalone Retail	9.2	1.5	3.7	23.8	3.0	5.7	0.0	0.0	0.0	0.0	7.5	54.3
Strip Mall	17.0	2.5	2.7	28.4	2.4	5.2	0.0	0.0	0.0	0.0	5.4	63.6
Primary School	3.7	0.3	2.0	7.5	2.9	4.5	0.1	0.9	0.0	0.2	18.7	40.8
Secondary School	3.7	0.3	3.1	5.2	3.9	4.6	0.1	0.5	0.3	0.1	12.7	34.6
Warehouse	3.0	1.0	0.5	18.1	0.1	0.7	0.0	0.0	0.0	0.0	2.5	26.0

Annex 2: Boiler Performance Curve

The fuel consumption at part-load conditions, derived by applying an adjustment factor to the fuel consumption at design conditions, shall be calculated using the following equation.

$Fuel_{parload}$=$Fuel_{design}$ * FHeatPLC (Eq B1)

FHeatPLC=a+b*$Q_{partload}$/Q_{design}+c*$Q_{partload}$/Q_{design})^2 (Eq B2)

FHeatPLC=a+b*$Q_{partload}$/Q_{design}+c*($Q_{partload}$/Q_{design})^2+d * T_{rwt}+ e * T_{rwt}^2 + f * T_{rwt} * $Q_{partload}$/Q_{design} (Eq B3)

Where:
Fuelpartload = fuel consumption at part-load conditions, in Btu/h for DOE2, W for E+
Fueldesign = fuel consumption at design conditions, in Btu/h for DOE2, W for E+, and
FHeatPLC = fuel heating part-load efficiency curve determined using equation and coefficients in Table B1.
Qpartload = *boiler* capacity at part-load conditions, in Btu/h for DOE2, W for E+
Qdesign = *boiler* capacity at design conditions, in Btu/h for DOE2, W for E+
Trwt = return water temperature in F for DOE2; C for E+
a, b, c, d, e, f = coefficients from Table B1

Table B1: Boiler Performance Equation Form and Coefficients

	Boiler Type	Equation	a	b	c	d	e	f
DOE 2	Non-condensing	Eq B2	0.082597	0.996764	-0.079361			
	Condensing	Eq B2	-0.09438953	0.90322417	0.01546033	0.00159778	-0.00000645	0.00111432
E+	Non-condensing	Eq B3	0.626700	0.674000	-0.307300			
	Condensing	Eq B3	1.193810	-0.110825	0.039514	-0.006371	0.000038	0.000830

The coefficients in rows 1,3,4 of Table B1 are from California Alternative Calculation Manual (ACM) Appendix 5.7 Equipment performance curves. The coefficients in row 2 of Table B1 are from the eQUEST technical documentation.