2023 TECHNICAL GUIDANCE

MASSACHUSETTS STRETCH ENERGY CODE

Attachment B

ASHRAE Appendix G: Relative Performance Simulation Guidelines

DOER
Massachusetts Department of Energy Resources

A reference and instructional guide for
Massachusetts Energy Stretch and Specialized Codes

#20230830

Attachment B
ASHRAE Appendix G: Relative Performance Simulation Guidelines

Contents

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:

- 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.
- 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.
- Explain PRM rules that are often misapplied or misinterpreted.
- Provide examples to illustrate 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.

1. 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.

2. 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 ASHRAE 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 exterior 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:
  - Projects where fenestration area across different exposures in the proposed design differs by less than 5%
  - 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.

Using This Guide

Look for these color-coded icons and boxes with helpful context, additional information and calculation support.

Important Information

Additional Resources

Example Calculation

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 rejection, 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/Open Studio
- 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). In addition, the submittal package must include signatures of the licensed professional(s) as required for all other compliance options.

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 following ASHRAE 90.1 2022 Addendum a, as described below. The method eliminates penalty that has previously existed for such projects. However, district systems still cannot contribute toward compliance with C407.2 irrespective of their efficiency.

Sections G3.1.1.1, GG3.1.1.2 and G3.1.1.3 shall be eliminated in their entirety. The HVAC systems in the baseline design for projects served by the district systems shall be modeled the same as for projects with on-site systems.

The proposed designs utilizing purchased thermal energy must be modeled with on-site systems providing hot water, steam, or chilled water as follows:

a. Systems in the proposed design that use purchased hot water or purchased steam for space heating shall be modeled with forced draft boiler(s) that comply with but do not exceed the mandatory and prescriptive requirements of Section 6. The number of boilers and boiler controls shall meet the requirements of Sections G3.2.3.2 through G3.2.3.6f.

b. Systems in the proposed design that use purchased chilled water shall be modeled with the type and number of chillers determined by following Sections G3.2.3.7 through G3.2.3.11 using equipment efficiency and controls that comply with but not exceed the mandatory and prescriptive requirements of Section 6.

c. Systems in the proposed design that use purchased hot water or purchased steam for service water heating shall be modeled with the same service water heating system type as in the baseline design and shall comply with but not exceed the mandatory and prescriptive requirements of Section 7.

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).

9. Simulated Schedules

Modeled occupancy, HVAC, and other schedules are not prescribed. The values must 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 must 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 must 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.

Example Calculation

Scenario: Combined Heat and Power Systems

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?

Solution

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).

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 either explicitly modeled or excluded from the model. Whichever approach is selected for each such space, it must be applied to that space in 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.

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, including but not limited to through-wall AC sleeves and PTAC/PTHP but excluding ventilation louvers, 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.

Example Calculation

Scenario: Mechanically Ventilated Parking Garage

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?

Solution

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.

f. The same infiltration modeling algorithm and schedule must be used for baseline and proposed design models.

g. 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 unoccupied 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 in the baseline design must be modeled as prescribed in Table G3.1 #5 based on occupancy type (residential/nonresidential) and space conditioning category (conditioned/semi-heated/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 in the baseline designs must be determined as follows:

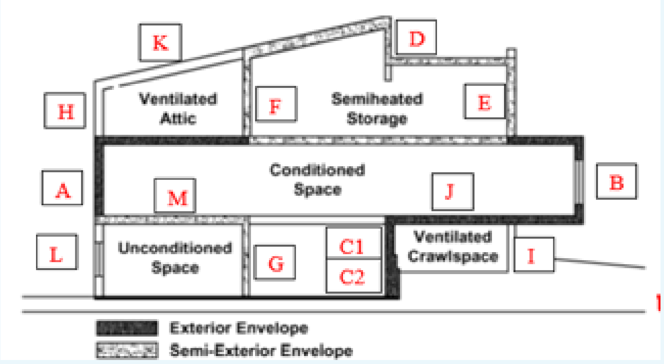
- For building types included in Table G3.1.1-1, based on the percentage of the above-grade wall area specified in the table. For building types not shown in Table G3.1.1-1, vertical fenestration areas must equal that in the proposed design or 40% of gross above-grade wall area, whichever is smaller. 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 Calculation

Scenario: Calculating Vertical Fenestration Area

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



Solution

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

d. The modeled air leakage rate in the baseline design must be based on 1.0 cfm/ft² of the building thermal envelope at 0.3" water gauge (75 Pa). The surface area must include the above- and below-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 except for emergency lighting that is automatically turned off during normal building operation.

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).

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.

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

Example Calculation

Scenario: Maximum Rated Fixture Wattage

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?

Solution

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.

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.

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:

- Fo*r luminaire* that meet requirements of C406.4 (enhanced digital lighting controls) the *occupancy sensor* reduction factor may be increased by 7.5%.

Example Calculation

Scenario: Lighting Power from Receptacles

Specified lighting in a 400ft² 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?

Solution

The specified lighting is (18+22)/400=0.1 W/ft² 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/ft² must be modeled in the proposed design based on the guest room allowance in 90.1 Table 9.6.1.

Scenario: Temporary Lighting

Core and shell project includes a 3,000ft² 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?

Solution

The baseline must be modeled with 1.50 W/ft² 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/ft² (Table 9.5.1). The specified temporary lighting is 1,000/3,000=0.33 W/ft² which is lower than this allowance. The retail area must be modeled with 0.84 W/ft² lighting power density in the proposed design.

- 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.
  - 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*.
  - The main control may have two controls, one for permanently wired lighting and one for switched receptacles.
  - 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 >5000ft² 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. The majority of 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.

- Zone 4: High-activity commercial districts in major metropolitan areas. Using Zone 4 allowances requires approval of 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 facades, automated teller machines, night depositories, and other applications listed in Table 9.4.2-2, Non-tradable Surfaces. 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 50%, 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 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.

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,

Example Calculation

Scenario: Estimating Exterior Lighting Runtime

Project involves a retail store with a parking lot. The specified exterior lighting fixtures have the total rated power of 1,000W and mounting height of 20'. What hours of operation should be modeled for these fixtures?

Solution

Based on Section 9.4.1.4(a), lighting must be turned off when sufficient lighting is available, which is typically assumed to be 12 hours per day on average. During the remaining 12 hours, lighting controls required by Section 9.4.1.4 (d) must automatically reduce the power of each luminaire by a minimum of 50% when no activity has been detected in the area illuminated by the controlled luminaires for a time of no longer than 15 minutes. To reflect these mandatory controls that must be specified in the proposed design, modeler may assume that parking lot fixtures run at 50% of the rated power for 10 hours and 100% of the rated power for 2 hours. These assumptions are equivalent to 7 full load hours.

Important Information

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-tradable surfaces based on the full allowance in 90.1 Table G3.6. The baseline non-tradable lighting must be modeled the same as in the proposed design.

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.

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

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):

Equation 1:

$$COP_{nfcooling} = –0.0076 \times SEER2 + 0.3796 \times SEER$$

Equation 2:

$$COP_{nfheating} = –0.0296 \times HSPF2 + 0.7134 \times HSPF$$

Where:

$COP_{nfcooling}$ = Coefficient of Performance (COP) cooling efficiency excluding AHRI rating fan power

c. $COP_{nfheating}$ = 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:

Equation 3:

$$EER_{ADJ} = \frac{Q_{T,RATED} + BHP_{SUPPLY} * 2.545}{\frac{Q_{T,RATED}}{EER} - BHP_{SUPPLY} * .7457}$$

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:

Equation 4:

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

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.

Example Calculation

Scenario: Baseline System Type for a Mixed-Use Building

New construction project involves a 5 story 100,000ft^2 building with a retail store on the first floor (25,000ft^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?

Solution: 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 residential zones on floors 2-5 shall be modeled with baseline System 1 – PTAC following Table G3.1.1-3 and the residential associated spaces on these floors shall be modeled with System 3 – PSZ- AC following 9.1-2019 Addendum ab G3.1.1.2 (f).

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.

Add the combined area of any remaining nonresidential building area types with less than 20,000ft² 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 20,000ft² 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.

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, G3.5.4, 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.

c. Following Section G3.1.2.5 Exception (4), baseline systems serving only laboratory spaces that are prohibited from recirculating return air by code or accreditation standards must by modeled with 100% OA in the baseline. This may result in higher ventilation rates in the baseline compared to the proposed design.

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 1,000ft^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).

Equation 5:

$$Power_{kW/CFM} = \frac{TSP_{in.wg}}{8520 \times \eta_{overall}}$$

If overall fan efficiency fraction 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 Equation 5 will cause an offsetting adjustment in the total static pressure.

Example Calculation

Scenario: Fan Power and Cooling Efficiency

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?

Solution: 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:

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

$$BHP = 0.00094 \times \text{CFM} + \text{A} = 0.00094 \times 4{,}850 + 1.23 = 5.8 \text{ bhp}$$

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:

$$P_{FAN} = BHP \times 746 \div \textit{Fan Motor Efficiency} = 5.8 \times 746 \div 0.895 = 4{,}834\ W$$

Continued on next page

The final step in determining baseline fan power is to apportion the total system PFAN 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 = 4,824 W. Application ratios and their usage in calculating power per unit flow for this example are listed in the table below.

Equipment	% of Total Fan Power in Proposed Design	Total Baseline Fan Power W	Baseline Fan Power kW
Supply Fan	2.8 / 4 = 0.7	4,824	0.7 * 4,824 = 3.38
Return Fan	1.1 / 4 = 0.275		0.275 * 4,824= 1.33
Bathroom Exhaust	(75 / 746) / 4 = 0.025		0.025 * 4,824 = 0.121

The baseline kW/CFM should either be entered directly into the modeling tool, or first converted into TSP and efficiency fraction inputs using *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 BHPSUPPLY, take the difference between gross and net cooling capacities and convert to HP using *Equation 4*:

$$EER_{ADJ} = \frac{144 + \frac{151{,}000 - 144{,}000}{2{,}545} * 2.545}{\frac{144}{11.5} - \frac{151{,}000 - 144{,}000}{2{,}545} * .7457} = \frac{151}{10.5} = 14.4$$

Proposed fan power should be modeled based on design documents, including all fan applications.

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 the 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, the 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 B must be modeled for the baseline design. For the proposed design, either the default performance curves included in Annex B or the actual performance curves for the specified boilers should be used.

17. **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. Table 4 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):

1. 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.
2. 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.
3. 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 *Equation 6*.

Equation 6:

$$HWD_{PROP} = HWD_{BASE} * (1 - R)$$

Equation 7:

$$R = \sum(R_A * F_A)$$

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

The table on page 21 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 *Common Mistakes When Calculationg Baseline Exterior Lighting*, on page 11.

Sample Hot-Water Demands and Use for Various Types of Buildings[1] *	
Type of Building	**Average Daily Usage**
Dormitories**	12.7 Gal/Student
Motels***	See note
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	See note
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

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

FA and RA 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 shower heads	Residential: 54% Commercial: estimate	1-FR/2.5	FR = average flow rate of installed shower heads (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 FA values must not exceed 100%

18. **Special Cases**

Core and Shell Projects

Core and shell projects include designs where 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.

a. Proposed Design shall be modeled as follows

1. 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.
2. Modeling proposed design based on efficiency of systems required by lease is not permitted.
3. When the shared heating, cooling and service water heating systems are specified but the terminal systems in the tenant spaces are not, the tenant systems of the appropriate type that minimally comply with ASHRAE Standard 90.1 2019 shall be modeled.
4. When proposed design includes plumbing fixtures but not the service water heater, the proposed design model must reflect requirements in Table G3.1, row #11 Service Water Heating Systems as follows:
   i. The proposed water heater shall be modeled as described in the Proposed Building Performance column item (c)
   ii. Savings from reduced service water heating load are permitted to be modeled as allowed in the Baseline Building Performance column Exceptions (1) and (2)

b. The baseline design must be modeled following the same rules as when all components are fully specified.

Example Calculation

Scenario: **Terminal Systems in Tenant Spaces**

When a core and shell project design includes water source heat pump plant equipment including boiler, cooling tower and heat rejection loop sized to serve the entire building, how should the proposed design be modeled?

Solution:

The proposed design must be modeled with as-designed plant equipment in conjunction with water source heat pump terminal units minimally compliant with requirements in 90.1 Section 6 including system efficiency, controls and anciliary features such as economizer and exhaust air energy recovery.

Example Calculation

Scenario: Core and Shell Project

Construction documents for a 180,000ft^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?

Solution: 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.

Continued on next page

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

When core and shell 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 project (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 Calculation

Scenario: Tenant Space Fit-out Zone Project

A 30,000ft^2 tenant space in the building described in Example 11 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?

Solution:

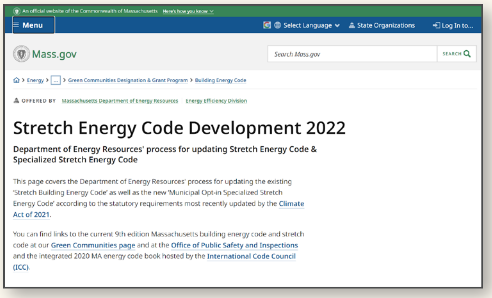
Model may include the full building or just the tenant space, as allowed in Table G3.1 #2, Additions and Alterations, Proposed Design column. If only the tenant portion of the building is modeled, the modeled capacity of the central heating and cooling plat should be prorated based on the modeled conditioned 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 Example 11. 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 Example 11 reflecting core-and-shell envelope design.	Envelope will be modeled as described in Example 11, Baseline column.
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.
4. Lighting in Tenant Spaces with No Lighting 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.
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.

Additional Resources

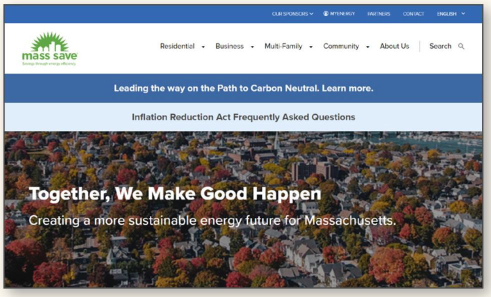
Still have questions?

Many resources are available to answer questions and assist with demonstrate compliance.



Visit the **Department of Energy Resources (DOER)** website for additional information about code development.

https://www.mass.gov/info-details/stretch-energy-code-development-2022



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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[1] 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 Apartment	3.8	2.4	13.8	30.2	1.9	3	0.7	0	1.8	0.4	11	69
Midrise Apartment	3.9	2	11.9	22.7	2.3	2.5	0	0	3.6	0	10.9	59.9
Hospital	16.4	1	5.3	64.5	12.4	17.2	4.2	1	10	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
Small Hotel	10.9	2.1	14.3	15.7	5.9	6.8	0	0	5.7	0	16.8	78.2
Large Office	9.8	1.9	1.2	16.4	8.7	4.5	1.3	0	3.7	0.3	28.9	76.7
Medium Office	9.8	4	1.6	16.9	3.9	1.7	0	0	3.1	0.6	11.3	53
Small Office	12.2	4.3	3.1	9.5	2.9	4	0	0	0	0	9.1	45
Outpatient Healthcare	14.2	5.3	5.9	50.3	14.8	12.7	0.1	0	15.1	0	32.2	150.6
Standalone Retail	18.9	4.4	3.8	32.9	6.3	18	0	0	0	0	7.5	91.8
Strip Mall	26.6	7	3	45.5	5.2	10.5	0	0	0	0	5.4	103.2
Primary School	15.5	1.1	2	26.6	6.1	9.9	0.1	1.7	0	0.6	20.6	84.3
Secondary School	14.8	1	3.1	15.7	7	11	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	2.5	42.2

1 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 Apartment	2.3	1.3	13.8	11.1	1.6	2.2	0.4	0	1.8	0.2	10.9	45.5
Midrise Apartment	2.3	0.7	11.9	6.6	1.7	1.9	0	0	3.5	0	10.8	39.6
Hospital	12.9	0.6	5.2	18.9	8	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	1	14.2	5.8	4.1	3.4	0	0	5.5	0	16	54
Large Office	4.9	0.7	1.2	4	5.2	3.9	0.5	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	2.9	0.2	10.3	31.1
Small Office	4.4	1	3.1	5.2	1.6	2.7	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	14.8	0	31.9	104.7
Standalone Retail	9.2	1.5	3.7	23.8	3	5.7	0	0	0	0	7.5	54.3
Strip Mall	17	2.5	2.7	28.4	2.4	5.2	0	0	0	0	5.4	63.6
Primary School	3.7	0.3	2	7.5	2.9	4.5	0.1	0.9	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	1	0.5	18.1	0.1	0.7	0	0	0	0	2.5	26

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.

Equation B1 $Fuel_{partload}=Fuel_{design} * FHeatPLC$

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

Equation B3 $FHeatPLC=a+b*Qp_{artload}/Q_{design}+c*(Q_{partload}/Q_{design})2+d * T_{rwt}+ e * T_{rw}{}^{t2} + f * T_{rwt} * Q_{partload}/Q_{design}$

Where:

$Fue_{lpartload}$ = fuel consumption at part-load conditions, in Btu/h for DOE2, W for E+

$Fuel_{design}$ = 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.

$Q_{partload}$ = boiler capacity at part-load conditions, in Btu/h for DOE2, W for E+

Q_{design} = boiler capacity at design conditions, in Btu/h for DOE2, W for E+

T_{rwt} = 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
DOE2	Non-condensing	Eq B2	0.083	0.997	-0.079			
	Condensing	Eq B2	-0.094	0.903	0.015	0.002	-0.000	0.001
E+	Non-condensing	Eq B3	0.627	0.674	-0.307			
	Condensing	Eq B3	1.194	-0.111	0.040	-0.006	0.000	0.001

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.

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