ENERGY STAR®

MULTIFAMILY NEW CONSTRUCTION PROGRAM

Simulation Guidelines-Appendix G 90.1-2016

Version 1, Revision 021

October 202019

Contents

1 Definitions

***ASHRAE 90.1-2016 (ASHRAE 90.1, 90.1)*:** energy standard for buildings, except low-rise residential buildings. Minimum requirements for the energy-efficient design of multifamily buildings over three stories above grade are included within this standard.

***ASHRAE 90.1-2016 Appendix G (Appendix G)*:** This appendix offers an alternative path for minimum standard compliance, and allows quantifying performance of projects that exceed the requirements of the standard.

***ASHRAE Path Calculator*:** set of spreadsheet calculators provided by the Program to assist energy modelers in generating certain specific data inputs needed to complete the energy model for the *Baseline Building Design* and *Proposed Design* as referenced in this document, as well as summarize modeling results. "ASHRAE Path Calculator_AppG2016" must be used in conjunction with these Simulation Guidelines, using the version required for the project.

***As-Built*:** conditions observed and measured in the completed building. The *As-Built* energy model must represent the actual observed and measured conditions in the constructed building, except where directed otherwise in this document.

***Baseline Building Design (baseline design, baseline)*:** a computer representation of a hypothetical design based on the Proposed Design. This representation is used as the basis for calculating the baseline building performance for rating above-standard design or when using the performance rating method as an alternative path for minimum standard compliance.

Baseline Building Performance: the annual energy use of the *Baseline Building Design*, expressed in the units of energy cost or alternate units if EPA guidance approves them for use.

Common Space: any space~~s~~ within a building that serves a function in support of the residential part of the building that is not part of a *dwelling* or *sleeping* *unit*. This includes spaces used by residents, such as corridors, stairs, lobbies, laundry rooms, exercise rooms, residential recreation rooms, and dining halls, as well as offices and other spaces used by building management, administration or maintenance in support of the residents. ~~parking used exclusively by residents, building staff, and their guests. This also includes offices used by building management, administration or maintenance and all special use areas located in the building to serve and support the residents such as day-care facilities, gyms, dining halls, etc.~~

***Design Team*:** group of professionals responsible for the final design of a building including, but not limited to: the developer, the general contractor, the architect, and design engineers.

***Dwelling Unit*:** a single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.

Dwelling Unit Mechanical Ventilation: A mechanical exhaust system, supply system, or combination thereof that provides each *dwelling unit* with outdoor air each hour at no less than the rate specified in Table 4.1a of ASHRAE 62.2-2010 or 2013, or equivalently, Equation 4.1a of ASHRAE 62.2-2010 or 2013, based on the floor area of the *dwelling unit* and number of bedrooms. Projects with specified ventilation rates in excess of the minimum required by local code or in

ASHRAE 62.2-2013 are considered over-ventilated and are subject to over-ventilation penalty as described in Section 6.5.12 of this document.

Energy Neutral**:** systems and components in the *Proposed Design* that are modeled to avoid a direct penalty or credit in the *Performance Rating Calculations*.

a) Energy neutral *Unregulated* systems and components must be modeled the same in the *baseline* and *proposed design*.
b) Energy neutral *Regulated* systems and components must be modeled as follows:

   Baseline must be modeled based on the applicable requirements of *Appendix G*. If not prescribed in the Appendix G, the baseline must reflect requirements in Section 5 to 10 of the *reference edition of 90.1*.

   Proposed Design must be modeled as meeting applicable requirements of *the reference edition of 90.1*.

In-Unit**:** term used to describe features in the building that are located within the *dwelling unit*s. For example, "in-unit lighting" is used to reference lighting located within the apartments.

Local Mechanical Exhaust: An intermittent or continuously operating exhaust fan that removes air from a conditioned space, such as the *dwelling unit*'s bathrooms and kitchen, and discharges to the outside. A bathroom is any room containing a bathtub, a shower, a spa, or similar source of moisture. A kitchen is any space containing cooking appliances.

Nonresidential**:** spaces in mixed-use buildings other than *residential*, ~~or~~ *common space*, or residential parking garages, such as commercial retail or office spaces that do not serve and support the residents. Parking garages or lots where the cost of the energy use of the parking garage or lot is not the responsibility of the Builder/Developer, Building Owner or Property Manager, are considered nonresidential.

Performance Rating**:** percent reduction in the *baseline building performance* compared to the *proposed building performance* or *as-built* performance across all end-uses, normalized to represent improvement relative to the *reference edition of 90.1*.

Performance Target**:** minimum *Performance Rating* required to earn the ENERGY STAR. The Performance Target depends on the state commercial code. Performance Target options are listed in the National Program Requirements and on the ENERGY STAR website. Energy savings associated with on-site power generation, including cogeneration, photovoltaics, or wind turbines, may not contribute to meeting the *Performance Target*, but may be used to exceed it.

Proposed Building Performance**:** the annual energy use of the *Proposed Design,* expressed in the units of energy cost or alternate units if EPA guidance approves them for use.

Proposed Design**:** a computer representation of the actual proposed building design or portion thereof used as the basis for calculating the design energy consumption.

Reference edition of 90.1: the version of ASHRAE Standard 90.1 that is used as the basis of the *Performance Rating*. For example, as of May 2020 ~~October 2016~~, New York energy code is based on the ASHRAE Standard 90.1-20136. Thus, ASHRAE Standard 90.1-20163 is the *reference edition of 90.1* for projects in New York that are governed by this code, and these projects must achieve the Performance Rating of 15% or higher over 90.1-20136 to meet the ENERGY STAR MFHR MFNC *performance target*.

Regulated Energy Use: energy used by building systems and components with requirements prescribed in ASHRAE 90.1 Sections 5 through 10. This includes energy used for interior lighting including lighting inside dwelling units, exterior lighting, Service Hot Water (SHW) heating, space heating, humidification, dehumidification, mechanical cooling, heat rejection, cooling towers, HVAC supply, return and exhaust fans, heat recovery fans and wheel energy, hydronic pumping including SHW recirculation and booster pumps, elevators, in-building transformers, and other building systems, components, and processes with requirements prescribed in Sections 5 through 10.

Residential: spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, *dwelling unit*s or *sleeping units*. This may include skilled nursing or assisted living units, when present in a building eligible for certification.

Residential-associated: see *common space*

Sleeping Units: A room or space in which people sleep, which can also include permanent provisions for living, eating, and either sanitation or kitchen facilities but not bothdoes not meet the definition of *dwelling unit*. Such rooms and spaces that are also part of a *dwelling unit* are not *sleeping units*. For the purpose of these Simulation Guidelines, model *sleeping units* in the same manner as *dwelling units*, unless otherwise specified, such as *local mechanical exhaust* requirements, which may not be applicable.

Ventilation: the process of supplying outdoor air to or removing outdoor air from a space by mechanical means.

Unregulated Energy Use: energy used by building systems and components that is not *regulated energy use*, such as energy used by kitchen and laundry appliances, and miscellaneous consumer electronics.

2 Purpose and Scope

These Simulation Guidelines (SG) contain the methodology for calculating a *Performance Rating* for multifamily buildings participating in EPA's ENERGY STAR Multifamily New Construction Program ("Program") and following the Performance Rating Method of *ASHRAE 90.1-2016 Appendix G.* This Performance Rating Method is required in states that have adopted a commercial code equivalent to or more efficient than 2018 IECC, or for buildings selecting a Performance Target of 15% better than ASHRAE 90.1-2013. It is optional for all other buildings. These SG must be used as a supplement to *ASHRAE 90.1-2016 Appendix G*. Buildings following the Performance Rating Method of ASHRAE 90.1-2007 Appendix G or ASHRAE 90.1-2010 Appendix G must instead use the "ENERGY STAR MFNC Simulation Guidelines".

The *ASHRAE 90.1* standard applies to a wide range of building types, and thus does not address certain characteristics commonly found in multifamily buildings with sufficient specificity to ensure that energy modeling results are consistent from one energy modeler to the next. While the scope of the *ASHRAE 90.1* standard does not include low-rise multifamily buildings, low-rise residential buildings following the ASHRAE Path of the ENERGY STAR Multifamily New Construction program are permitted to follow the modeling protocols within *Appendix G* for purposes of demonstrating compliance with their Performance Target for ENERGY STAR certification. These projects must follow these Simulation Guidelines, including the noted modifications of the *Appendix G* protocols for low-rise buildings. Exception: Townhouses are not permitted to use the ASHRAE Path.

This document is designed to meet the following objectives:

a. Ensure a consistent simulation methodology from building to building and from energy modeler to energy modeler.
b. Ensure a consistent approach to simulating components that are not included in *Appendix G*, or included without the level of detail needed to support the simulation process.
c. Provide consistent interpretation for the "grey areas" in the *Appendix G*
d. Re-iterate and clarify the areas where simulation mistakes are often made
e. Address areas that *Appendix G* leaves for the "rating authority" to decide. The "rating authority" is EPA.

3 Simulation Methodology

3.1 General

Buildings shall be simulated following *ASHRAE 90.1-2016 Appendix G* Performance Rating Method (PRM, Appendix G) and as described in this document.

> **Exception**: Compliance with *Appendix G* Section G.1.2.1 is not required.

Addenda to *ASHRAE 90.1-2016* will be reviewed by EPA. If EPA issues guidance that the addenda may be used, it must be explicitly referenced in the submittals and followed in its entirety. The guidance document will specify whether one addendum or several addenda may be used without having to use all the addenda.

The *Baseline Building Design* and *Proposed Design* shall be based on the final design of the building, not the initial or preliminary design that was received by the energy modeler from the *design team*. Thus, both the *Baseline Building Design and Proposed Design* may require changes until all the design parameters are finalized.

3.2 Required energy simulations

The *baseline design* model shall follow requirements of *Appendix G* and Simulation Guidelines.

The *proposed design* must be modeled as described in *Appendix G*, and reflect the proposed building components, except where otherwise specified in this document. The *proposed design* must comply with the mandatory requirements of this *Program* and the applicable state and local codes.

As-Built model must be based on the *proposed design* model updated to reflect the actual building components, as verified or measured during site inspections. At the completion of the construction, these same guidelines must be used to calculate the *Performance Rating* for the *As-Built* model, by substituting "*As-Built*" where you find "*Proposed Design*". Some components that are not required to reflect *As-Built* conditions within the energy model are specified in the relevant sections below. Although some required measurements are not incorporated in the energy model, such as total in-unit duct leakage tests, they do have restrictions as described in the mandatory requirements of this *Program*.

3.3 Modeled end uses

a. *Baseline* and *proposed design* models shall include all the energy uses within and associated with the building. This includes loads that are not regulated by *ASHRAE 90.1*, except where explicitly required otherwise in the Simulation Guidelines.

b. Baseline model shall not include end uses that do not exist in the proposed building.

> EXAMPLE 3-1 - Unlit Parking Lot
>
> Q. Building design includes a parking lot that is not lit. What lighting power allowance can be used in the baseline model for the parking lot?
>
> A. Since the parking lot in the proposed design is not lit, the parking lot lighting power allowance cannot be added to the baseline energy consumption.

Exception: Space cooling must be modeled in all conditioned spaces per *Appendix G* Table G3.1-1.b whether or not it is specified, except in spaces designed with heating only systems serving storage rooms, stairwells, vestibules, electrical/mechanical rooms, and restrooms not exhausting or transferring air from mechanically cooled thermal zones in the *proposed design*.

> EXAMPLE 3-2 Spaces with No Cooling Specified
>
> Q. A multifamily building in Climate Zone 4A includes dwelling units, common corridors, stairwells, tenant storage, and mechanical/utility rooms. No cooling is specified for any of the spaces. Should cooling be included in the baseline and the proposed design model?
>
> A. Based on the definition of *space* in ASHRAE 90.1 Section 3 and heating output of the equipment specified in the proposed design, the dwelling units, corridors, and tenant storage are conditioned spaces, and stairwells and mechanical/utility rooms are semi-heated. Thus, cooling must be modeled as follows in both the baseline and proposed design:
>
> - Dwelling units and corridors must be modeled with cooling.
> - Tenant storage is subject to Appendix G Exception to G3.1-1.b, and must be modeled with no cooling.
> - Stairwells and mechanical/utility rooms are not conditioned spaces and must also be modeled with no cooling.
>
> Cooling system efficiency must be modeled as described in SG Section 6.5.5.

3.4 Approved Simulation Tools

Simulation software must comply with the requirements outlined in *Appendix G* Section G2.2. Examples of allowed tools include eQUEST, DOE2.1, Energy Plus, Carrier HAP, Open Studio, and Trane Trace 700. Other software tools may be approved on a case by case basis.

3.5 Project Boundary

The models shall include all *dwelling units*, ~~and~~ *common spaces*, and residential parking garages in the building. Other *nonresidential* areas such as retail stores or offices open to the general public and unrelated to the building's residential function may be included or excluded from the simulations at the discretion of the energy modeler. If included, energy savings may only be modeled for a measure if it meets the relevant mandatory program requirements . Otherwise, they must be modeled *energy neutral*. If excluded, the building may not be able ~~will not be eligible~~ to receive the "Designed to Earn ENERGY STAR (DEES)" credential, unless the energy use for the nonresidential areas has been estimated using other calculations, when generating a Statement of Energy Design Intent while applying for the recognition.

Note: Earning the DEES credential is not a requirement of the ENERGY STAR MFNC program, but an option available to eligible projects to promote the energy efficient design of their building during the construction process.

3.6 Projects involving multiple buildings

Separate *Baseline Building Design* and *Proposed Design* models shall be created for each non-identical building in the project. The *Performance Rating* shall be calculated individually for each such building.

3.7 Schedules

The models must include the schedules described in this document, or approved equivalent. All schedules that differ from the ones specified in the Simulation Guidelines shall be documented and submitted to an EPA-recognized Multifamily Review Organization (MRO) for review and approval.

The same schedules must be used in both the *Baseline Building Design* and *Proposed Design* unless explicitly allowed otherwise in *Appendix G* or this document. Any difference in the schedules must be documented.

3.8 Exceptional Calculations

If an approved simulation tool used for the project does not have the capability to calculate energy usage and/or savings for a design feature allowed by *Appendix G* and SG, supplemental calculations may be used. All such calculations must be documented following requirements of *90.1* Section G2.5 summarized below:

- **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 value assumed;
- **d.** If the design feature in the exceptional calculations is related to HVAC, then the calculations shall be performed on a time step basis consistent with the simulation program used;
- **e.** The energy use with and without the Exceptional Calculation Method must be submitted.

The total savings from the Exceptional Calculations must not account for more than half of the documented improvement over code. Exceptional calculations not described in this document shall be submitted to an EPA-recognized Multifamily Review Organization (MRO) for review and approval.

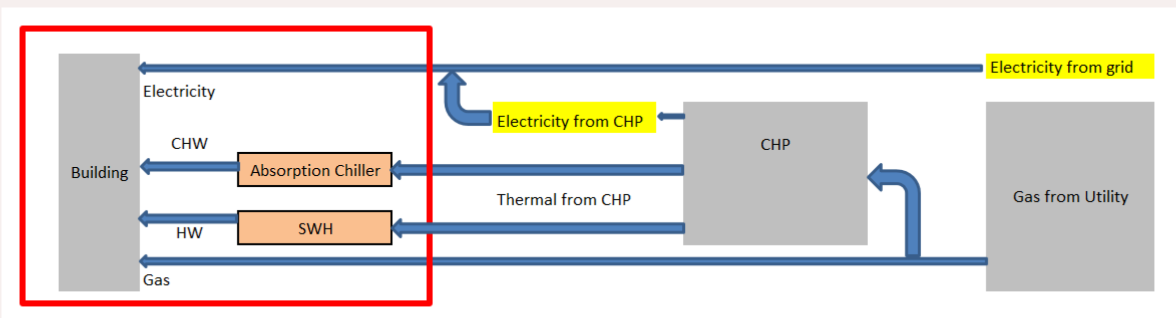
3.9 Excluded Systems

Energy savings associated with on-site power generation, including cogeneration with the associated waste heat recovery, photovoltaics, or wind turbines, may not contribute to meeting the *Performance Target*, but may be used to exceed it. To demonstrate achievement of the *Performance Target*, *Proposed Building Performance* must be determined without any credit for reduced annual energy costs from on-site power generation. The specified backup systems shall be modeled in place of waste heat recovery as applicable. If backup system is not specified, or does not have the sufficient capacity, the systems modeled in place of waste heat must be modeled as *energy neutral*.

EXAMPLE 3-3 – Excluding CHP from the Model

Q. Multifamily building design includes CHP that meets some of the electricity loads in the building. Waste heat is used for the absorption chiller and service water heating. How should the project be modeled to evaluate achievement of the Performance Target?

A. The Baseline Design must be modeled without CHP, following the general rules of Appendix G and Simulation Guidelines. The Proposed Design model must reflect systems within the red boundary in the figure below, except the thermal energy from CHP must be replaced with the specified back-up boilers. If back-up boilers are not sized to meet the full SWH or absorption chiller heating load, or if back-up heating source is not specified, boilers minimally compliant with the 90.1 reference edition must be modeled for the unmet load.



3.10 Modeling Future Systems and Components

EXAMPLE 3 – 4 Modeling Future Systems and Components

Q. Project includes common laundry with clothes washer and dryer hookups. The appliances will be leased or purchased in future, and are not installed at the As-Built stage. How should the future clothes washers and dryers be modeled?

A. Appliances are categorized as *unregulated* load based on the definition in Section 1, and thus must be modeled the same in the baseline and proposed design following the definition of "energy neutral" as applied to unregulated load in Section 1. The values used shall be consistent with the values in SG Section 6.8.

Q. How should cooling in the dwelling units be modeled for the project described in Example 3-2, which does not have cooling specified?

A. Cooling is categorized as regulated energy use based on the definition in Section 1. To treat it as energy neutral following definition in Section 1, the baseline PTACs must be modeled with the efficiency based on Appendix G Table G3.5.4, and meeting other *Appendix G* requirements applicable to the baseline HVAC. In the *proposed design*, the cooling system must be modeled the same as in the *baseline*, except with the PTAC cooling efficiency required in the *reference edition of 90.1* Section 6.

The energy-related features that are not designed or installed at the *As-Built* stage must be kept *energy neutral*, and modeled as described in the Definition section, depending on whether they are regulated or unregulated. This rule replaces *Appendix G* Table G3.1 No. 1 (c) in the *Proposed Building Performance* column.

EXAMPLE 3 – 4 Modeling Future Systems and Components

Q. Project includes common laundry with clothes washer and dryer hookups. The appliances will be leased or purchased in future, and are not installed at the As-Built stage. How should the future clothes washers and dryers be modeled?

A. Appliances are categorized as *unregulated* load based on the definition in Section 1, and thus must be modeled the same in the baseline and proposed design following the definition of "energy neutral" as applied to unregulated load in Section 1. The values used shall be consistent with the values in SG Section 6.8.

Q. How should cooling in the dwelling units be modeled for the project described in Example 3-2, which does not have cooling specified?

A. Cooling is categorized as regulated energy use based on the definition in Section 1. To treat it as energy neutral following definition in Section 1, the baseline PTACs must be modeled with the efficiency based on Appendix G Table G3.5.4, and meeting

3.11 Renovation Projects

The *baseline design* for renovation projects must be modeled the same as for new construction and additions, following *Appendix G* Table G3.1 No. 2 *Baseline Building Performance* column, unless allowed otherwise in this document.

EXAMPLE 3 – 5 Modeling Renovation Projects

Q. Project includes a major renovation of a school that is converted to an apartment building. The scope of the renovation includes added roof insulation, window replacement, and all new interior lighting and mechanical systems. Exterior walls and exterior lighting remain as is. How should the baseline and proposed design be modeled?

A. All baseline systems must be modeled the same as for the new construction project. The proposed design model must reflect the specified roof, windows, interior lighting, and mechanical systems, and the existing exterior lighting and exterior walls. The project's performance rating will be negatively affected by excluding exterior lighting and exterior walls from the scope of retrofit.

4 Energy Rates

Unless provided otherwise by EPA, per *Appendix G*, Section G2.4.2, use either actual rates for purchased energy or state average energy prices published by DOE's Energy Information Administration in energy simulations of *Baseline Building Design*, *Proposed Design*, and *As-Built* (www.eia.doe.gov). The selected source must be used for all fuels in the project. The rate schedule used in the *Baseline Building Design* must be the same as in simulations of the *Proposed Design* and *As-Built*.

If actual rate schedules and pricing, according to the rate class that will most likely be assigned to the property are used, supporting documentation must be provided showing monthly pricing for 12 consecutive months.

Performance credit for the reduced energy cost may be claimed only if the cost reduction is due to the reduced energy consumption or demand. Following this rule, savings associated with sub-metering shall not be included in the *Performance Rating*.

5 Performance Rating Calculations

The *Performance Rating* is calculated as described in this section. The calculation is incorporated into the ASHRAE Path Calculator_AppG2016 and is provided for reference.

Performance Rating = 100∗ (PCIt−PCI)/PCIt

PCIt = (BBUEC + (BPF x BBREC))/BBP

PCI = PBP/BBP

where:

PCI = Performance Cost Index

PCIt= Performance Cost Index Target

BBP = Baseline Building Performance

PBP= Proposed Building Performance

BBREC = Baseline Building Regulated Energy Cost. The portion of the annual energy cost of a *baseline building design* that is due to *regulated energy use*, calculated by multiplying the total energy cost by the ratio of *regulated energy use* to total energy use for each fuel type.

BBUEC = Baseline Building Unregulated Energy Cost. The portion of the annual energy cost of a *baseline building design* that is due to *unregulated energy use*, calculated by subtracting regulated energy cost from total energy cost.

BPF= Building Performance Factor from Table 1, based on the *reference edition of 90.1* and the climate zone. For mixed use buildings, the BPF shall be calculated as the area-weighted average of the building area types, as described in Section 4 of- ~~"Developing Performance Cost Index Targets for~~ ASHRAE Standard 90.1-2016 ~~Appendix G – Performance Rating Method", March 2016, M Rosenberg and R Hart (PNNL-25202 Rev. 1)~~.

Table 1: Multifamily Building Performance Factors (BPF)

Reference Edition of 90.1	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
2007	0.96	0.96	0.93	0.91	0.93	0.92	0.85	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.93	0.95
2010	0.92	0.91	0.88	0.86	0.87	0.87	0.8	0.9	0.93	0.92	0.88	0.92	0.92	0.88	0.91	0.83	0.89
2013	0.78	0.78	0.76	0.74	0.79	0.78	0.73	0.83	0.86	0.86	0.81	0.85	0.86	0.81	0.84	0.79	0.85
2016	0.73	0.73	0.71	0.69	0.74	0.73	0.68	0.78	0.81	0.81	0.76	0.8	0.81	0.76	0.79	0.74	0.8
2019	0.68	0.70	0.66	0.66	0.69	0.68	0.59	0.74	0.76	0.74	0.70	0.73	0.75	0.68	0.71	0.68	0.72

6 System - Specific Requirements

6.1 Building Envelope

6.1.1 Baseline Design

a. General Requirements

Opaque assemblies and fenestration of new buildings, existing buildings, and additions shall be modeled as described in *Appendix G* Table G3.1 No. 5, with the assemblies detailed in *90.1* Appendix A, and matching the appropriate assembly maximum U-factors in *Appendix G* Tables G3.4-1 through G3.4-8, depending on the project climate zone.

Exception: Maximum U-factors for walls, floors, and roofs in multifamily buildings 3 stories and less are based on the requirements from ASHRAE 90.1-2004, Table 5.5-1 through 5.5-8, depending on the project climate zone, for wood-frame above-grade walls, floors, and attic.

'*Residential*' envelope requirements apply only to the exterior building envelope of *dwelling* or *sleeping units*.

'*Nonresidential*' envelope requirements apply to the exterior building envelope of *common spaces* such as corridors, stairwells, and lobbies, and commercial spaces included in the energy model.

'Semiheated' envelope requirements apply to the envelope components separating conditioned spaces from semiheated or unconditioned spaces, or separating semiheated spaces from the exterior. Refer to the definition of space types in *90.1* Section 3, and *90.1* Figure 5.5.2. For example, indirectly conditioned basements and non-vented crawlspaces with insulated walls, rather than ceilings, are considered 'conditioned space' for the purpose of determining the envelope baseline, and therefore the '*nonresidential*' requirements apply instead of 'semiheated'.

b. Spandrel assemblies

Spandrel areas of curtain wall systems are opaque assemblies, and must be modeled in the baseline as steel-framed walls with the appropriate U-factor.

c. Through-wall PTAC/PTHP sleeves

Thermal properties of through-wall PTAC/PTHP sleeves and penetrations must not be modeled in the *Baseline Design*.

d. Fenestration area of the major renovation projects

The fenestration area shall equal the existing fenestration area prior to the proposed work and shall be distributed on each face of the building in the same proportions as the existing building, based on *Appendix G* Table G3.1 No. 5 (c), Baseline Building Performance column.

e. Orientation

The baseline for renovations and additions must reflect the actual building orientation. Baseline orientation for new construction projects must be as described in *Appendix G* Table G3.1 No. 5 (a), Baseline Building Performance column.

6.1.2 Proposed Design Model

6.1.2.1 Thermal Bridging

a. Framing members

Thermal properties of framing, including but not limited to steel-framed assemblies, must be determined following ASHRAE 90.1 Appendix A to capture thermal bridging.

EXAMPLE 6-1 – Cavity Insulation and Steel Framed Walls

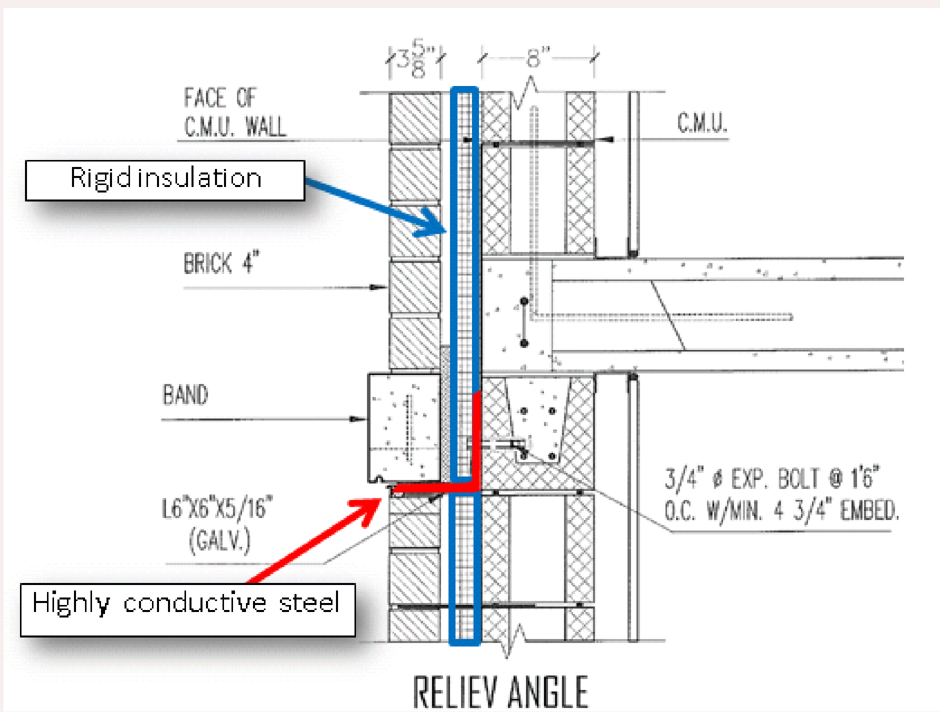
Q. A project has 16" on center steel framed walls with R-13 cavity insulation and R-10 continuous insulation. How should this assembly be modeled?

A. Based on ASHRAE 90.1 Table A3.3.3.1, the effective thermal resistance of the R-13 cavity insulation is R-6, thus the overall R-value of the cavity and continuous insulation is 6 + 10 = 16.

EXAMPLE 6-2 – Shelf Angles

Q. The wall assembly has rigid insulation and cavity insulation for the overall U-0.064. The vertical component of the shelf angle shown on the figure below comprises 5% of the vertical wall area. The U-factor of the areas thermally bypassed by the shelf angle is U-0.097, based on the cavity insulation only, excluding the rigid insulation. What overall U-factor of the wall assembly should be modeled in the proposed design?

A. The wall should be modeled as U-0.066 in the proposed design, calculated as follows: 0.064*0.95+0.097*0.05=0.066



Wall construction utilizing shelf angle

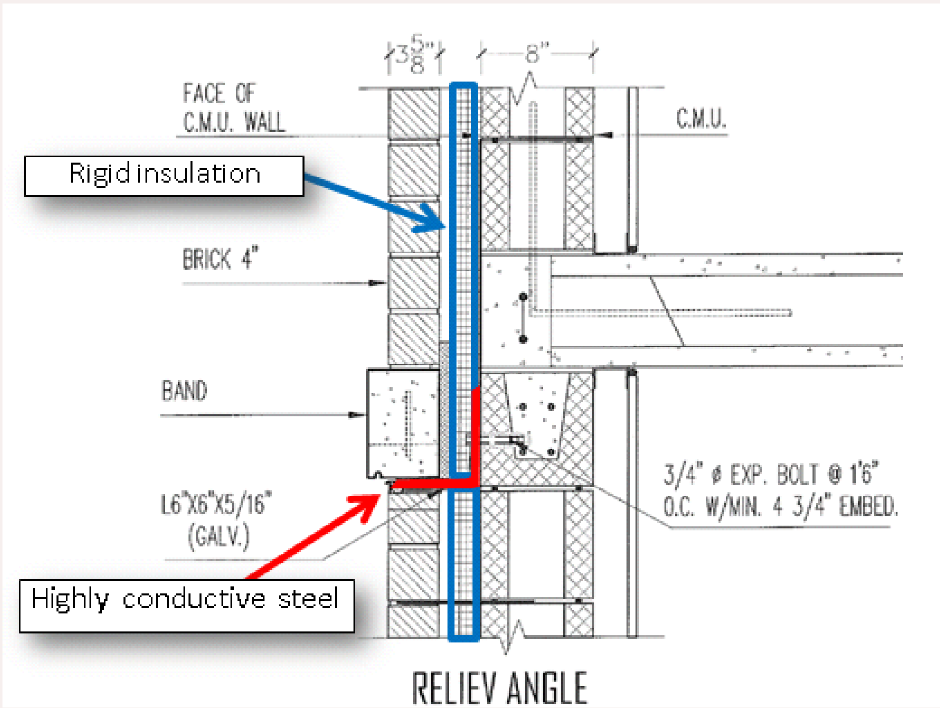
b. Shelf Angles

The *Proposed Design* model must account for thermal bridging through portions of the wall assembly where non-thermally broken shelf angles, metal clips, z-girts, brick ties, or other continuous metal fastened to the wall are used. Where those conditions exist, the insulation cannot contribute to the assembly U-factor for those areas. An overall U-factor shall be calculated based on an area weighted average of the thermal properties.

EXAMPLE 6-2 – Shelf Angles

Q. The wall assembly has rigid insulation and cavity insulation for the overall U-0.064. The vertical component of the shelf angle shown on the figure below comprises 5% of the vertical wall area. The U-factor of the areas thermally bypassed by the shelf angle is U-0.097, based on the cavity insulation only, excluding the rigid insulation. What overall U-factor of the wall assembly should be modeled in the proposed design?

A. The wall should be modeled as U-0.066 in the proposed design, calculated as follows: 0.064*0.95+0.097*0.05=0.066



6.1.2.2 Fenestration

Fenestration must be modeled as specified, to reflect whole window assembly SHGC and U-factors including frame (not the center-of-glass U-factor). Acceptable sources include:

- NFRC rating from the window manufacturer for the entire fenestration unit. (This is usually available only for standard window sizes.)
- LBNL WINDOW software
- NFRC's CMAST software
- ASHRAE 2009 Fundamentals [9], Chapter 15 Table 4 and 10.
- Certification provided by the installer or supplier listing the assembly U-factor and SHGC can be used in lieu of NFRC labels, provided that they comply with the fenestration rating requirements in Section 5.8.2 of the *reference version of 90.1*.

6.1.2.3 HVAC Penetrations

Through-wall AC sleeves and PTAC/PTHP penetrations must be modeled in the *Proposed Design* with a U-factor of 0.5. Any R-value associated with an insulated cover shall not be included in the model.

6.1.2.4 Unique envelope assemblies

Unique envelope assemblies such as projecting balconies, perimeter edges of intermediate floor slabs, concrete floor beams over parking garages, and roof parapets, shall be separately modeled in the *Proposed Design*, per *Appendix G* Table G3.1, No. 5 (a). A weighted average of the U-factors of these assemblies is acceptable in the simulation. Projected balconies and perimeter edges of intermediate floor slabs are considered to be a wall, per wall definition in Section 3 of *90.1*, and shall be modeled in the *Baseline Building Design* with the same U-factor and construction as the exterior walls in the Baseline Building Design.

6.1.3 Partially glazed doors

In the proposed design, the door U-factor and SHGC shall be modeled as per the NFRC label for the door specified in the final design.

Doors that are more than one-half glass:

I. The entire door area shall be counted as vertical fenestration when calculating the vertical fenestration-to-wall ratio.
II. The door shall be modeled as a single fenestration unit in both the *Baseline Building Design* and *Proposed Design*.
III. The door U-factor and SHGC in the *Baseline Building Design* shall be determined based on requirements for baseline vertical fenestration in *Appendix G* Tables G3.4-1 to G3.4-8 for the applicable climate zone.

Doors that have glazing area of 50% or less:

I. Only the glazed portion of the door shall be included when calculating the vertical fenestration-to-wall ratio.
II. Use one of the following options to model the door:

- Model the entire door as opaque in the *Baseline Building Design* and *Proposed Design*. The baseline door U-factor shall be modeled based on the *Appendix G* Tables G3.4-1 to G3.4-8 requirements for opaque doors of appropriate type[1].
- Model the *Baseline Building Design* with a door of identical distribution of opaque/glazed area to the proposed door and apply the requirements in *Appendix G* Tables G3.4-1 to G3.4-8 for opaque doors of appropriate type to the opaque area, and the fenestration U-factor and SHGC to the glazing area.

6.1.4 Shading

a. Automatically-controlled fenestration shades or blinds and permanent shading devices that are part of the building, including but not limited to side fins, overhangs, and balconies, must be modeled in the *proposed design*, and not modeled in the *baseline*.

b. Manual shading such as blinds or shades must not be modeled in either the *baseline* or *proposed design*.

c. Shading by the adjacent structures and terrains must be included in both the *baseline* and *proposed design* models, as described in *Appendix G* Table G3.1 No. 14.

6.1.5 F-factor

If the energy modeling software tool does not allow input of the perimeter heat loss factor (F-factor), then the slab-on-grade construction that corresponds to the F-factor shall be modeled as is appropriate for the software tool being used. If the slab-on-grade insulation in the *Proposed Design* is a permitted method, as shown on Figure 5-S of the ASHRAE 90.1-2013 User's Manual, model slab-on-grade as *energy neutral*. If the slab-on-grade insulation is not a permitted method, model as uninsulated in the *Proposed Design,* and based on the requirements in *Appendix G* Table G3.4.1 to G3.4.8 in the *baseline*.

6.2 Infiltration

Infiltration rates must be modeled in the *baseline* and *proposed design* as described in *Appendix G* Table G3.1 No. 5 (b), and must be calculated following *Appendix G* Section G3.1.1.4. Lower infiltration may be modeled in the *proposed design* based upon the anticipated air leakage test results or maximum air leakage allowed by the Program, per exception to *Appendix G* Table G3.1 No. 5 (b), *Proposed Building Performance* column. The infiltration rate in the *As-Built* model shall reflect the air leakage testing results of a sample of individual apartments (compartmentalization testing), or whole building air leakage testing. If compartmentalization testing results are used, infiltration rate for the entire building shall be modeled based on the highest compartmentalization test result (i.e. the leakiest) of all units subject to testing.

Exception: Each unit subject to testing is permitted to be modeled with their actual tested rate.

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[1] The intent of this procedure is to simplify the modeling requirements for doors with less than 50% glazing area and not to create an energy penalty in the analysis for doors with less than 50% glazing area.

If the energy modeling software supports multiple infiltration algorithms, the same method must be used in the *Baseline Building Design* and *Proposed Design*. Infiltration rate must be modeled at 100% (i.e. with the schedule fraction of 1) during all hours of the year.

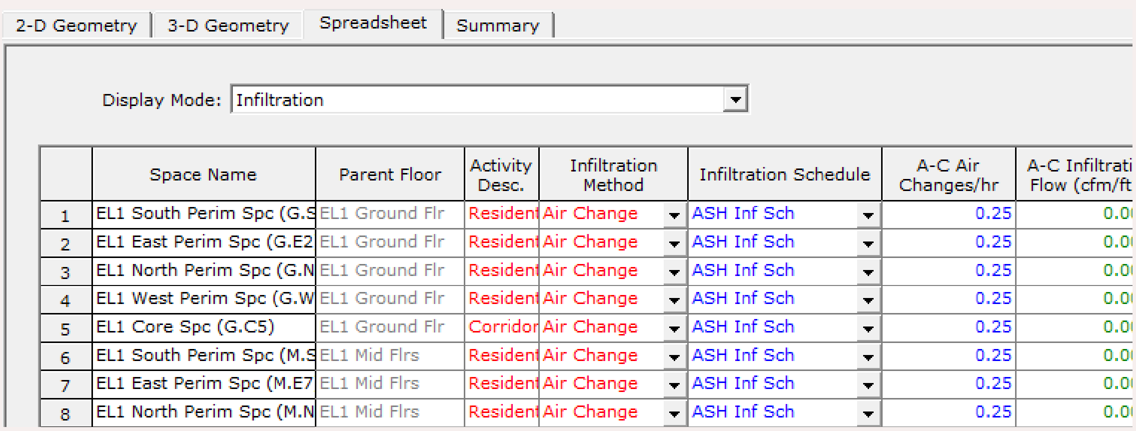
EXAMPLE 6-3 – Baseline Infiltration Modeling

Q. The project involves a 5-story multifamily building with slab-on-grade foundation. Each floor is 8,000 ft^2. The total gross floor area is 40,000. The total gross wall area is 17,117 ft^2. The total conditioned building volume is 360,068 ft^3. The project is modeled in eQUEST. How should be baseline infiltration rate be entered?

A. Based on Appendix G Table G3.1 No.5 (b), the baseline infiltration at 75 Pa is 0.4 CFM/SF of the total area of the envelope air pressure boundary, including the lowest floor, any below- or above-grade walls, and roof (or ceiling) including windows and skylights, separating the interior conditioned space from the unconditioned environment. The total envelope air pressure boundary for the project is
S=8,000 x 2 + 17,117=33,117 ft^2

The air leakage at 75 Pa must be converted to leakage at the wind pressure using equations in Section G3.1.1.4 as follows:
I=33,117*0.4*0.112=1,484 CFM

Table G3.1 No.5 (b) requires that simulation accounts for the factors such as weather conditions. “Air Change” method is the best fit for it in eQUEST. The calculated flow rate is converted to the air-change rate for input into eQUEST as follows:
1,484 [CFM] * 60 [min/hr] / 360,068 [ft^3] = 0.25 [ACH]. The modeled infiltration schedule “ASH Inf Sch” has hourly fraction of 1 for all hours.



	Space Name	Parent Floor	Activity Desc.	Infiltration Method	Infiltration Schedule	A-C Air Changes/hr	A-C Infiltrati Flow (cfm/ft
1	EL1 South Perim Spc (G.S	EL1 Ground Flr	Resident	Air Change	ASH Inf Sch	0.25	0.0
2	EL1 East Perim Spc (G.E2	EL1 Ground Flr	Resident	Air Change	ASH Inf Sch	0.25	0.0
3	EL1 North Perim Spc (G.N	EL1 Ground Flr	Resident	Air Change	ASH Inf Sch	0.25	0.0
4	EL1 West Perim Spc (G.W	EL1 Ground Flr	Resident	Air Change	ASH Inf Sch	0.25	0.0
5	EL1 Core Spc (G.C5)	EL1 Ground Flr	Corridor	Air Change	ASH Inf Sch	0.25	0.0
6	EL1 South Perim Spc (M.S	EL1 Mid Flrs	Resident	Air Change	ASH Inf Sch	0.25	0.0
7	EL1 East Perim Spc (M.E7	EL1 Mid Flrs	Resident	Air Change	ASH Inf Sch	0.25	0.0
8	EL1 North Perim Spc (M.N	EL1 Mid Flrs	Resident	Air Change	ASH Inf Sch	0.25	0.0

EXAMPLE 6-4 – As-Built Infiltration Modeling

Q. The same project tests a sample of units for compartmentalization and the worst measured value is 0.36 CFM/SF at 75 Pa. How should the As-Built infiltration rate be entered?

A. The tested air leakage at 75 Pa must be converted to leakage at the wind pressure using equations in Section G3.1.1.4 as follows:
I=33,117*0.36*0.112=1,335 CFM

“Air Change” method must be used in the As-Built, since it was used in the Baseline. The calculated flow rate is converted to the air-change rate for input into eQUEST as follows:
1,335 [CFM] * 60 [min/hr] / 360,068 [ft^3] = 0.22 [ACH]. The modeled infiltration schedule “ASH Inf Sch” has hourly fraction of 1 for

EXAMPLE 6-4 – As-Built Infiltration Modeling

Q. The same project tests a sample of units for compartmentalization and the worst measured value is 0.36 CFM/SF at 75 Pa. How should the As-Built infiltration rate be entered?

A. The tested air leakage at 75 Pa must be converted to leakage at the wind pressure using equations in Section G3.1.1.4 as follows:
I=33,117*0.36*0.112=1,335 CFM

"Air Change" method must be used in the As-Built, since it was used in the Baseline. The calculated flow rate is converted to the air-change rate for input into eQUEST as follows:
1,335 [CFM] * 60 [min/hr] / 360,068 [ft^3] = 0.22 [ACH]. The modeled infiltration schedule "ASH Inf Sch" has hourly fraction of 1 for all hours.

EXAMPLE 6-3 – Baseline Infiltration Modeling

Q. The project involves a 5-story multifamily building with slab-on-grade foundation. Each floor is 8,000 ft^2. The total gross floor area is 40,000. The total gross wall area is 17,117 ft^2. The total conditioned building volume is 360,068 ft^3. The project is modeled in eQUEST. How should be baseline infiltration rate be entered?

A. Based on Appendix G Table G3.1 No.5 (b), the baseline infiltration at 75 Pa is 0.4 CFM/SF of the total area of the envelope air pressure boundary, including the lowest floor, any below- or above-grade walls, and roof (or ceiling) including windows and skylights, separating the interior conditioned space from the unconditioned environment. The total envelope air pressure boundary for the project is S=8,000 x 2 + 17,117=33,117 ft^2

The air leakage at 75 Pa must be converted to leakage at the wind pressure using equations in Section G3.1.1.4 as follows:
I=33,117*0.4*0.112=1,484 CFM

Table G3.1 No.5 (b) requires that simulation accounts for the factors such as weather conditions. "Air Change" method is the best fit for it in eQUEST. The calculated flow rate is converted to the air-change rate for input into eQUEST as follows:
1,484 [CFM] * 60 [min/hr] / 360,068 [ft^3] = 0.25 [ACH]. The modeled infiltration schedule "ASH Inf Sch" has hourly fraction of 1 for all hours.

2-D Geometry | 3-D Geometry | Spreadsheet | Summary

Display Mode: Infiltration

	Space Name	Parent Floor	Activity Desc.	Infiltration Method	Infiltration Schedule	A-C Air Changes/hr	A-C Infiltration Flow (cfm/ft2)
1	EL1 South Perim Spc (G.S	EL1 Ground Flr	Resident	Air Change	ASH Inf Sch	0.25	0.0000
2	EL1 East Perim Spc (G.E2	EL1 Ground Flr	Resident	Air Change	ASH Inf Sch	0.25	0.0000
3	EL1 North Perim Spc (G.N	EL1 Ground Flr	Resident	Air Change	ASH Inf Sch	0.25	0.0000
4	EL1 West Perim Spc (G.W	EL1 Ground Flr	Resident	Air Change	ASH Inf Sch	0.25	0.0000
5	EL1 Core Spc (G.C5)	EL1 Ground Flr	Corridor	Air Change	ASH Inf Sch	0.25	0.0000
6	EL1 South Perim Spc (M.S	EL1 Mid Flrs	Resident	Air Change	ASH Inf Sch	0.25	0.0000
7	EL1 East Perim Spc (M.E7	EL1 Mid Flrs	Resident	Air Change	ASH Inf Sch	0.25	0.0000
8	EL1 North Perim Spc (M.N	EL1 Mid Flrs	Resident	Air Change	ASH Inf Sch	0.25	0.0000
9	EL1 West Perim Spc (M.W	EL1 Mid Flrs	Resident	Air Change	ASH Inf Sch	0.25	0.0000
10	EL1 Core Spc (M.C10)	EL1 Mid Flrs	Corridor	Air Change	ASH Inf Sch	0.25	0.0000
11	EL1 South Perim Spc (T.S	EL1 Top Flr	Resident	Air Change	ASH Inf Sch	0.25	0.0000

6.3 Interior Lighting

6.3.1 Lighting Schedule

a. *Baseline* and *Proposed Design* lighting inside *dwelling unit*s shall be modeled as lit for 2.34 hours per day. No schedule-based performance credits may be claimed for lighting inside *dwelling unit*s.

b. Balcony lighting shall use the same schedule as the *dwelling unit*s.

c. Baseline lighting in corridors, stairwells and lobbies shall be modeled as lit for 24 hours per day.

d. Hours of operation of Baseline lighting fixtures in areas not identified above may be estimated by the energy modeler based on the occupancy type of each space.

e. The lighting schedule for the *Proposed Design* must be adjusted to account for the lighting controls in *common space*s using Occupancy Sensor Reduction fraction from *Appendix G* Table G3.7, including the footnotes.

6.3.2 Baseline Lighting

6.3.2.1 Lighting Power

a. In-unit lighting shall be modeled with the lighting power density of 1.07 W/ft^2. Lighting power in other spaces must be established using space-by-space method, as described in *Appendix G* Table G3.1 No. 6, *Baseline Building Performance* column, and Table G3.7. For types of spaces not listed in Table G3.7, a reasonable equivalent space type must be used. For the spaces listed in Table 2, the equivalent space type has been established, and the lighting power density and Occupancy Sensor Reduction that may be claimed by the proposed designs has been listed for your convenience.

Table 2: Space Type Mapping

Multifamily Space Type	Equivalent Space Type in 90.1 Table G3.7	LPD (W/ft2)	Occupancy Sensor (OS) Reduction
Lounge/Recreation Community Room	All other lounge/breakroom	1.20	No credit, OS required in both baseline and proposed
Exercise Room	Exercise area	0.90	35%
Trash Chute/Room Janitor Closet Tenant Storage	Storage Room <>50 sf	0.80	45%
Retail	Sales Area	1.70	15%
Laundry Room	Laundry/Washing Area	0.60	10%
Elevator (interior)	Table G3.1 #16	3.14	25%

b. For rooms that include more than one space type, such as a large basement space with part of the area housing electrical/mechanical equipment, and the rest used for storage, apply the lighting power density to the appropriate square footage, and model the area-weighted lighting power density in the *baseline*.

c. Senior housing projects can use allowances for facilities for the visually impaired in *Appendix G* Table G3.7 for spaces used primarily by building residents. For example, 1.15 W/SF lighting power allowance may be used for the corridors in the *baseline*. To qualify for the increased allowance, the project must be designed to comply with the light levels in ANSI/IES RP-28 and must provide housing for seniors and/or people with special visual needs. Documentation shall be provided to the MRO that demonstrates eligibility to use this allowance.

d. Baseline lighting power allowance for corridors must be modeled as 0.83 W/SF instead of 0.5 W/SF listed in *Appendix G* Table G3.7, to reflect the increase in the illuminance requirements for corridors since 2004.

e. Decorative lighting allowance described in *ASHRAE 90.1* Section 9.6.2 must not be used to increase the baseline lighting power density for any of the spaces.

6.3.2.2 Lighting Controls

No automatic lighting controls shall be modeled in the *baseline* except in employee lunch and break rooms, conference/meeting rooms, and classrooms if applicable, following *Appendix G* Table G3.1 No. 6 *Baseline Building Performance* column. These controls shall be reflected in the *baseline building design* lighting schedules and modeled the same in the *baseline* and *proposed design*. No automatic lighting controls, e.g., controls for daylight utilization and occupancy sensors in space types not listed above, shall be modeled in the *Baseline Building Design*.

6.3.3 Proposed Lighting

6.3.3.1 Lighting Power

a. The installed lighting power must be modeled as described in *Appendix G* Table G3.1 No. 6 (a), and include all power used by the luminaire, including lamps, ballasts/drivers, transformers, and control devices as described in *ASHRAE 90.1* Section 9.1.3, and based on the actual installed lamp. For example, a screw-based fixture rated at 75 Watt maximum, with 26 Watt CFL installed, may be modeled as 26 Watts. For rooms or portions of rooms with no specified hardwired lighting, in-unit lighting power density of 1.07 W/ft^2 shall be modeled, except where the *reference edition of 90.1* is 2016, in which case 0.6 W/ft^2 shall be modeled.

b. Light fixtures in rooms such as bedrooms and living rooms, that may be supplemented by lighting connected to receptacles, must be estimated to provide illumination at a rate of no more than 3 ft^2/Watt. The following calculations may be used to claim Illumination Rate Allowance (IRA) over 3 ft^2/Watt:

IRA [ft^2/Watt] = Efficacy x CU / FC
IRA = Illumination Rate Allowance, [ft^2/Watt]
Efficacy = rated efficacy of the specified fixture, [lm/Watt]
FC = target general illuminance level; FC = 10 [footcandles]

CU = Coefficient of Utilization

RCR	1	2	3	4	5	6	7	8	9	10
CU	0.88	0.78	0.69	0.61	0.55	0.49	0.45	0.41	0.37	0.34

RCR = Room Cavity Ratio

Rectangular rooms: RCR = 5 x H x (L + W)/(L x W)

Irregularly shaped rooms: RCR = 2.5 x H x P / A

H = vertical distance from the work plane to the center line of the lighting fixture; for living rooms and bedrooms, the work plane is 4' above the floor

L = room length, [ft]

W = room width, [ft]

P = room perimeter length, [ft]

A = room area, [ft^2]

EXAMPLE 6-5 – Calculating In-Unit Lighting Power Density

Q. 12' x 18' living room with 8' ceiling height has hard-wired 39W fixture with the rated efficacy of 65 lm/Watt. What lighting wattage should be modeled for this space in the *baseline* and *proposed design* if the *reference edition of 90.1* ~~-~~is 2013?

A. Calculate the area of the room illuminated by the specified fixture:

RCR=5 x (8-4) x (12 + 18) / (12 x 18) =3

CU = 0.69

IRA = 65 x 0.69 / 10 = 4.49 ft^2 / W

4.49 [ft^2 / W] x 39 [W]=175 ft^2

The total room area is 12 x 18 = 216 ft^2. The floor area that must be modeled with the baseline LPD is then 216-175=41 [ft^2], and thus requires 41 [ft^2] x 1.07 [W/ft^2] = 43.87 [Watt]. The total proposed wattage for the living room is 39+ 43.87 = 82.87 [Watt]. The corresponding baseline wattage is 216 [ft^2] x 1.07 [W/ ft^2] = 231 [Watt]

c. Lighting energy savings may be claimed only for hardwired lighting fixtures. As per the exception to *Appendix G* Table G3.1 No. 6, *Proposed Design* column, identical lighting power shall be assumed in the *Baseline Building Design* and *Proposed Design* for any lighting that is connected via receptacles and/or not shown or provided for on building plans.

d. If lighting is specified for only a portion of the space, the lighting power allowance based on the *reference edition of 90.1* must be assigned to the remainder of the space. The Lighting Counts worksheet of the ASHRAE Path Calculator_AppG2016 shall be used to calculate interior lighting power trade-offs.

e. If proposed lighting power of a common space or parking garage represents a 30% reduction compared to the space-by-space lighting power allowance in the *reference edition of 90.1*, or if the proposed in-unit lighting is below 0.6 W/SF, the savings in excess of these limits (i.e. higher than 30% savings for common spaces, or lower than 0.6 W/SF in-unit lighting power density) may be modeled only if the proposed fixtures are demonstrated to meet the recommended weighted average footcandles based on the 10th edition of the Illuminating Engineering Society (IESNA) Lighting Handbook for the given space type, as quoted in Table 3.

Table 3: Recommended Light Levels

ASHRAE Space Type	Recommended Light Levels (Weighted Avg. Footcandles)	ASHRAE Space Type	Recommended Light Levels (Weighted Avg. Footcandles)
Apartments	10	Stairs - Active	5
Storage, >50ft²	5	Restroom	5
Storage, <50ft²	10	Office	30
Lounge/Recreation	15	Conference/meeting/ multipurpose	30
Exercise Area	15	Electrical/Mechanical	10
Lobby	10	Workshop	40
Corridor/Transition	~~10~~5	Parking garage	5
Laundry	20		

6.3.3.2 Lighting Controls

a. Automatic daylighting controls shall be modeled directly in the whole building simulation tool or through the schedule adjustments determined by a separate approved daylighting analysis, and as described in *Appendix G* Table G3.1 No. 6 (g). The savings projected by the external analysis must be incorporated into whole building simulation tool as an equivalent adjustment to the lighting schedule. The summary outputs from the daylighting software and explanation on how the findings were incorporated into the whole building simulation tool must be included in the appendix to the report. Visual light transmittance of the specified windows affects daylighting savings and must be captured in the tool used to model the daylighting.

b. Other automatic lighting controls shall be modeled by adjusting lighting power or lighting schedule each hour by the occupancy sensor reduction factors in *Appendix G* Table G3.7, including the footnotes, and as described in *Appendix G* Table G3.1 No. 6 (h). Performance credit can be taken with bilevel or multilevel light fixtures or with occupancy sensors that activate select fixtures ON/OFF, as long as the selected design strategy achieves at least one intermediate step between full ON and full OFF that provides 30-70% of full lighting power to that space.

6.4 Exterior Lighting

6.4.1 General

Exterior lighting that is connected to the site utility meters, including but not limited to pole fixtures for walkways and parking, and exterior lighting attached to the building, shall be included in the *Baseline Building Design* and *Proposed Design*. Exterior lighting performance credit may be claimed only for the Tradable Surfaces described in *ASHRAE 90.1* Table 9.4.5 for which lighting is specified on the drawings. For example, if the parking lot in the *Proposed Design* is not lit, then no parking lot lighting power shall be modeled in either the *Baseline Building Design* or *Proposed Design*.

Performance credit can only be modeled if associated with energy-efficiency, rather than a decrease in illumination, or reduction in the illuminated area or surface.

Lighting specified for apartment balconies can be evaluated as Tradable, using “Other doors”, or as Non-tradable, using “Building façades”.

Exterior lighting for unregulated applications such as swimming pools, athletic fields, etc. must be modeled as energy neutral.

Use the General Lighting worksheet of the ASHRAE Path Calculator_AppG2016 for exterior lighting calculations.

6.4.2 Schedule

Exterior lighting shall be modeled as lit for no more than 12 hours per day. The same schedule must be modeled in the *baseline* and *proposed design* and is assumed to include the specified lighting controls.

6.4.3 Lighting Power

6.4.3.1 Baseline Lighting Power

a. Exterior lighting in areas identified as “Tradable Surfaces” in *Appendix G* Table G3.6 shall be modeled with the baseline lighting power shown in Table G3.6. Tradable exterior lighting applications include uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs, and outdoor sales areas. The baseline exterior lighting is the product of the lighting allowance from *Appendix G* Table G3.6 and the associated area or length for which illumination is provided in the *proposed design*.
Other exterior lighting, including unregulated and non-tradable applications, shall be modeled the same in the *baseline building design* as in the *proposed design*.

6.4.3.2 Proposed Lighting Power

a. The lighting power in the *Proposed Design* must be modeled as described in *Appendix G* Table G3.1 No. 6 (a), and include all power used by the luminaire, including lamps, ballasts/drivers, transformers, and control devices as described in *ASHRAE 90.1* Section 9.1.3, and based on the actual installed lamp**.**

EXAMPLE 6-6 - Exterior Lighting Calculations

Q. A multifamily building has a 40,000 ft² parking lot and a 3,500 ft² façade. The proposed lighting for the parking lot is 4 kW; the façade is 430 W. The project is in Lighting Zone 3. What exterior lighting power should be modeled in the *baseline* and *proposed design*?

A. The table below shows lighting inputs in the *baseline* and *proposed designs* for this example. While the maximum façade allowance was 525 W, since this is non-tradable, the *Baseline* is modeled the same as the *Proposed*, or 430 W.

	Parking Lot		Building Façade	
Surface Area	40,000 ft^2		3,500 ft^2	
Lighting Allowance	0.15 W/ ft^2 (Table G3.6)		0.15 W/ ft^2 (Table 9.4.2-2)	
Maximum Allowed Wattage	0.15 W/ ft^2*40,000 ft^2=6 kW		0.15W/ ft^2*3,500 ft^2=525 W	
Allowance Type (Table 9.4.5)	Tradable		Non-tradable	
Modeled Wattage	Baseline Model	Proposed	Baseline Model	Proposed
	6 kW	4 kW	430 W	430 W

6.5 Heating, Ventilation, and Air Conditioning

6.5.1 Thermostat Setpoints

Setpoint temperature of 72°F and setback temperature of 70°F shall be used for heating. Setpoint temperature of 78°F and setback temperature of 80°F shall be used for cooling. The simulated hourly schedules shall be as described in Table 4.

Table 4: Hourly Thermostat schedule

Hour of day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating set-point °F	70	70	70	70	70	70	70	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	70
Cooling set-point °F	78	78	78	78	78	78	78	78	78	80	80	80	80	80	80	78	78	78	78	78	78	78	78	78

6.5.2 Space conditioning (Table G3.1 No. 1 b)

All conditioned spaces in the *proposed design* shall be simulated as being both heated and cooled, even if no heating or cooling system is to be installed, and as described in SG Section 3.3.

6.5.3 Baseline HVAC System Type

The HVAC systems in the *baseline building design* shall be of the type and description specified in *Appendix G* Section G3.1.1, shall meet the general HVAC system requirements specified in Section G3.1.2, and shall meet any system-specific requirements in Section G3.1.3 that are applicable to the baseline HVAC system types. As clarified in the first note below *Appendix G* Table G3.1.1-3, a multifamily building is a *residential* building type. Thus, the *common spaces* that are essential to the building's *residential* function, such as corridors, lobby, etc. must be modeled with the <u>residential</u> baseline HVAC system type (System 1 or 2 only) depending on the project's climate zone. *Appendix G* Section G3.1.1(b) requires using additional system types for non-predominant conditions, if they total more than 20,000 ft^2, does not apply. Baseline HVAC System Types 3-8 may not be used, except in appropriate *nonresidential* spaces that exceed 20,000 ft^2.

EXAMPLE 6-7 – Baseline HVAC System Type

Q: 25 story multifamily building in Climate Zone 4A has 1,000 ft2 of common space on each floor, including corridors, trash rooms, and stairwells. Together, these spaces account for 25,000 ft2. Corridors are heated with gas and cooled. Stairs are heated with electric resistance but not cooled. What baseline system type should be modeled for the common spaces?

A: <u>Correct Approach:</u> Apartments and corridors are modeled with Baseline HVAC System 1-PTAC. Stairs that are heated but not cooled, and are modeled with System 9 – Constant Volume, gas-fired furnace. Baseline heating source is natural gas irrespective of heating source in the proposed design, since the building is located in Climate Zone 4A.

<u>Incorrect Approach</u>: Common spaces are modeled with baseline System 7 following exception G3.1.1(b), since they account for over 20,000 ft2 and cover more than 5 floors.

6.5.4 Baseline HVAC System Capacity

Baseline HVAC system coil capacities shall be oversized by 15% for cooling and 25% for heating; i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be 1.15 for cooling and 1.25 for heating. Only the coil capacities, and not the fan flow rates, shall be over-sized.

Weather conditions used in sizing runs to determine baseline equipment capacities shall be based either on hourly historical weather files containing typical peak conditions or on design days developed using 99.6% heating design temperatures and 1% dry-bulb and 1% wet-bulb cooling design temperatures per *Appendix G* Section G3.1.2.2.1. The <u>typical</u> hourly schedules for lighting, equipment, occupancy, and infiltration must be used in the sizing runs for Systems 1 and 2, and not the peak loads.

Where multiple HVAC zones or residential spaces are combined into a single thermal block, the efficiencies for baseline HVAC Systems shall be based on the equipment capacity of the thermal block divided by the number of HVAC zones or residential spaces.

6.5.5 Baseline HVAC DX System Efficiency

a. DX efficiency for the baseline Systems 1 any 2 must be based on *Appendix G* Table G3.5.4. The corresponding values are included in Table 5 for convenience.

Table 5: DX Efficiency of Baseline System 1 and 2

Equipment Capacity	Rated Efficiency (EER cooling, COP heating)
PTAC All Capacities (cooling mode)	12.5 – (0.213 x Capacity/1000)
PTHP All Capacities (cooling mode)	12.3 – (0.213 x Capacity/1000)
All Capacities (heating mode)	3.2 – (0.026 × Cap/1000)

”Capacity” used in the efficiency equations must be based on the total net cooling capacity of the individual baseline systems as defined in SG Section 6.5.4, but no less than 7,000 Btu/h and no greater than 15000 Btu/h, per footnote (a) to *Appendix G* Table G3.5.4.

b. Where efficiency ratings include supply fan energy, the efficiency rating shall be adjusted to remove the supply fan energy as follows, per *Appendix G* Section G3.1.2.1:

$COP_{nfcooling} = 7.84\text{E-}8 \times EER \times Q + 0.338 \times EER$

$COP_{nfcooling} = –0.0076 \times \text{SEER}^2 + 0.3796 \times SEER$ (applies to baseline PSZ systems < 65 kBtu/hr)

$COP_{nfheating} = 1.48\text{E-}7 \times COP_{47} \times Q + 1.062 \times COP_{47}$ (applies to heat pump heating *efficiency* only)

$COP_{nfheating} = –0.0296 \times \text{HSPF}^2 + 0.7134 \times HSPF$ (applies to baseline PSZ - HP systems < 65 kBtu/hr)

COPnfcooling and *COPnfheating* are the packaged HVAC equipment cooling and heating efficiencies, respectively, excluding supply fan power.

Q is the cooling capacity in Btu/h, and is equal to “Capacity” as defined in SG Section 6.5.5.

EER, SEER, COP, and HSPF must be based on *Appendix G* Tables G3.5.1, 2 & 4.

6.5.6 Baseline Boiler and Furnace Efficiency

Baseline gas-fired boiler and furnace efficiencies must be based on *Appendix G* Table G3.5.6 and G3.5.5 respectively, quoted in Table 6.

Table 6: Gas-fired Heating Equipment Efficiency

Equipment Type	Size Category	Minimum Efficiency
Warm-air furnace	<225,000 Btu/h	78% *AFUE* or 80% *Et*
	>=225,000 Btu/h	80% *Ec*
Unit Heater	All capacities	80% *Ec*
Boiler	<300,000 Btu/h	80% *AFUE*
	>=300,000 Btu/h and <=2,500,000 Btu/h	75% *Et*

	>2,500,000 Btu/h	80% *Ec*

The same units must be used to enter heating efficiency into the simulation tool for the *baseline* and *proposed design* using conversions described below.

a. Where the annual fuel utilization ration (AFUE) is provided, the thermal efficiency (Et) shall be calculated as follows:

Packaged and split systems: Et = 0.0051427*AFUE + 0.3989
Boilers with 75%<=AFUE<80%: Et=0.1*AFUE+72.5%
Boilers with AFUE>=80%: Et=0.875*AFUE+10.5%

b. For furnaces and boilers with efficiency rating prescribed as combustion efficiency (Ec), 2% jacket losses shall be assumed

Et=Ec-2%

6.5.7 Baseline PTHP Heating Control

Projects in Climate Zones 0 to 3A shall be modeled with System 2 - PTHP in the baseline (*Appendix G* Table G3.1.1-3). Following *Appendix G* Section G3.1.3.1, the electric auxiliary heat may not be modeled at ambient temperatures above 40°F. The PTHP must be modeled to allow operation in conjunction with the auxiliary heat at temperatures of 25°F and higher. Below 25°F, only the auxiliary heat should be modeled. For example, for eQUEST users, set “Minimum HP Heat Temp” to 25°F and “Maximum HP Supp Temp” to 40°F.

6.5.8 Performance Curves

Projects that use custom performance curves for HVAC systems in the proposed design must use baseline performance curves from ASHRAE 90.1-2016 Performance Rating Method Reference Manual [2] which are better aligned with 90.1 efficiency requirements than some default software curves.

6.5.9 Proposed HVAC System Capacity and Efficiency

The *Proposed Design* equipment shall be modeled using the specified system type, capacity, and supply airflow. Auto-sizing cannot be used.

In all cases, the same modeling method and/or efficiency units shall be used in the Baseline and Proposed model. Conversions provided in Section 6.5.1 must be used.

Where efficiency ratings include supply fan energy, the efficiency rating shall be adjusted to remove the supply fan energy from the efficiency rating in the *baseline building design* using manufacturers’ data at the AHRI rated conditions, and equations below.

[2] http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-25130.pdf,

Exception: If the supply fan in the *proposed design* cycles with load and fan energy is included in the energy-efficiency rating of the equipment, fan energy shall not be modeled explicitly.

Where efficiency rating of the specified DX cooling and heating systems includes supply fan energy, the efficiency rating shall be adjusted to remove the supply fan energy as follows:

a. Cooling:

EER=Net Cooling [Btu/h] / Total Input Power [W]

Indoor Fan Power [W]= (Gross Cooling [Btu/h]-Net Cooling [Btu/h])/3.412[Btu/h x W]

COPnfcooling =Gross Cooling [Btu/h]/((Total Input Power [W]–Indoor Fan Power[W])x3.412[Btu/h x W])

b. Heating:

COPheating=Net Heating [Btu/h]/ (Total Input Power [W] x 3.412 [Btu/h x W]

Indoor Fan Power [W]= (Net Heating [Btu/h]-Gross Heating [Btu/h])/3.412[Btu/h x W]
COPnfheating =Gross Heating [Btu/h]/((Total Input Power [W] – Indoor Fan Power [W])x3.412[Btu/h x W])

EXAMPLE 6-8 – Proposed HVAC System Efficiency

Q: Apartments in the proposed design have EER 13 through-the-wall air-conditioners that cycle with the cooling load, and hydronic baseboards. Ventilation is provided by an energy recovery ventilator. Corridors are served by the rooftop unit (RTU) with parameters specified below. How should cooling efficiency of the RTU and through-the-wall AC be calculated and modeled in eQUEST?

Cooling Performance[a]	
Gross Cooling Capacity - Full Load	103,000
EER/IEER[b]	12.6/22.5
Nominal cfm/AHRI Rated cfm	3,400/2,975
AHRI Net Cooling Capacity - Full Load	99,000
System Power (kW)	7.86

A: RTU cooling efficiency with fan power extracted (COPnfcooling) is calculated as shown below. EIR=0.2214 is entered in eQUEST. Fan energy is modeled based on the BHP of the specified RTU supply fan.

Net Cooling Capacity	Btu/hr	A	99,000
EER		B	12.6
Total Packaged Unit Power	W	C=A/B	7,857
Gross cooling capacity	Btu/hr	D	103,000
Supply fan power	W	E= (D-A)/3.412	1172
COPnfcool		F=D/3.412/(C-E)	4.52
EIR		1/F	0.2214

Through-the-wall AC cycles with load, thus fan power does not have to be extracted and explicitly modeled. The cooling efficiency including fan power is calculated as COP=13/3.412=3.81. It is entered in eQUEST as EIR=1/3.81=0.262. AC fan power is modeled as 0 W/CFM, since it is captured in the efficiency rating.

6.5.10 HVAC Fan System Energy

6.5.10.1 Baseline System Power

a. The design supply flow rate for the baseline systems, except System 8 and 9, must be based on a supply-air-to-room temperature set-point difference of 20°F or the minimum outdoor airflow rate, whichever is greater (*Appendix G* Section G3.1.2.8). For baseline Systems 9 and 10, the temperature difference between the supply air temperature setpoint of 105°F and the design space heating temperature setpoint shall be used instead of 20°F difference (*Appendix G* Section G3.1.2.9)

The baseline system fan power must be modeled following *Appendix G* Section G3.1.2.9. The fan power allowance for Baseline Systems 1, 2, 9, and 10, which are common in multifamily projects, is shown below for convenience.

$P_{fan} = CFM_S \cdot 0.3$

P_{fan} = electric power to fan motor (watts)

CFM_S = the baseline system maximum design supply fan airflow rate in cfm, established as described above.

Fan power allowance for baseline Systems 9 and 10 may be increased to account for non-mechanical cooling, if provided in the *proposed design*, as described in G3.1.2.9.

b. The calculated system fan power shall be distributed to supply, return, exhaust, and relief fans in the same proportion as the *proposed design*. It represents the total fan power allowance including supply, return, and exhaust fans, central and zonal. No additional fan energy allowance, such as for continuously or intermittently running local exhaust fans

EXAMPLE 6-9 – Baseline Fan Power Allowance

Q: Proposed design has 100% outdoor air roof-top unit (RTU) serving corridors and waster-source heat pumps in apartments. Each apartment is served by continuously running rooftop bathroom exhaust fans and intermittent in-unit kitchen exhaust fans. There is an exhaust fan serving elevator machine room, with the unconditioned make-up air supplied from the outdoors. A rooftop exhaust fan serves trash rooms on each floor, with make-up air coming from the corridor RTU. What is the baseline fan power allowance for each thermal block?

A: Baseline fan power allowance is shown in the table below.

Apartments	0.3 W/CFM, with no additional fan power allowance for kitchen and bathroom exhaust fans
Corridors, including trash rooms	0.3 W/CFM, with no additional fan power allowance for trash room exhaust fan, since it exhausts conditioned air and is part of the same HVAC zone as the corridors
Elevator machine room	Elevator machine room is not a conditioned space, and the make-up air exhausted by the fan is unconditioned. Thus, the space will not be modeled with the baseline PTAC, and the PTAC fan power allowance does not apply. The exhaust fan must be modeled as described in SG Section 6.10.1.

serving dwelling units or dedicated make-up air unit that may be specified for the *proposed design*, shall be included in the *baseline*.

c. 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. 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 and overall fan efficiency fraction (including motor, drive, and mechanical efficiencies) using the following equation to convert between kW/cfm (power per unit flow) and TSP in.wg.

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

6.5.10.2 Proposed System Power

Proposed Design HVAC fan power and flow for exhaust, supply, and return fans must be modeled explicitly, as specified.

Exception: fan energy of ductless packaged systems that cycle with load, such as PTHP, PTAC, room air-conditioners, and variable refrigerant flow heat pumps shall not be modeled explicitly if the fan power is included in the equipment efficiency rating.

6.5.10.3 HVAC Fan System Schedule

Baseline Building Design: Supply and return fans shall operate continuously whenever spaces are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours (*Appendix G* Section G3.1.2.4). Following this rule, the baseline HVAC systems in apartments and corridors must be modeled as running continuously. Unoccupied periods may exist in supporting spaces such as rental office, mechanical rooms, etc.

Proposed Design: HVAC fans that provide outdoor air for ventilation shall run continuously whenever spaces are occupied, and shall be cycled to meet heating and cooling loads during unoccupied hours. (*Appendix G* Table G3.1 No. 4).

EXAMPLE 6-10 – HVAC Fan Schedule

Q1: A multifamily project has fan-coil units that provide heating and cooling to apartments. A dedicated make-up air unit with energy recovery provides outdoor air to apartments and corridors. What should be the baseline and proposed fan power and schedule for systems serving apartments and corridors?

A1: Proposed Design must reflect the fan power and schedule of the specified systems, including individual apartment fan coils cycling with heating/cooling load and continuously running make-up air unit.

Baseline Building Design must be modeled with continuously running System 1/2 (depending on the project's climate zone) serving each apartment and corridors. The total baseline fan power allowance is 0.3 W/CFMS, with no additional allowance for the dedicated make-up air unit used in the Proposed Design or energy recovery. Energy Recovery fan power adjustment does not apply to the baseline Systems 1/2 (*Appendix G* Section G3.1.2.9). Furthermore, since ventilation to each apartment and corridor is provided by System 1/2 serving each apartment and corridor, the exhaust air energy recovery must not be modeled in the baseline following *Appendix G* Section G3.1.2.10.

Q2: Apartments in a multifamily project are heated by hydronic baseboards and use window AC for cooling. Dwelling-unit ventilation is provided by a continuously running bathroom exhaust fan that pulls make-up air through trickle vents in bedrooms and living areas. Local mechanical exhaust for the bathroom is met by the same continuously running exhaust fan. Local mechanical exhaust for the kitchen is met by an intermittent range hood. What should be the baseline and proposed fan power and schedule for systems serving apartments?

A2: Proposed Design must reflect the fan power and schedule of the specified systems, including continuously running bathroom exhaust fan, and intermittent kitchen exhaust fan. Fan energy of window AC does not have to be modeled explicitly, since it's included in the efficiency ratings and the units cycling with cooling load and not run continuously.

Baseline Building Design must be modeled with continuously running System 1/2 (depending on the project's climate zone) serving each apartment and corridors. The total baseline fan power allowance is 0.3 W/CFMS, with no additional allowance for bathroom and kitchen exhaust fans.

Q3: Apartments in a multifamily project are heated and cooled by individual split-system heat pumps. Dwelling unit mechanical ventilation is provided by supplying outside air directly into the return ductwork of the air handler. Local mechanical exhaust for the bathroom is met by an intermittently running exhaust fan. Local mechanical exhaust for the kitchen is met by an intermittent range hood. What should be the baseline and proposed fan power and schedule for systems serving apartments?

A3: Proposed Design must reflect the fan power and schedule of the specified systems, including individual apartment air handlers running continuously, and intermittent bathroom and kitchen exhaust fans.

Baseline Building Design must be modeled with continuously running System 1/2 (depending on the project's climate zone) serving each apartment and corridors. The total baseline fan power allowance is 0.3 W/CFMS, with no additional allowance for bathroom and kitchen exhaust fans.

6.5.11 HVAC Distribution System

6.5.11.1 Baseline Hot Water Distribution System

Hot water pump energy, and hot water loop control on projects with the baseline system 1 – PTAC shall be modeled as described in *Appendix G* sections G3.1.3.3, G3.1.3.4 and G3.1.3.5, and as described below:

a. Hot-water design supply temperature shall be modeled as 180°F and design return temperature as 130°F.

b. 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.
c. Hot-water pump power shall be modeled as 19W/GPM.
d. Pumping system shall be modeled with continuous variable flow, i.e. with two way valves on PTACs. The minimum flow through the boiler shall be 25% of design flow rate.
e. Systems serving 120,000 ft^2 or more shall be modeled with variable-speed drives, and systems serving less than 120,000 ft^2 shall be modeled as riding the pump curve. PTACs must be modeled with the two-way valves on the hot water loop.
f. Hot water loop should be modeled as operating "on demand", with pumps shut off when heating is not required.

6.5.11.2 Proposed Hot Water Distribution

HVAC pumps in the *Proposed Design* shall be modeled using the actual system parameters including but not limited to head, flow control, and pump motor efficiency.

6.5.11.3 Piping and Duct Losses

Do not model piping or duct losses. Refer to program requirements for specifications relating to pipe insulation, duct insulation and duct leakage amounts.

Projects *may* pursue performance credit for sealing central exhaust ventilation ductwork. To receive this credit, the actual measured duct leakage must be below the mandatory requirements of the program. To model the energy savings, the actual measured leakage shall be added to exhaust CFM in the *Proposed Design*. Similarly, add the exhaust leakage allowed in the mandatory requirements to the exhaust CFM in the *Baseline Building Design*.

6.5.12 Mechanical Ventilation

6.5.12.1 Baseline Building Design

a. Ventilation in Dwelling Units

Minimum *ventilation* outdoor air intake flow shall be the same as in the *proposed design* (*Appendix G*, Section G3.1.2.5), except where indicated otherwise in the following provisions.
The baseline ventilation method (mechanical versus natural) and controls (continuous versus intermittent) must be modeled as specified for each application.

The baseline local mechanical exhaust from bathrooms and kitchens, and the baseline dwelling-unit ventilation rate shall be modeled using the same rates as in the *Proposed Design*, without exceeding the minimum required by ASHRAE 62.2-2016 or the building code, whichever is greater, by more than 15 cfm or 15%.

If the same mechanical ventilation system is used to provide both *local mechanical exhaust* and *dwelling unit ventilation*, the baseline ventilation rate must be based on the greater of the two rates.

> EXAMPLE 6-11 – Combination Local Exhaust and Dwelling Unit Mechanical Ventilation
>
> A two-bedroom, 1,000 ft2 apartment with one bathroom, requires 32.5 CFM to meet the minimum recommendations for dwelling unit mechanical ventilation, per Equation 4.1a of ASHRAE 62.2-2010. The local mechanical exhaust system serving the bathroom runs continuously to simultaneously provide dwelling unit mechanical ventilation. It may be modeled as 32.5 CFM in the Baseline, even though it exceeds the local mechanical exhaust requirement of 20 CFM.

b. Ventilation in spaces other than dwelling units

The *baseline* ventilation rate in common spaces shall be modeled using the same rates as in the *Proposed Design*, without exceeding the minimum required by ASHRAE 62.1-2016 or the building code, whichever is greater, by more than 15 cfm or 15%. Where corridors in the *Proposed Design* are supplied with outdoor air to meet the required rates for both the corridor and dwelling units, corridors in the *Baseline Building Design* shall only be modeled with outdoor air at the rates required just for the corridor.

6.5.12.2 Proposed Design

Exhaust and supply ventilation rates and controls must be modeled as specified.

6.5.12.3 Mechanical Ventilation Schedule

a. The mechanical ventilation schedule may differ between *Baseline Building Design* and *Proposed Design* when necessary to model nonstandard efficiency measures, provided that the revised schedules are approved by the rating authority. Measures that may warrant use of different schedules include Demand Control Ventilation (DCV), as described in *Appendix G*, Table G3.1 No. 4 Exception 2.

b. DCV in parking garages must be modeled as described in SG Section 6.6. Individual exhaust ventilation in kitchens and bathrooms with manual control or interlocked with lighting switch does not qualify as a DCV measure. DCV in common laundry rooms must be modeled as follows:

- the baseline ventilation CFM must be based on the lesser of the design ventilation flow rates required by the applicable code or recommended by the manufacture of the laundry equipment, if any, and the actual specified flow rate.
- the modeled reduction in runtime hours must be documented and is subject to approval by the rating authority.

c. If not specified, intermittent *local mechanical exhaust*, such as intermittently running range hoods or bathroom exhaust fans, shall be modeled with a 2 hr/day runtime, or converted to an equivalent 24 hr/day runtime if combined with *dwelling unit mechanical ventilation*. The same modeling method and schedule must be used in the baseline and proposed design.

6.5.13 District Systems

The baseline HVAC system must be modeled as described in *Appendix G*, Section G3.1.1.1 – 5, G3.1.3.9, and G3.1.3.10 for projects with purchased chilled water and heat. The purchased chilled water energy use must be converted into the associated energy use using IPLV from *Appendix G* Table G3.5.3, based on the modeled cooling load, and type and number of chillers prescribed by G3.1.3.7. The purchased heat must be converted into the associated energy use using boiler efficiency from Table IPLV from *Appendix G* Table G3.5.6, based on the modeled heating load, and type and number of boilers prescribed by G3.1.3.2.

The proposed HVAC system must be modeled as specified, with the purchased chilled water and/or heat, and including the associated pumps and other related equipment. Purchased chilled water and heat must be converted to source energy assuming the same type and number of chillers and boilers as in the baseline, the minimum part load IPLV chiller, and the minimum boiler efficiency from Section 6 of the *reference edition of 90.1*.

6.6 Other Heating and Ventilation Systems

6.6.1 Systems for snow/ice melt, pipe freeze protection, and garage/plenum heating

If snow/ice melting systems, freeze protection for piping, and/or other space heating systems are installed in a garage, plenum, or other unconditioned areas (such as carports, passageways, sidewalks), the associated energy use must be included in the *Proposed Design* and *As-Built*, and the *Baseline*. In mixed used buildings where the nonresidential spaces are not being modeled, if these systems serve both residential and nonresidential spaces, they shall be pro-rated accordingly.

6.6.2 Ventilation Control in Garages

Baseline and proposed garage exhaust fans must be modeled as described below, and treated as a regulated load.

$E_{base} = BHP_{base} \times 0.746 / Eff_{base} \times 8760$ [hrs/yr]

$E_{prop} = BHP_{prop} \times 0.746 / Eff_{prop} \times 365 \times (8.4 + PDW_{min} \times 15.6)$

where,

E_{base} [kWh] = annual energy consumption of the baseline garage exhaust fan

BHP_{prop} = brake horse power of the specified exhaust fan

BHP_{base} = brake horse power of the baseline exhaust fan;

$BHP_{base} = BHP_{prop} \times CFM_{base} / CFM_{prop}$

CFM_{prop} = specified design exhaust CFM

CFM_{base} = the lesser of the CFM_{prop} and A[ft^2] x 0.75 [CFM/ft^2], where A is the garage floor area and 0.75 [CFM/ft^2] is the garage exhaust flow required by ASHRAE Standard 62.1

Eff_{base} = baseline motor efficiency from Appendix G Table G3.9.1 for the next motor size larger than BHP

E_{prop} [kWh] = annual energy consumption of the proposed garage exhaust fan

Eff_{prop} = electrical efficiency of the specified fan motor

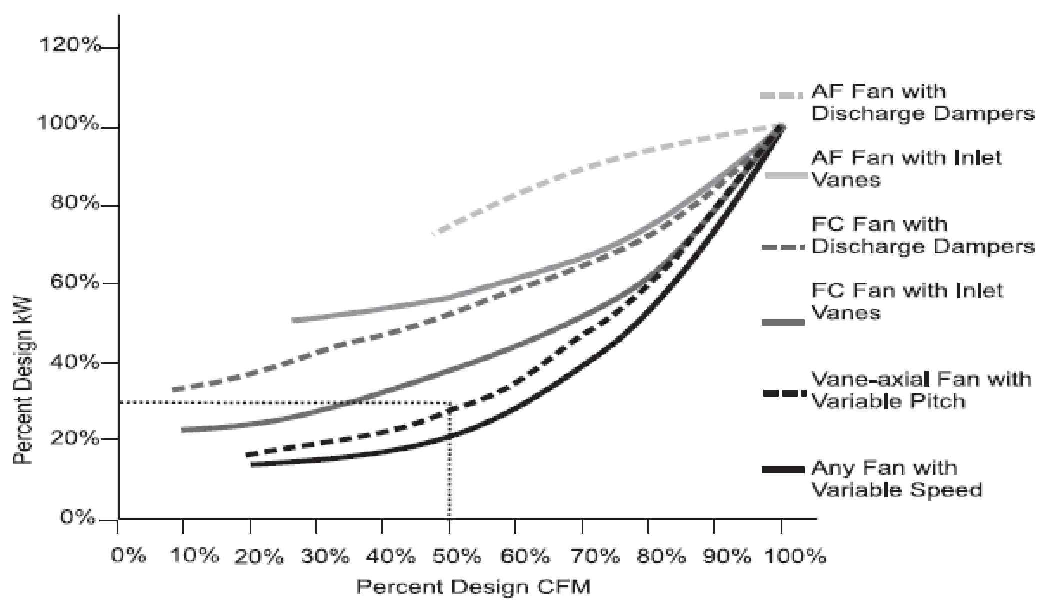
PDW_{min} = Percent Design kW fraction determined from graph below, based on the specified flow control method and the minimum Percent Design CFM, equal to the ratio of design exhaust CFM and the minimum CFM allowed by the specified controls.

0.746[kW/bhp] = kW to BHP conversion factor

365 [days/yr] = number of days in a year

8.4 [hrs/day] = hours per day when exhaust fan runs at design CFM

15.6 [hrs/day] = hours per day when contaminant level allows fan to run at the min CFM



EXAMPLE 6-12 – Demand Control Ventilation in Garage

Q: Proposed Design has 26 BHP exhaust fan sized to provide 1 cfm/ft^2 peak flow. The fan run is controlled by CO sensor with the VSD drive that allows turndown to 20% of design CFM. Fan motor efficiency is 94%. What should be the baseline and proposed exhaust fan energy?

A: The baseline and proposed fan energy are calculated as shown below, and are treated as regulated load. The proposed fan is sized for the maximum exhaust flow that exceeds the minimum required by ASHRAE 62.1, thus the baseline BHP is prorated in proportion to the exess flow.

BHP_{base} = 0.75*26= 19.5; Eff_{base} = 0.9; $\mathbf{E}_{\mathbf{base}}$ = 19.5*0.746/0.9*8760=141,591 [kWh]

$\mathbf{E}_{\mathbf{prop}}$ = 26*0.746/0.94*365*(8.4+0.1*15.6)=98,6919 [kWh]

6.7 Domestic (Service) Water Heating (Appendix G Table G3.1 No. 11)

6.7.1 Equipment Type and Efficiency

6.7.1.1 Baseline Building Design

a. The baseline must be modeled with the central natural gas-fired storage water heater (*Appendix G* Table G3.1.1-2). If natural gas is not available on-site, propane must be used in lieu of natural gas. Water heater efficiency shall be as follows per ASHRAE 90.1 Table 7.8:

Thermal Efficiency, Et: 80% Et

Stand-by loss, SL, Btu/h: Q/800+110 √ V

Q = nameplate input rate in Btu/h, based on the proposed design

V= the rated tank volume in gallons, based on the proposed design

<u>Exception:</u> If proposed design has in-unit water heaters, the baseline must be modeled with a gas storage in-unit water heater with efficiency EF=0.544.

b. Unfired storage tank insulation in the *Baseline Building Design,* if applicable, shall be R-12.5, per ASHRAE 90.1 Table 7.8.

6.7.1.2 Proposed Building Design

The service water heating system type, heating source, capacity, and efficiency in the modeled must be consistent with design documents.

Where a combined system has been specified to meet both space heating and service water-heating loads, the proposed design shall reflect the actual system type using actual component capacities and efficiencies.

Water heater efficiency may be described through different parameters including thermal efficiency, combustion efficiency, stand-by loss, recovery efficiency, energy factor, etc. The same units of efficiency shall be used in *Baseline Building Design* and *Proposed Design*. If modeling software requires the input of more than one efficiency type (for example Recovery Efficiency and Energy Factor), but only one efficiency type is provided in ASHRAE 90.1 or manufacturer specifications, then the same algorithm shall be used to generate the missing efficiency for both the *Baseline Building Design* and *Proposed Design*. All such conversions must be documented and submitted with the model.

6.7.2 Hot Water Demand.

6.7.2.1 Baseline

Hot water demand in the *Baseline Building Design* shall be determined based on the number of occupants in the building when fully occupied assuming one person per bedroom. Per-person consumption of 12/25/44 gal/day shall be used based on low/medium/high usage determined based on appropriate occupancy demographics. Low per-person values are associated with buildings having such occupant demographics as all occupants working, seniors, and middle income. High usage is associated with high percentages of children, low income, public assistance, or no occupants working, and can only be used if the building qualifies as affordable housing. Hot water consumption of clothes washers and dishwashers is not included in the per-person usages above, and shall be added according to the calculations described below.

6.7.2.2 Proposed Design

a. **Low-flow Fixtures.**

   Hot water demand in the *Proposed Design* may be reduced to reflect lower flow rates of the installed fixtures if lower than required by the Energy Policy Act 1992 (EPACT 1992). The adjusted demand shall be calculated as follows:
   ProposedHWDemand[Gal/day]=BaselineHWDemand*(0.36+0.54*LFS/2.5+0.1*LFF/2.5)

   Where:

   LFS [GPM_{80psi}] = rated flow rate of the low-flow showerheads specified on the drawings

   LFF[GPM_{80psi}] = rated flow rate of the low-flow faucets specified on the drawings

   OR, for faucets rated at 60 psi:

   ProposedHWDemand[Gal/day]=BaselineHWDemand*(0.36+0.54*LFS/2.5+0.1*LFF/2.2)

   Where:

LFS [GPM_{80psi}] = rated flow rate of the low-flow showerheads specified on the drawings

LFF[GPM_{60psi}] = rated flow rate of the low-flow faucets specified on the drawings

b. Dishwashers.

In the *Proposed Design*, if no dishwasher is specified or a dishwasher is specified that is not ENERGY STAR certified, in the *Baseline Building Design* and *Proposed Design*, model hot water consumption of 1290 gal/year per apartment for washing dishes.

Water savings from ENERGY STAR dishwashers may be calculated as follows:

- Assume proposed water consumption of 860 gal/year per ENERGY STAR dishwasher [this default is used by EPA for an ENERGY STAR certified dishwasher].
- Calculate annual per-unit hot water demand reduction by subtracting annual hot water usage of the Proposed dishwasher from 1290 gal/year for standard dishwasher [this default is used by EPA for conventional dishwashers].
- Divide annual per unit savings calculated in the previous step by 365 and multiply by the number of dishwashers in the building to obtain total daily savings for the building.
- Subtract total daily savings from ProposedHWDemand to obtain adjusted daily demand of the *Proposed Design*.

Use the Service Water Heating worksheet of the ASHRAE Path Calculator_AppG2016 for reduced hot water demand calculations.

c. Clothes Washer Hot Water Usage.

If clothes washers are not specified in the *Proposed Design*, neither the *Baseline Building Design* nor *Proposed Design* shall be modeled with hot water consumption associated with washing clothes. If clothes washers are specified in the *Proposed Design*, determine hot water usage by each clothes washer in Baseline and Proposed Design as follows, using the Baseline values in the *Proposed Design* for clothes washers that are not ENERGY STAR certified:

	Baseline Design **Hot Water Gal/yr**	**Proposed Design** **Hot Water Gal/yr** **(ENERGY STAR certified only)**
In-unit clothes washer	0.2*12,179	0.2*5,637
Common space clothes washer	0.2*29,515	0.2*13,661

0.2 = estimated ratio of hot water to total water consumed per year.

Values based on annual water consumption of conventional and ENERGY STAR clothes washers, from EPA Savings Calculator for Clothes Washers.

Usage assumptions used by EPA for commercial clothes washers are based on 950 loads/year.

Convert annual hot water consumption calculated above to hourly values using appropriate hourly load profile as recommended by the energy modeling software tool.

6.7.3 Domestic Hot Water Distribution System

- **a.** Distribution losses shall not be modeled in either baseline or proposed design.
- **b.** The same hot water setpoint capable of delivering a temperature of 120°F at the point of use shall be used in both *Baseline Building Design* and *Proposed Design*.
- **c.** If hot water recirculation system is present in the *Proposed Design*, it shall be included in both *Baseline* and *Proposed Designs*, per *Appendix G* Table G3.1 No. 11 (f).

6.8 Receptacles and other plug loads (Appendix G Table G3.1, Section 12)

- **a.** Non-lighting receptacle loads shall be included in the simulation and shall be identical in the *Baseline Building Design* and *Proposed Design*, unless the particular load source, such as appliances, is impacted by a specific Energy Reduction Measure. Where the appliance is not specified or installed but a space or room is intended for an appliance, its energy consumption shall be included in the simulation.

  Exception: Energy consumption of dishwashers, clothes washers, and clothes dryers shall not be included in either *Baseline Building Design* or *Proposed Design* if they are not specified for the project and no space or room has been designed for them.

- **b.** The fraction of loads contributing to internal heat gain, shall be identical in the *Baseline Building Design* and *Proposed Design,* as specified in the following table.
- **c.** Where the *Proposed Design* specifies ENERGY STAR certified appliances, the default values in the following table may be used. Alternatively, the rated energy consumption of the installed appliance may be used in the *Proposed Design*, if the Baseline electricity usage is based on the maximum allowed by the Federal Standard for that specific appliance.
- **d.** Where the *Proposed Design* specifies non-ENERGY STAR certified appliances, and energy savings are not being modeled, energy consumption for the appliances in the *Baseline Building Design* and *Proposed Design* can both either be the Baseline values in the table below or can be the rated energy consumption of the installed appliance.
- **e.** Where the *Proposed Design* specifies non-ENERGY STAR certified appliances, and energy savings are being modeled, the rated energy consumption of the installed appliance shall be used in the *Proposed Design*, and the Baseline electricity usage must be based on the maximum allowed by the Federal Standard for that specific appliance.
- **f.** Where annual or daily consumption is provided in the table below, it must be converted into the equivalent design load (Watt or Watt/ft^2) and hourly schedule as appropriate for the energy modeling software being used.

Load Source	Energy Consumption	Sensible/ Latent Load Fraction (4)
Refrigerator (1)	529 kWh/yr Baseline Building electricity usage (conventional unit) 423 kWh/yr Proposed Design electricity usage (ENERGY STAR unit)	1.00/0.0
Dishwasher (1)	206 kWh/yr Baseline Building electricity usage (conventional unit) 164 kWh/yr Proposed Design electricity usage (ENERGY STAR unit)	0.60/0.15
Clothes Washer (1)	In-unit clothes washers: 81 kWh/yr Baseline Building electricity usage (conventional unit) 57 kWh/yr Proposed Design electricity usage (ENERGY STAR unit) Commercial clothes washers: 196 kWh/yr Baseline Building electricity usage (conventional unit) 138 kWh/yr Proposed Design electricity usage (ENERGY STAR unit)	0.80/0.0
Cooking (2) (electric stove/range)	604 kWh/year	0.40/0.30
Cooking (2) (gas stove/range)	45 Therms/year	0.30/0.20
Clothes Dryer (2)(5)	Vented/Ventless Electric Dryer, Standard: kWh/yr = [418 + (139*Nbr)]*F (conventional unit) kWh/yr = [331 + (110*Nbr)]*F (ENERGY STAR unit)	Electric Dryer: 0.15/0.05
	Vented/Ventless Electric Dryer, Compact (120 V): 282*F kWh/yr (conventional unit) 223*F kWh/yr (ENERGY STAR unit)	Electric Dryer: 0.15/0.05
	Vented Electric Dryer, Compact (240 V): 311*F kWh/yr (conventional unit) 246*F kWh/yr (ENERGY STAR unit)	Electric Dryer: 0.15/0.05

Load Source	Energy Consumption	Sensible/ Latent Load Fraction (4)
	Ventless Electric Dryer, Compact (240 V): 399*F kWh/yr (conventional unit) 317*F kWh/yr (ENERGY STAR unit)	Electric Dryer: 0.15/0.05
	Gas Dryer: Electricity: kWh/yr = [38.0 + (12.7*Nbr)]*F (conventional unit) Gas: Therms/yr = [26.5 + (8.8*Nbr)]*F (conventional unit) Electricity: kWh/yr = [31.0 + (10.4*Nbr)]*F (ENERGY STAR unit) Gas: Therms/yr = [21.6 + (7.2*Nbr)]*F (ENERGY STAR unit)	Gas Dryer: Electricity – 1.0/0.0 Gas – 0.10/0.05
	Nbr = Average number of Bedrooms in dwelling units. F = scale factor to account for increased number of cycles of common space clothes dryers. F=1 for in-unit clothes dryers. F=2.423 for common space clothes dryers.	
Miscellaneous dwelling unit Plug Loads (3)	0.5 W/ft^2 or 1.05 kWh/FFA FFA = Finished Floor Area of living space in square feet	0.90/0.1
Miscellaneous Non-dwelling unit Plug Loads (3)	Corridors, restrooms, stairs, and support areas: 0.2 W/ft^2 design; 0.7 kWh/ft^2 annual usage. Offices: 1.5 W/ft^2 design; 4.9 kWh/ft^2 annual usage Other Multifamily Public& Common Areas: 0.5 W/ft^2 design; 1.6 kWh/ft^2 annual usage	1.0/0.0

Notes to table:

(1) Energy consumption of refrigerator, dishwashers and clothes washers is based on information posted at www.energystar.gov, including the *Product Lists* and *Savings Calculators*

(2) Energy consumption data is per Table 11 of the Building America Research Benchmark Definition, Updated December 29, 2004, as made available at

http://www.p2pays.org/ref/36/35765.pdf

(3) Plug loads are per Table N2-3 of California's 2005 *Nonresidential* ACM Manual; non-dwelling units modeled with a 9 hour/day schedule, *dwelling unit*s modeled with a 5.8 hour/day schedule.

(4) Sensible and Latent Load Fractions are expressed as the fraction of the annual energy consumption and are based on Table 11 of the Building America Research Benchmark Definition, Updated December 29, 2004, as made available at

http://www.p2pays.org/ref/36/35765.pdf

(5) Performance credit for reduced mechanical exhaust rates may be awarded for use of ventless dryers. Infiltration rate reduction of 3 CFM per dryer may be modeled in the proposed design if ventless dryers are specified. See Example 6-13. Sensible/latent load fraction shall be 0.6/0.15.

EXAMPLE 6-13 – Baseline Infiltration Modeling with Ventless Dryers in Proposed Design

Q. The project involves a 5-story multifamily building with slab-on-grade foundation. Each floor is 8,000 ft^2. The total gross floor area is 40,000. The total gross wall area is 17,117 ft^2. The total conditioned building volume is 360,068 ft^3. The project is modeled in eQUEST. How should be baseline infiltration rate be entered?

A. Based on Appendix G Table G3.1 No.5 (b), the baseline infiltration at 75 Pa is 0.4 CFM/SF of the total area of the envelope air pressure boundary, including the lowest floor, any below- or above-grade walls, and roof (or ceiling) including windows and skylights, separating the interior conditioned space from the unconditioned environment. The total envelope air pressure boundary for the project is S=8,000 x 2 + 17,117=33,117 ft^2

The air leakage at 75 Pa must be converted to leakage at the wind pressure using equations in Section G3.1.1.4 as follows:
I=33,117*0.4*0.112=1,484 CFM

Assuming there are 10 ventless dryers, add 3 CFM per dryer [1,484 + 3*10=1,514 CFM]. As-Built infiltration modeling does not change.

Table G3.1 No.5 (b) requires that simulation accounts for the factors such as weather conditions. "Air Change" method is the best fit for it in eQUEST. The calculated flow rate is converted to the air-change rate for input into eQUEST as follows:
1,514 [CFM] * 60 [min/hr] / 360,068 [ft^3] = 0.2523 [ACH]. The modeled infiltration schedule "ASH Inf Sch" has hourly fraction of 1 for all hours.

6.9 Elevators

In order to take credit for energy savings associated with improvements to the elevator system, baseline and *Proposed Design* energy estimates must be completed by a design engineer using a simulation based on first principles, traffic models, and engineering data from empirical studies. This energy model must include energy consumed when the elevator is idling and in stand-by as well as the energy consumed when actively transporting the cabs (loaded and unloaded) based on an appropriate traffic model for the building. Some elevator equipment manufacturers will provide these calculations upon request as part of their design assistance service.

When elevator energy usage is modeled using the approach described above, the baseline elevator design shall use the following assumptions:

a. The baseline elevator technology shall be based on number of stories serviced by the elevator as shown in the following table:

Elevator Service Height	Baseline Technology
4 to 6 stories	hydraulic
7-20 stories	geared traction
21+ stories	gearless traction

- **b.** Standard efficiency DC motors
- **c.** Variable Voltage Variable Frequency Drive
- **d.** No regeneration of braking power losses
- **e.** Controls based on simple elevator algorithm
    1. Continue traveling in same direction if there are remaining calls for service in that direction
    2. If no more calls for service in direction being traveled, stop and remain idle, or change direction if there are calls for service in that direction
- **f.** Traction elevators are equipped with counterweights sized at 50% of full load capacity. Hydraulic elevators have no counterweight or hydraulic accumulators.
- **g.** Worm gears for geared traction elevators
- **h.** 2:1 roping scheme

If the elevator system is not modeled using the approach described above, use the default table below to determine the total energy consumption associated with all elevators in the building for both the *Baseline Building Design* and the *Proposed Design*. If "NA", model as *energy neutral*, using no less than 2.0 MWh per year.

Default Elevator Energy Usage Table

	Annual Energy Consumption (MWh)		
Class	**HYDRAULIC (1-6 stories)**	**GEARED TRACTION (7-20 stories)**	**GEARLESS TRACTION (21+ stories)**
1: UP TO 6 DWELLING UNITS	1.91	NA	NA
2: 7 TO 20 DWELLING UNITS	2.15	NA	NA
3: 21 TO 50 DWELLING UNITS	2.94	3.15	NA
4: MORE THAN 50 DWELLING UNITS	4.12	4.55	7.57

10% of elevator energy usage shall be added to space heat gains.

Savings related to lighting in the cabin may be claimed as a separate performance credit if not included in an elevator system simulation. Cab lighting in the baseline model shall be equal to 1.3 W/ft^2 operated 24/7.

Ventilation system improvements may also claim savings based on high efficiency fans and/or modified control systems. Elevator cab ventilation in the baseline model shall be modeled using standard efficiency fans operating 24/7.

6.10 Other Loads

6.10.1 Non-HVAC Motors 1 HP or larger

Energy use of motors other than in systems that provide heating, ventilation, and air-conditioning, including, but not limited, to water booster pumps and hot water recirculation pumps, shall be modeled, and calculated as follows:

$P_{fan,base}$ = bhp x 746 / Fan Motor Efficiency$_{base}$
$P_{fan,prop}$=bhp x 746 / Fan Motor Efficiency$_{prop}$

$P_{fan,base}$ = electric power of the baseline motor [Watt]
$P_{fan,prop}$ = electric power of the proposed motor [Watt]
bhp = break horse power of the motor specified in the proposed design
Fan Motor Efficiency $_{base}$ = baseline motor efficiency from *Appendix G* Table G3.9.1, based on the next motor size greater than bhp
Fan Motor Efficiency$_{prop}$ = proposed motor efficiency, as specified

Savings may be claimed for improved motor efficiency or improved equipment controls, such as installing Variable Speed Drive on booster pumps. Constant flow capacity control may be assumed in the *Baseline Building Design*. Actual capacity control may be modeled in the *Proposed Design*.

When modeling non-HVAC motors, the baseline and proposed runtime hours used in the model must be documented and submitted with the model.

6.11 Water Savings (Optional)

In addition to energy cost savings associated with reduction in hot water usage, water saving measures can result in additional utility cost savings. The following guidelines indicate how these measures can be calculated to determine associated savings. Detailed calculations can be found in the Water Savings worksheet of the ASHRAE Path Calculator, that is used by projects not following these Simulation Guidelines.

a. Cost savings associated with reduced water use can be documented but are not factored into the *Performance Target*. For example, low-flow toilets can be included in the proposed measures, but do not impact the *Performance Target*. Energy cost savings associated with reduced hot water use from low-flow showerheads can contribute to the *Performance Target*.

b. Water cost savings for all measures may be calculated as follows:

Calculate baseline usage (in gallons) for each measure. EPAct 1992 flow requirements shall be used for baseline calculations. From the following table, determine the baseline flow rate for the appropriate fixture:

Baseline Fixtures	
Fixture	**Flow Rate**
Toilets (GPF)	1.6
Urinals (GPF)	1.0
Showerheads (GPM)	2.5
Bathroom Faucets (GPM)	2.5
Kitchen Faucets (GPM)	2.5

Determine the number of uses per day per occupant and usage duration for the appropriate HW demand and fixture from the table below:

Fixture Use				
Fixture Type	**Duration (sec)**			**Uses/Day/Occupant**
Toilets	--			5
Urinals	--			5
HW gallons/day/person	12	25	44	--
Showerheads	150	300	600	1
Bathroom Faucets	8	15	30	5
Kitchen Faucets	30	60	80	4

a. Calculate total baseline usage for each fixture type using the calculations detailed in the Water Savings worksheet of the ASHRAE Path Calculator.
b. Once baseline usage for each measure has been calculated, proposed usage shall be calculated similarly.
c. GPF Fixtures: Calculate proposed usage using the same usage assumptions as for the baseline, and the actual flow rate of the specified fixtures.
d. GPM Fixtures: Calculate proposed usage using the same usage assumptions as for the baseline, and the actual flow rate of the specified fixtures. (This will result in a total proposed water usage for cold and hot water combined. Please refer to Section 6.7.2 of these Simulation Guidelines to find guidance on calculating hot water usage savings to include as energy savings.
e. When on-site collected graywater or rainwater is used for sewage conveyance, the total estimated annual graywater quantity may be subtracted from the total annual design case

water usage. Estimated graywater quantity may not be greater than the total usage of fixtures that utilize it. For example, if graywater will be used only in flush toilets, the estimated graywater quantity cannot be greater than the total annual water usage for toilets.

f. To calculate water cost savings ($), multiply the calculated water savings by the current local rates for municipal water/sewer service.

APPENDIX A: Referenced Standards and Data Sources (Informative)

ANSI/ASHRAE/IESNA Standard 90.1 -2016 Energy Standard for Buildings Except Low-Rise Residential Buildings**:** Primary source document for *Baseline Building Design* features and guidance for creating a performance-based evaluation of a proposed building's energy features (Appendix G).

ANSI/ASHRAE/IES Standard 90.1-2013 User's Manual

ANSI/ASHRAE/IES Standard 90.1- 2016 Performance Rating Method Reference Manual, PNNL

Illuminating Engineering Society Lighting Handbook: handbook of lighting design published by the Illuminating Engineering Society of North America (IESNA), www.iesna.org.

Air-conditioning, Heating, and Refrigeration Institute (AHRI): reference AHRI ratings to determine seasonal efficiencies of heating and cooling systems, www.ahridirectory.org.

Energy Policy Act 1992 (EPACT 1992): federal legislation including provisions describing minimum efficiencies for certain appliances and plumbing fixtures. The complete document can be found in the Library of Congress website at http://thomas.loc.gov/cgi-bin/query/z?c102:H.R.776.ENR:

ASHRAE Standard 62.1-2010/13: Ventilation for Acceptable Indoor Air Quality: Provides guidance for ventilation system design and other related building features to ensure acceptable indoor air quality. Scope includes all buildings except low-rise residential.

ASHRAE Standard 62.2-2010/13: Ventilation and Acceptable Indoor Air Quality in Low Rise Residential Buildings: Provides guidance for ventilation system design and other related building features to ensure acceptable indoor air quality.