Energy Conscious Blueprint (ECB) Energy Modeling Guidelines for Connecticut

Version 4.2

November 2023

Prepared for Energize CT for use with 2022 Connecticut State Building Code based on ANSI/ASHRAE/IESNA Standard 90.1 2019 by Karpman Consulting.

Contents

1. Purpose and Applicability

1.1. Purpose

The purpose of the Energy Conscious Blueprint (ECB) Energy Modeling Guidelines (EMGs) is to establish clear, transparent, peer-reviewed modeling policies that improve the accuracy and technical integrity of models developed to support the Energy Conscious Blueprint (ECB) program pathways. Towards this end, these guidelines aim to fulfill the following objectives:

a. Describe program policies that deviate from ANSI/ASHRAE/IESNA Standard 90.1 2019 Appendix G ("90.1 Appendix G") modeling protocol to reflect incentive program funding rules.
b. Define program technical policies (such as required assumptions or methodologies) in areas left unregulated or ambiguous by Appendix G (e.g., rules governing modeled schedules).
c. Reiterate and explain Appendix G rules that are often misapplied or misinterpreted.
d. Provide examples to illustrate all the above.

The energy modeling guidelines (EMGs) are not a standalone document and must be used in conjunction with the modeling requirements in ASHRAE 90.1 2019 Appendix G.

1.2. Applicability

Projects with design requirements to meet IECC 2021 / ASHRAE 90.1 2019 must follow Energy Modeling Guidelines (EMGs) v4.0 - v4.2 based on the EMG version in effect when the Design Agreement is executed.

Projects required to meet IECC 2015 / ASHRAE 90.1 2013 must use EMG v3.x – v3.4 based on the EMG version in effect when the Design Agreement is executed. Projects required to meet IECC 2012 / ASHRAE 90.1 2010 or earlier codes must use EMG v2.0.

2. Additional Reference Materials

The following additional reference materials are available:

a. ASHRAE 90.1 2019 Users' Manual
b. ASHRAE 90.1 Section 11 and Appendix G Submittal Review Manual[1] is a comprehensive reference for reviewing modeling-based submittals. The Manual is a companion to the DOE/PNNL 90.1 Section 11 and Appendix G Compliance Form and supports 2016 and 2019 editions of ANSI/ASHRAE Standard 90.1. The document was developed to help authorities having jurisdiction/rating authorities review modeling-based submittals. It is recommended that energy modelers and design teams use the Manual to self-check the models before submitting documentation to the program.

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[1] ASHRAE 90.1 Section 11 and Appendix G Submittal Review Manual https://www.energycodes.gov/sites/default/files/2022-09/90.1%20Secton%2011%20and%20Appendix%20G%20Review%20Manual%20V03.pdf

c. ASHRAE Standard 90.1 Performance Based Compliance Form[2] (DOE/PNNL Compliance Form) is spreadsheet-based and meets the documentation requirements of Standards 90.1-2016 and 2019 for the Appendix G Performance Rating Method. It helps the modeler establish simulation inputs for the baseline and proposed design models. It is a program requirement that this tool be filled out and submitted to participate in the ECB program for Paths 1 and 2.

   When filling out the DOE/PNNL Compliance Form for the ECB program for Path 1 and Path 2 begin by making the following selections on the General Information tab:

   - For the Code/Beyond Code Program field select "Default-Selected Version of 90.1".
   - For Compliance path select "ASHRAE 90.1-2019: Appendix G".
   - Ensure that it says "Above Code Performance" directly to the right of the Compliance path in cell L20.

d. Connecticut ECB Compliance Form Companion Tool (ECB Companion Tool)[3] is spreadsheet based and performs calculations unique to the ECB program. Information entered in the DOE/PNNL Compliance Form can be directly imported into the ECB Companion Tool which avoids redundant data entry across the tools.

3. Modeling Approach

Compliance is established based on the relative site energy use of two models – the baseline design model and proposed design model. See Table 3-1 below for key differences between 90.1 2019 Appendix G and ECB program rules.

The proposed design model reflects building systems, components and controls specified in the construction documents. The modeled operating conditions and schedules must reflect the expected operation of the building or typical for the given building use type.

The following systems must be excluded from the baseline and proposed design models per the rules of the ECB program:

- On-site renewable energy systems
- Exterior lighting systems
- Parking garage lighting and ventilation systems

The baseline design model is a virtual building and shall be modeled according to the rules described in Appendix G as modified by this document. The baseline design model has the following characteristics:

- The same building use type, programming, envelope shape, HVAC zoning and operating schedules as the proposed design model.
- Most other systems and components such as envelope construction, fenestration area, HVAC

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[2] DOE/PNNL ASHRAE Standard 90.1 Performance Based Compliance Form

[3] Energy Conscious Blueprint web page: https://energizect.com/explore-solutions/new-construction-building-efficiency/new-business-construction

system type and controls, SWH system type and lighting power and controls are prescribed in 90.1 Appendix G and are independent and different from the systems in the proposed design.

- All systems are modeled at the efficiency levels approximately aligned with requirements of ASHARE 90.1 2004 (as specified in 90.1 2019 Appendix G).
- Parameters of the baseline model that are not explicitly defined in 90.1 PRM must be modeled the same as in the proposed design.
- The end uses that are not included in the proposed design must not be modeled in the baseline. For example, if the project includes a service water heating system in which no booster pumps are specified, booster pumps cannot be modeled in the baseline.
- Where parameters of the baseline model are not defined by ASHRAE Standard 90.1, they should be modeled matching the proposed design. If no corresponding parameters exist in the proposed design model, the baseline must be based on modeling best practice (see e.g., COMNET[4] or the Performance Rating Method Reference Manual (PRM RM)[5]) or typical industry practice, and is subject to Utility approval.
- Baseline energy use is calculated as an average of four alternative orientations of the baseline design model. There are two exceptions that allow using the same orientation for the baseline as specified for the proposed design:
    1. projects where fenestration area across different exposures in the proposed design differs by less than 5%.
    2. projects where exposure is dictated by the building site. The second exception may apply to retrofits and additions, and also new construction projects in urban areas where orientation is dictated by street frontage.

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[4] COMNET Commercial Buildings Energy Modeling Guidelines and Procedures and Appendices http://www.comnet.org/reference-appendices.

[5] PNNL Performance Rating Method Reference Manual https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26917.pdf

- Contrary to Appendix G, spaces without cooling in the proposed design shall be modeled without cooling in the baseline design. The baseline system type must be determined using the rules in Appendix G but with no cooling modeled.

EXAMPLE 1- No Cooling Specified

Q. An energy modeling project involves a 100,000 ft^2 school that includes cooling in the administrative wing but has no cooling in classrooms and mechanical rooms. Based on the definition of space in ASHRAE 90.1 Section 3 and the heating output of the equipment specified for various spaces in the proposed design, the classrooms are considered conditioned spaces while the mechanical rooms fall into the unconditioned category. Heating to all spaces is provided by gas-fired boilers. Should cooling be modeled in classrooms and mechanical rooms for either the baseline model or the proposed design model?

A. Cooling should not be modeled in spaces where cooling is not included in the proposed design. Thus, both the mechanical rooms and the classrooms should not be modeled with cooling in the baseline. Classrooms should be modeled with System 5 - PVAVS (based on Appendix G Table G3.1.1-3) but without a DX coil. Mechanical spaces should be modeled with the same system type as specified in the proposed design since they are unconditioned.

Exceptions:

(1) Apartments in multifamily buildings must be modeled as heated and cooled in both the baseline and proposed design, as required in Table G3.1 #1 (b), Proposed Building Performance column, even if no cooling is specified, to account for impact of envelope, lighting, etc. on the cooling energy associated with room air conditioners that will be installed by tenants.

(2) Yet to be designed areas where the expectation is that tenants will install cooling equipment in the future (e.g., unspecified system and components in core and shell projects and future tenant fit-out spaces) must be modeled as heated and cooled in both the baseline and proposed design, as required in Table G3.1 #1 (b), Proposed Building Performance column, even if no cooling is specified, to account for impact of envelope, lighting, etc. on the cooling energy associated with future equipment that will be installed by tenants.

3.1. Performance Calculations

3.1.1. Modeling Protocol

Buildings shall be modeled following ASHRAE/IESNA Standard 90.1-2019 (ASHRAE 90.1, 90.1) Normative Appendix G Performance Rating Method (Appendix G, PRM), and as described in this document.

Where a contradiction exists between these references, specific instructions from the Utility, followed by this document shall govern.

ASHRAE 90.1 Section 11 (ECB Method) and the International Energy Conservation Construction Code Section C407 Total Building Performance must not be used in developing energy models except where explicitly permitted in this document.

The ASHRAE 90.1 Appendix G Performance Rating Method (PRM) establishes compliance based on the relative energy use of two models - the proposed design model and the baseline design model (Figure 3-1). The proposed design model must reflect design documents. Prior to the 2016 edition of 90.1, the baseline model represented a version of the proposed design with all its systems and components modified to minimally comply with the current edition of 90.1. However, this approach had several important shortcomings. Measuring performance of the proposed designs relative to a different baseline with each new edition of 90.1 made it impossible to track progress toward net zero goals as energy code evolved. It also complicated standard development and energy modeling on projects since the baseline rules had to be substantially updated for each new edition.

Starting with the 2016 edition of 90.1, the baseline model is fixed at efficiency levels that are approximately aligned with 90.1 2004. The increase in stringency of the consecutive editions of 90.1 is achieved by increasing the margin of improvement that proposed design must demonstrate relative to this stable baseline. In addition, except for the programming and operating schedules, configuration of the baseline model became independent of the proposed design – the baseline heating fuel is no longer aligned with the specified heating energy source, area of fenestration as percentage of exterior wall area is prescribed for many building types and is independent of the fenestration area in the proposed design, baseline service water heater type is prescribed based on building use type, etc.

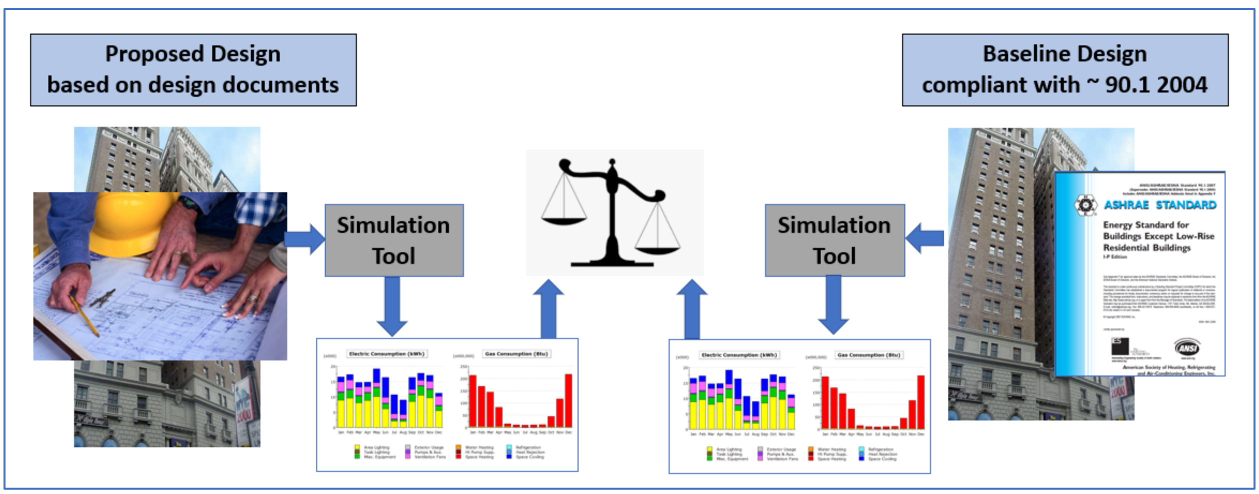

Figure 3-1:General Concept of the Relative Performance Path

Compliance is established by calculating the performance index as a ratio of the proposed building energy use to the baseline building energy use and comparing this performance index to the performance index target. Projects with performance index below the performance index target comply with code (Figure 3-2).

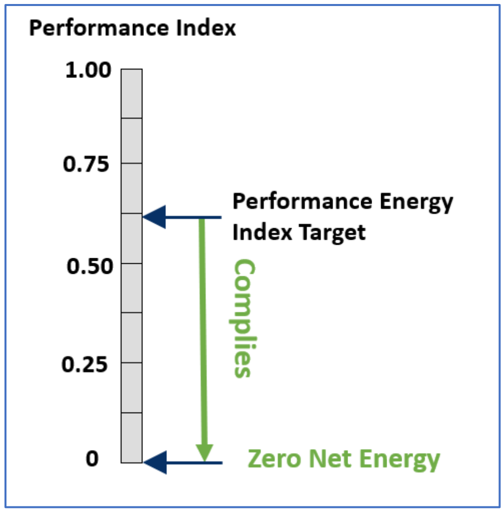

Figure 3-2 Compliance Using Performance Index Target

Table 3-1: Key Differences Between 90.1 2019 Appendix G and the ECB Program for Paths 1 and 2

	90.1 2019 Appendix G	CT ECB Program
Performance Criteria	Modeled energy use of the proposed design must improve over modeled baseline energy use by minimum margin for the project to be eligible for incentives	
Performance Metric	Energy cost	Site energy
Performance Calculation	Established using published building performance factors (BPFs)	Established using site energy end-use performance factors (SEEUPFs)
Allows contribution of renewable energy toward compliance?	Yes, up to 5% of baseline energy cost	No
Service water heater requirements	90.1 mandatory provisions must be met.	90.1 mandatory provisions must be met and for electric storage water heaters in multifamily buildings the criteria in Section 5 must be met.
Treatment of exterior and parking garage lighting and parking garage ventilation fans	Included in the energy model	Excluded from the energy model
Treatment of space without	Modeled as both heated and	Modeled without cooling in the

cooling specified in the design	cooled in the baseline and proposed models per 90.1 Table G3.1 #10 d.	baseline and proposed design models. The baseline system type must be determined using the rules in Appendix G but with no cooling modeled. See above for exceptions.
Dwelling unit lighting	No credit for lighting power density when lighting is to be supplemented with plug-in fixtures. No credit for lighting controls.	Credit can be documented following the rules in Section 11 of these guidelines.
Natural gas is not available at the building	Fossil fuel systems are modeled with propane in the baseline design model.	Fossil fuel systems shall be modeled using the same fuel type in the baseline as is specified in the proposed design.
HVAC baseline system type selection	Determining the baseline HVAC is per the rules in 90.1 2019.	90.1 2019 addendum ab[6] clarified and streamlined the process of determining the baseline HVAC system types. These updated requirements must be followed when documenting performance with the ECB program.
Exhaust air energy recovery for labs	All HVAC systems serving laboratory HVAC zones in the baseline with a cfm greater than or equal to 5,000 and a OA fraction greater or equal to 70% are required to model exhaust air energy recovery (unless exceptions apply).	Following 90.1 2019 Addendum i[7], HVAC systems serving laboratory HVAC zones in the baseline with a total laboratory exhaust volume greater than 15,000 cfm should not be modeled with exhaust air energy recovery.
Retail display lighting	No additional lighting power allowance in the baseline for retail	Where retail display lighting is included in the proposed building

[6] ASHRAE 90.1 2019 Addendum ab
https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_ab_20220727.pdf

[7] ASHRAE 90.1 2019 Addendum I
https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_i_20201030.pdf

	display lighting.	design in accordance with Section 9.6.2b, the baseline building design retail display lighting additional power should be equal to the limits established by Section 9.6.2b or same as proposed which ever less (90.1 2019 addendum af[8]).
Measure granularity	No requirements for modeling measures.	There are requirements for modeling measures. See Section 6.2.2 below for minimum granularity and fuel switch measure modeling requirements.
Thermal bridging	Does not include an explicit methodology for derating wall assembly U-factors to account for linear and point thermal bridges.	90.1 2019 addendum av[9] includes a requirement and methodology for derating wall assembly U-factors to account for linear and point thermal bridges.

Using the site energy metric instead of energy cost or source energy has profound impact on compliance outcomes. The average 2021 price of electricity in Connecticut was $0.1832/kWh and $1.065/therm for natural gas[10], making electricity nearly 5 times more expensive than gas. Because of that, using natural gas for space and service water heating is advantageous compared to electricity when compliance is based on energy cost. Using site energy metric reverses this dynamic because heating systems that use electricity (heat pumps and even electric resistance) are substantially more efficient than even the best gas furnaces or boilers. In addition, since electricity rates for many commercial customers include demand charges, the change in metric also means that reduction in peak demand can no longer contribute toward compliance.

In order to calculate the performance index target, simulation results for the baseline must be separated into baseline building unregulated site energy and baseline building regulated site energy.

- Regulated energy use is associated with building systems and components with requirements

[8] ASHRAE 90.1 2019 Addendum af https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_af_bc_cd_db_20201116.pdf

[9] ASHRAE 90.1 2019 Addendum av https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_av_20220729.pdf

[10] U.S. Energy Information Administration, Connecticut Natural Gas Prices (eia.gov), Connecticut Electricity Profile 2021 - U.S. Energy Information Administration (EIA)

prescribed in 90.1 Sections 5-10 such as interior and exterior lighting, space heating and cooling, heat rejections, ventilation and parking garage fans, pumps, service water heating, refrigeration, elevators and escalators.

- Unregulated end uses are limited to interior lighting designed to comply with health or life safety regulations (90. Section 9.1.1 Exception 2), industrial process equipment, and systems installed by tenants that are not shown on construction documents such as miscellaneous plug loads.

3.1.2. Performance Rating Calculation

For projects participating through the ECB Path 1 and 2 programs, the performance rating must be calculated based on the site energy usage index (EUI), in units of kBtu per square foot, using the following conversion factors shown in Table 3-2. If the software tool used for energy modeling deviates from these conversions when converting energy consumption to units of energy (i.e., when converting from kBtu to kWh) enter energy consumption in Table 3-2 on the Compliance Calculations tab in the DOE/PNNL Compliance Form in units of MMBtu. In this scenario, MMBtu will also need to be selected as the Energy Consumption Units in Table 1 on the Energy Sources tab in the DOE/PNNL Compliance Form.

Table 3-2: Energy Conversion Factors

Energy Source	Units	Site Energy kBtu/Unit	Source Energy kBtu/Unit
Electricity	kWh	3.412	10.20
Natural Gas	CCF	102.9	112.16
Natural Gas	Therm	100	109
Propane	Gallon	91.33	92.24
Fuel oil	Gallon	138.690	140.08

For projects qualifying based on site EUI, EUI is defined as a measure of a building's gross annual energy consumption relative to its gross square footage. Gross square footage shall include conditioned and semiheated floor area only (See Section 3 of 90.1 for definitions). Gross square footage excludes parking garages and penthouse square footage, as these are not conditioned space. EUI calculations must exclude all exterior lighting, parking garage lighting, and loads associated with garage exhaust fans. If there are enclosed conditioned or semiheated spaces in garages with equipment loads (i.e. unit heaters in elevator lobbies), these loads and ft^2 must be included in the building EUI.

Performance shall be determined using the equations shown below which deviates from ASHRAE 90.1 2019 Appendix G. These calculations are automated in the ECB Companion Tool.

BSEU2019, i, j = SEEUPF2019,i*BSEUi,j

BSEU2019, i, j = Baseline site energy use compliant with the 2019 edition of 90.1 for end use "i" and fuel "j".

SEEUPF2019,i = Site energy end use performance factor for the 2019 edition of 90.1 for end use "i".

BSEUi,j = modeled baseline site energy use for end use “i” and fuel “j”.

Savings of the proposed design relative to code for each end use and fuel is calculated as a difference between BSEU2019,i,j and the modeled energy use of the proposed design for the same end use and fuel. The total savings by fuel of the proposed design relative to code (i.e., 2019 baseline) is calculated as the sum of savings for the individual end uses for each fuel. Total 2019 baseline (sum of BSEU2019, i, j converted to kBtus for all end uses and fuels) and proposed energy consumption are converted to kBtus and normalized by the building’s gross floor area to arrive at a 2019 baseline EUI and a proposed EUI. The percent difference in these EUIs is the project performance and will be used to establish the incentive tier.

I**nformative Note:** The compliance calculations in 90.1 2019 Appendix G require using the Building Performance Factors (BPFs) to measure difference in stringency between 90.1 2004 (which is the basis of Appendix G baseline) and 90.1 2019 (CT state code). Instead of using a whole building adjustment via the BPF, the program applies adjustment factors to individual end uses. These adjustments are referred to as Site Energy End Use Performance Factors (SEEUPF) and are determined using a methodology that is conceptually similar to that used to determine the BPF. Calculating savings on end use bases results in more accurate savings relative to code and supports reporting results by fuel.

3.2. Oil, Propane, and Non-Firm Gas Modeling Approach

Oil and propane customers must follow all the rules included in this document and Appendix G with the exception that if natural gas is not available at the building, then fossil fuel systems shall be modeled using the same fuel type in the baseline as is specified in the proposed design.

Propane and oil-fired equipment does not qualify for any incentives even when it improves over the minimum code requirements. For example, incentives are not available for a propane-fired boiler with an efficiency that exceeds the minimum requirements of 90.1-2019.

All savings should be reported that will contribute towards determining the Performance Rating (and incentive tier), however, incentives will be prorated to exclude oil and propane savings for equipment efficiency measures.

Modelers are required to perform and submit the following in order for the Utility to prorate the incentive:

1. Perform modeling following the rules of Appendix G for all measures (baseline per Appendix G and the proposed as-designed).
2. Populate a DOE/PNNL Compliance Form with the modeling results and import the data into the ECB Companion Tool so that performance can be assessed with all measures included.
3. Revise the energy model such that all oil, propane, and non-firm gas equipment is modeled with minimum efficiency requirements per 90.1 Tables 6.8.1-1 through 6.8.1-20 as applicable in the proposed model.
4. Populate a DOE/PNNL Compliance Form with the revised modeling results and import the data into a new ECB Companion Tool so that performance can be assessed with the equipment

efficiency measures excluded.

5. Provide both sets of DOE/PNNL Compliance Forms and ECB Companion Tools when submitting the project to the Utility.

4. Approved Building Energy Modeling Tools and Calculation Methods

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

- eQUEST
- Openstudio/EnergyPlus
- Trane Trace

Other software tools may be approved by Utility on a case-by-case basis. Contact the Utility prior to beginning energy modeling if seeking approval for an alternative simulation tool.

The modeling approach for any non-typical measures must be coordinated with Utility.

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

a. Step-by-step documentation of the exceptional calculation method performed detailed enough to reproduce the results.
b. Copies of all spreadsheets used to perform the calculations.
c. A sensitivity analysis of energy consumption when each of the input parameters is varied from half to double the assumed value.
d. The calculations shall be performed on an hourly time step basis.
e. The performance energy use calculated with and without the exceptional calculation method.
f. The total savings documented using the exceptional calculation methods cannot account for more than half of the difference between the baseline building performance and the proposed building performance. This cap is incorporated in the DOE/PNNL Compliance Form and ECB Companion Tool.
g. Fill out the Exceptional Calculations tab in the DOE/PNNL Compliance Form and Table 1c on the Performance by End Use & Fuel in the ECB Companion Tool to include savings from the exceptional calculation method in project performance.

5. Mandatory Requirements

a. The proposed design must comply with the mandatory requirements of ASHRAE Standard 90.1, which are listed in sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 of the Standard.

b. Multifamily buildings with electric resistance storage water heaters in the proposed design must meet the following requirements:

- Energy factor (EF) of at least 0.95 (UEF ≥ 0.93),
- Hot water piping insulation of R-4 $ft^2h°F/Btu$ or better

- ENERGY STAR certified dishwashers and clothes washers
- WaterSense® certified bathroom faucets/aerators and showerheads, and kitchen faucets maximum flow of 2.0 gpm.

6. Reporting and Measure Modeling Requirements

To meet program requirements, projects must submit the filled out DOE/PNNL ASHRAE Standard 90.1 Performance Based Compliance Form[2] and the CT ECB Compliance Form Companion Tool (ECB Companion Tool)[3]. Projects where the design agreement is executed after November 15, 2023 are required to use v1.5 or later version of the Companion Tool.

6.1. Demand Reporting

6.1.1. Electricity Demand

Summer electric demand for both the baseline and proposed design models shall be expressed in units of kW and must be calculated by averaging the peak coincident demand for the months of June, July, and August.

Winter electric demand for both the baseline and proposed models must be calculated by averaging the peak coincident demand for the months of December and January.

Both calculations are automated in the CT ECB Companion Tool. The Hourly Input or the Hrly eQuest Results tabs must be populated with baseline and proposed demand data. Table 1 on the Demand Savings tab in the ECB Companion Tool can be filled out manually only if the approved simulation tool used is not capable of providing the data necessary to populate the hourly demand tabs.

EXAMPLE 2– Demand Reporting

Q. An elementary school is participating in the Energy Conscious Blueprint Program. According to the proposed model, a building peak demand of 528.8 kW occurs in September, when school is in session. Peak demand for June, July, and August is 341.1, 320.2, and 360.0 respectively. How should the proposed peak demand for the project be reported?

A. Although, the building peak occurs in September due to the nature of the project, the proposed peak demand must be reported following Program requirements; peak demand for June, July, and August must be averaged. For the project in question, this calculation yields:

$$(341.1 + 320.2 + 360.0) \div 3 = 340.4 \text{ kW}$$

Thus, reported proposed peak demand must equal 340.4 kW.

6.1.2. Natural Gas Demand

Natural Gas demand shall be reported for the baseline and proposed during the coldest day (24 hours) in the weather file used in the simulation, as shown in Table 6-1. This calculation is automated in the CT ECB Companion Tool. The Hourly Input or the Hrly eQuest Results tabs must be populated with baseline and proposed demand data. Table 2 on the Demand Savings tab can be filled out manually only if the approved simulation tool used is not capable of providing the data necessary to populate the hourly demand tabs.

Table 6-1: Coldest Day (24 hours) for Gas Demand Savings Reporting

City	TMY file Type & name	Coldest Dry Bulb Temp, F 24 hr average	Day
Bridgeport	TMY2_bridgeport	12	2/20
Hartford	TMY2_hartfoct	3	1/15
Bridgeport	TMY3_CT_Bridgeport_Sikorsky	4	1/21
Danbury	TMY3_CT_Danbury_Municipal	7	1/21
Groton/New London	TMY3_CT_Groton_New_London_AP	9	1/6
Hartford - Bradley	TMY3_CT_Hartford_Bradley_Intl	12	12/14
Hartford - Brainard	TMY3_CT_Hartford_Brainard_Fd	6	1/22
New Haven	TMY3_CT_New_Haven_Tweed_Airport	9	1/6
Oxford	TMY3_CT_Oxford_(AWOS)	2	1/17

6.2. Reporting Simulation Results by Measure

Simulation results must be reported at the measure level, including energy usage, electricity peak demand, energy cost, and energy savings for each measure (a measure is when a component differs between the baseline and proposed).

6.2.1. Background

There are many areas where the proposed design differs from the baseline. Many of these differences involve improvements in the performance of like components. For example, the thermal resistance of the proposed exterior walls may exceed the thermal resistance of the baseline exterior walls. Additionally, some of the components in the proposed design may be less efficient than like components in the baseline. For example, the proposed window to wall ratio may exceed the baseline, which is capped based on the window to wall ratios in Table G3.1.1-1, or the proposed lighting power density may exceed the Appendix G baseline lighting power density in some spaces. Moreover, the proposed design may include systems and equipment that are not present in the baseline. For example, a project with an all-air baseline HVAC system may have pumps, boilers or chillers in the proposed design.

Following the ASHRAE modeling protocol, all the differences between the baseline and proposed design are captured by only two models – the proposed design model and the baseline design model. However, for participation in the ECB Path 1 and 2 programs, the proposed model must be developed incrementally using multiple Measures, so that the impact of individual systems on the performance of the proposed design can be reported. This requirement will help to support and expedite the program's quality control process.

Each Measure includes one or more differences between the baseline and proposed design models. All of the Measures combined must account for all of the differences between the baseline and proposed design models, and no difference can be included in more than one Measure.

Annual energy consumption by end use must be reported for each Measure on the Detailed Measures tab in the CT ECB Companion Tool.

6.2.2. Measure Granularity

6.2.2.1. Minimum Measure Granularity

At a minimum, differences between the baseline and proposed design models related to HVAC and SWH fuel switches, lighting systems, building envelope components, plug and process loads, other HVAC system measures, and service water heating systems must be included as separate Measures. For example, a high efficiency condensing boiler cannot be grouped into a single Measure with triple-pane glazing.

In addition, any design features requiring exceptional calculation methods should be reported as separate Measures.

Eligible projects must have at least two Measures.

6.2.2.2. Special Fuel Switch Measure Modeling Requirements

The first measure (referred to as the "fuel switch" measure in these guidelines) shall include proposed HVAC system types, heating and cooling efficiencies, fan power, and fan controls for all thermal blocks where there is a fuel switch between the baseline and proposed. The first measure shall also include all proposed service water heating (SWH) system types, efficiencies, and controls in which a fuel switch has occurred between the baseline and proposed systems. If creating the models measure by measure from the proposed to the baseline (instead of starting with the baseline model) then these changes shall be included in the last measure before the baseline. Thermal blocks or SWH systems where no fuel switch has occurred between the baseline and proposed shall be modeled the same as in the baseline model for this fuel switch measure. All other parameters other than those described above shall remain consistent with the baseline. See Examples 3 and 4 for illustrations of these concepts.

Excluded from the fuel switch measure (i.e., model as required in the baseline regardless of the proposed design parameters):

- Heating, cooling, pump GPM, and fan CFM capacities (i.e., these shall remain autosized)
- Exhaust air energy recovery
- Demand-controlled ventilation
- Air-side economizer controls
- Pump controls (i.e., constant versus variable volume)

Included in fuel switch measure:

- Proposed system types
- Proposed heating and cooling system efficiencies
- Proposed fan power
- Proposed fan controls (e.g., variable air volume versus constant volume, cycling with load versus continuous operation, etc.)

- Controls integral to the operation of the proposed HVAC system (e.g., supply air setpoint controls)

EXAMPLE 3– Multifamily Dwelling Unit Fuel Switch Measure Example

Q. A multifamily building is participating in the Energy Conscious Blueprint Program.

Baseline systems:

- System 1 – packaged terminal air conditioning units (PTACs) which provide both outdoor air (OA) CFM ventilation and heating and cooling and are served by a gas-fired hot water boiler plant. These serve dwelling units and common areas. The PTAC fans operate continuously to provide OA CFM.
- System 9 – gas-fired unit heaters serving storage rooms and stairwells.

Proposed systems:

- All electric variable refrigerant flow (VRF) heat pump systems with direct outdoor air systems (DOAS) providing OA CFM ventilation. The DOAS units have gas-fired heating coils and exhaust air energy recovery. The DOAS fans operate continuously and the VRF fans cycle on and off with heating and cooling loads. These systems serve dwelling units and common areas.
- Gas-fired high-efficiency condensing unit heaters serving storage rooms and stairwells.

What should the fuel switch measure include?

A. The fuel switch measure should include the following proposed design features:

- VRF systems providing heating and cooling instead of the PTACs.
- VRF system heating and cooling efficiencies.
- VRF system fan power and operation (i.e., fans shall be modeled as cycling with load).
- DOAS with the gas-fired heating coil providing outdoor air ventilation instead of the PTACs.
- DOAS fan power and operation (i.e., fans shall be modeled as operating continuously).
- DOAS supply temperature setpoints should be modeled consistently with the proposed design because they are integral to the operation of the DOAS heating coil.
- DOAS heating efficiency.

Proposed design HVAC related features excluded from the first measure (i.e., modeled the same as the baseline):

- Exhaust air energy recovery.
- OA ventilation rates shall match baseline.
- Equipment capacities shall be autosized.
- Economizer controls
- Stairwell and storage room unit heater proposed efficiency (there is no fuel switch associated with these thermal blocks, so they are modeled identically in the baseline and proposed)

EXAMPLE 4– Small Office Fuel Switch Measure Example

Q. A small 35,000 ft^2 2-story office building is participating in the Energy Conscious Blueprint Program.

Baseline systems:

- System 5 – packaged variable air volume with reheat which provides both outdoor air (OA) CFM ventilation and heating and cooling (direct expansion cooling coil). The reheat coils are served by a gas-fired hot water boiler plant. The packaged unit fans operate continuously during occupied hours to provide OA CFM and cycle with load during unoccupied hours.

Proposed systems:

- All electric single zone constant volume variable refrigerant flow (VRF) heat pump systems with a variable air volume direct outdoor air system (DOAS) providing OA CFM ventilation. The DOAS is variable air volume due to demand-controlled ventilation (DCV) controls. The DOAS has a gas-fired furnace heating coil and exhaust air energy recovery. The DOAS fans operate continuously during occupied hours and are off during unoccupied hours and the VRF fans cycle on and off with heating and cooling loads.

What should the first measure (i.e., fuel switch measure) include?

A. The first measure should include the following proposed design features:

- VRF systems providing heating and cooling instead of the multizone VAV with reheat system.
- VRF system heating and cooling efficiencies.
- VRF system fan power and operation (i.e., fans shall be modeled as constant volume and cycling with load).
- DOAS with the gas-fired furnace heating coil providing outdoor air ventilation instead of the multizone VAV with reheat system.
- DOAS fan power and operation (i.e., fans shall be modeled as operating continuously).
- DOAS shall operate as variable air volume if DCV is required in the baseline. If not, then it shall operate as constant volume since DCV is not included in this fuel switch measure.
- DOAS supply temperature setpoints should be modeled consistently with the proposed design because they are integral to the operation of the DOAS heating coil.
- DOAS heating efficiency.

Proposed design HVAC related features excluded from the fuel switch measure (i.e., modeled the same as the baseline):

- Exhaust air energy recovery
- OA ventilation rates shall match baseline.
- Equipment capacities shall be autosized.
- Economizer controls
- DCV should only be modeled where required in the baseline.

6.2.2.3. Recommended Measure Granularity

Beyond the minimum prescribed measure granularity, program participants are encouraged to comply with the following guidelines for measure granularity. Doing so will expedite the review process.

However, because modeling tools have various degrees of measure modeling support, the criteria listed below are recommendations rather than requirements.

1. Changes to the roof, walls, and windows should not be bundled and should be reported as separate measures.
2. Changes to lighting systems, automatic daylighting control, and other lighting controls should not be bundled and should be reported as separate measures.
3. Chillers, boilers, heat rejection equipment, different air-side system types, individual control strategies such as demand control ventilation, hot water pumps, chilled water pumps, and condenser water pumps should not be bundled together and should be reported as separate Measures, unless differences between the baseline and proposed HVAC system types preclude doing so (for example, if the baseline does not include a hot water loop, the proposed boiler need not be reported as a separate measure). Special program requirements regarding fuel switch measure modeling described in Section 6.2.2.2 take precedence over this recommendation.

6.2.2.4. Measure Modeling Approach

Measures shall be added cumulatively to the baseline model, so that the last measure run represents the proposed design model. Beginning with the baseline, the fuel switch measure shall be modeled first (see Section 6.2.2.2), followed by building envelope, lighting measures, plug and process load measures, HVAC measures, and service water heating measures. Within each category, the order of the measures is left to the judgment of the modeler.

Alternatively, measures can be subtracted from the proposed model, with the final measure run representing the baseline design. In this case, the order described above would be reversed. Both methods, if performed properly, will produce identical results.

EXAMPLE 5– Measure Modeling Example <u>with No Fuel Switch</u>

Q. An office building is participating in the program. The following differences exist between the baseline and the proposed design:

		Baseline	Proposed
Envelope	Roof	U-0.063	U-0.030
	Walls	U-0.084	U-0.052
Lighting	Lighting	Average LPD 0.95	Average LPD 0.8
HVAC	HVAC System Type	System 7 – VAV w/ HW Reheat; System 3 – PSZ in assembly spaces w/ energy recovery;	Chilled beams and CV dedicated outdoor air system with energy recovery; SZ VAV air handlers in assembly spaces w/ DCV
	Chiller Efficiency	Two water-cooled centrifugal chillers ≥300 tons, 0.576 kW/ton full load, 0.549 IPLV	Two frictionless (magnetic bearing) centrifugal chillers, COP = 6.0, IPLV = 10.1
	Chilled Water Loop Pump Energy and Control	Primary/Secondary (one-speed/VFD), 35 kW total pump energy	Primary/Secondary, (VFD/VFD), 39 kW total pump energy
	Cooling Tower	One axial fan cooling tower, 38.2 gpm/hp, variable speed motors	One two-cell axial fan cooling tower, 44.1 gpm/hp, variable speed motors
	Condenser Loop Pump Energy and Control	Total pump energy 34 kW, constant speed, constant volume	Total pump energy 30 kW, constant speed, constant volume
	Boiler Efficiency	Two natural-draft boilers, 80% Efficient	Two condensing boilers, 95% efficient
	Hot Water Loop Pump Energy and Control	11 kW total pump energy, VFD	15 kW total pump energy, VFD

How should this project be broken into measures?

A. <u>Minimum Required Measure Granularity</u>

Baseline – ASHRAE 90.1 baseline run

Measure 1 – ASHRAE 90.1 baseline run + Envelope Measures (Roof and Wall improvements)

Measure 2 – Measure 1 + Lighting Measure (LPD improvement)

Measure 3 – Measure 2 + HVAC Measures (all air-side and water-side measures noted above, including the system type switches, improvements over the baseline, and parameters worse than the baseline [e.g., HW loop pumps])

Note that the Measure 3 model run in this scenario represents the Proposed Design model, and the performance rating should be calculated by comparing the Baseline Run to the Measure 3 Run.

<u>Recommended Measure Granularity</u> (should be followed if the modeling tool supports parametric runs or similar functionality)

Baseline – ASHRAE 90.1 baseline run

Measure 1 – ASHRAE 90.1 baseline run + Proposed Roof

Measure 2 – Measure 1 + Proposed Wall

Measure 3 – Measure 2 + Proposed Lighting

Measure 4 – Measure 3 + Chilled Beam System (including the system switch, configuration of the DOAS unit w/ heat recovery, and all associated controls)

Measure 5 – Measure 4 + SZ AHUs serving assembly spaces (including system switch and configuration of all associated controls, except for single zone VAV [unit should be modeled as CV]

Measure 6 – Measure 5 + SZ VAV control for AHUs serving assembly spaces

Measure 7 – Measure 6 + Proposed Chillers

Measure 8 – Measure 7 + Proposed CHW Pumps and Control (pump power increase versus baseline + primary pump VFD)

Measure 9 – Measure 8 + Proposed Cooling Tower

Measure 10 – Measure 9 + Proposed CW Pump Power

Measure 11 – Measure 10 + Condensing Boilers

Measure 12 – Measure 11 + Proposed HW Pump Power (note that this model run will represent the Proposed Design model)

7. District Energy Systems

Projects with space heating, cooling or service water heating provided by a district plant in lieu of on-site systems must be modeled as using the purchased energy (chilled water, hot water, and/or steam) in both the baseline and proposed models, as described in 90.1 G3.1.1.1, G3.1.1.2, G3.1.1.3. When modeling district systems, the modeler must select “District Steam”, "District Hot Water", and/or " District Cooling", as applicable, in DOE/PNNL Compliance Form on the Energy Sources tab in Table 1.

While district system energy savings are always counted towards determining the performance rating and incentive tier, incentives for district energy system savings (for example, due to increased insulation) are only paid if the owner of the district systems pays into the energy efficiency (EE) fund. If the owner of the district system does not pay into the energy efficiency fund, incentives are prorated to exclude these savings. There is a required field in the ECB Companion Tool for projects to indicate whether district systems pay into the EE fund.

New heating and cooling plants designed to serve multiple buildings may be eligible for incentives via prescriptive pathway. The application must be coordinated with the Utility.

For projects that use electricity and other energy sources generated by district combined heat and power (CHP), the methodology for converting modeled energy savings to the equivalent savings of fuels for which the owner of the district systems pays into the energy efficiency fund is subject to Utility approval.

8. Electricity Generation Systems

Contribution of renewable electricity generation systems toward performance is not allowed according to ECB program rules. Such systems should not be modeled in either the proposed design or baseline design.

Electric generation is not incentivized under ECB and shall be excluded from both the baseline and proposed energy models or otherwise modeled as energy neutral. If the proposed building is served by an existing generation system such as CHP, the model must reflect district heating, cooling and watering heating, as applicable, supplied by the CHP.

Energy savings offset by the CHP recovered waste heat can contribute toward incentives but adjustments to the energy savings may need to be made by the Utility for reporting purposes. If the baseline load exceeds CHP waste heat capacity, the corresponding baseline system shall be modeled based on the energy source used as the backup energy source. There is a checkbox in the ECB Companion Tool to indicate whether CHP waste heat savings are applicable to the project. If applicable, this box must be checked to alert the Utility that an adjustment to the savings may be required for reporting. In addition, the modeling approach must be described on the Modeling Plan Charrette tab of the ECB Companion Tool and is subject to Utility approval.

9. Simulated Schedules

Modeled occupancy, HVAC, and other schedules should not deviate significantly (i.e. have Effective Full Load Hours (EFLH) differing by more than 15%) from the schedules in Tables G-D to G-M of the 90.1 –

2013 User's Manual[11], COMNET Commercial Buildings Energy Modeling Guidelines and Procedures Appendix C – Default Schedules[4], 90.1 Section C3.5.5.3 Schedules and Internal Loads[12], or, for multifamily buildings, the ENERGY STAR Multifamily New Construction Program Simulation Guidelines[13], as applicable, unless documentation is available substantiating the modeled schedules.

Modeled interior lighting runtime should not deviate significantly (i.e. have EFLH differing by more than 15%) from the EFLH calculated as described in Annex 3 of this document unless documentation is provided substantiating the modeled schedules.

Examples of acceptable documentation include but are not limited to a statement from the owner with anticipated project's operating hours, or operating hours of a similar franchise.

Schedules must be modeled identically in the baseline and proposed design models, unless otherwise permitted by 90.1 Appendix G rules or the rules set forth in this document, or unless documented in an exceptional calculation method.

10. Building Envelope

Proposed Design

a. Areas that are not classified as enclosed spaces per 90.1 definition including ventilated attics, ventilated crawlspaces and parking garages that are mechanically or naturally ventilated shall be excluded from the energy model per the rules of the ECB program. The associated surfaces that are not part of the building envelope must also be excluded from the model, and surfaces that are part of the building envelope must be modeled as having direct exterior exposure.

> **EXAMPLE 6**
>
> **Q:** Building has a mechanically ventilated parking garage on the first floor and hotel occupancy on floors 2-6. How should the parking garage be modeled?
>
> **A:** Parking garage shall be omitted from the model and the floor of the hotel above the parking garage must be modeled as adjacent to exterior. This approach must be used for both the baseline and proposed design. Parking garage loads such as lighting and ventilation must also be excluded from the model.

b. Modeled envelope properties must reflect materials and constructions included in design documents.

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[11] ANSI/ASHRAE/IESNA Standard 90.1-2019 User's Manual

[12] 90.1 Section C3.5.5.3 Schedules and Internal Loads, http://sspc901.ashraepcs.org/documents.php

[13] ENERGY STAR Multifamily New Construction Program Simulation Guidelines – Appendix G 90.1 – 2016 Version 1, Revision 03, September 2022 https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_MFNC_Simulation_Guidelines_AppG2016_Version_1_Rev03.pdf

c. Models must account for thermal bridging effects. For example, steel framing members penetrate cavity insulation and significantly decrease the effective R-value of the assembly.

- 90.1 2019 addendum av[14] includes a methodology and requirement to derate wall assemblies to account for the impacts of clear-field, linear, and point thermal bridges for the proposed building envelope. The revisions to Appendix G in this addendum must be followed when documenting performance with the ECB program. Although models have always been required to account for thermal bridging effects, addendum av includes a standardized methodology for derating wall U-factors to account for the effects of linear and point thermal bridges. It requires that each linear thermal bridge and point thermal bridge identified in Section 5.5.5, as modified in the addendum, is modeled using either a) a separate model of the assembly within the energy simulation model or b) adjustment of the clear-field U-factor in accordance with Section A10.2 as shown in the addendum.

  Note that de-rating insulation using the 90.1 2019 Appendix A tables results in the clear-field U-factor (i.e., thermal transmittance), U_o, which needs to be adjusted in accordance with equation A10.2 in addendum av for above-grade walls unless the thermal bridging is explicitly modeled in the simulation tool. Backup calculations are required to demonstrate that assembly U-values have been adjusted as required in addendum av.

EXAMPLE 7– Cavity Insulation and Steel Framed Walls with a Parapet

Q. A project has 16” on center steel framed walls with R-13 cavity insulation and R-10 continuous insulation. There is a parapet around the perimeter of the roof with unmitigated thermal bridging. The perimeter of the roof is 550 ft^2 and the total area of the steel framed walls is 18,150 ft^2. How should this assembly be modeled?

A. Based on ASHRAE 90.1 Table A3.3.3.1, the clear-field U-factor for the base wall assembly is U-0.055. From addendum av Table A10.1, the psi-factor of unmitigated parapets for a steel-framed wall is 0.289 Btu/(h*ft*°F).

The overall thermal transmittance (U_{tot}) to be modeled is (0.289 Btu/(h*ft*°F) * 550 ft)/18,150 ft^2 + 0.055 Btu/(h*ft^2*°F) = 0.064 Btu/(h*ft^2*°F)

d. When the total area of penetrations from mechanical equipment, such as through-wall AC sleeves and PTAC/PTHP, exceeds 1% of the opaque above-grade wall area, the area of the penetrations must be modeled in the Proposed Design with a default U-factor of 0.5. When mechanical equipment has been tested in accordance with approved testing standards, the mechanical equipment penetration area may be calculated as a separate wall assembly with the U-factor as determined by such test. Insulated covers for the through-wall AC units must not be modeled even

[14] ASHRAE 90.1 2019 Addendum av https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_av_20220729.pdf

when specified.

e. Fenestration must be modeled to reflect whole window assembly U-factors (including framing) and not the center-of-glass U-factor. Acceptable sources for overall fenestration U-factors include the following:

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

f. The same infiltration modeling algorithm and schedule must be used for baseline and proposed design models. Infiltration must be modeled at 100% (i.e. with schedule fraction of 1) during un-occupied hours when HVAC systems are off, and at 25% during occupied hours (i.e. with schedule fraction of 0.25). If simulation tool restricts changes to infiltration schedule, infiltration can be ignored during occupied hours by modeling infiltration schedule fraction of 0 when fans are on.

g. The air leakage rate of the building envelope (75 Pa) at a fixed building pressure differential of 0.3 in. of water shall be 0.6 cfm/ft^2 for buildings providing verification in accordance with 90.1 Section 5.9.1.2.

Exception: When whole-building air leakage testing, in accordance with 90.1 Section 5.4.3.1.1, is specified during design and completed after construction, the proposed design air leakage rate of the building envelope shall be modeled as measured.

Baseline Design

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

b. The vertical fenestration areas for new buildings and additions must be determined as follows:

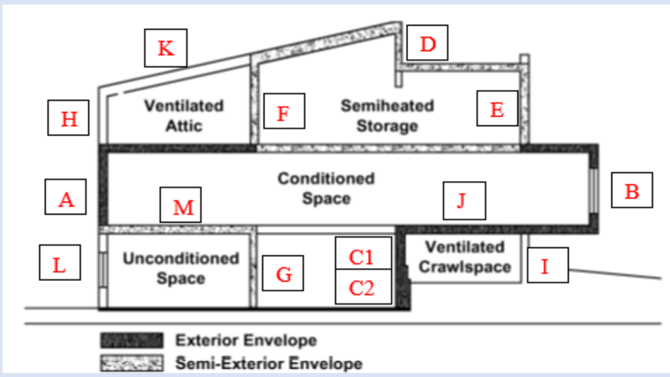
- For building types included in Table G3.1.1-1, based on the percentage of the above-grade wall area specified in the table. For building types not shown in Table G3.1.1-1, vertical fenestration areas must equal that in the proposed design or 40% of gross above-grade wall area, whichever is smaller.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

prior to the proposed work.

Wall area used to determine fenestration area includes all walls that are part of the exterior and semi-exterior building envelope (per 90.1 2019 addendum ct[15]).

EXAMPLE 8

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



A: Area of walls F, D, E, B, A, C1 and G must be included when calculating baseline fenestration area in accordance with Table G3.1 part 5 item c. C2 is not included because it is below grade.

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

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

11. Interior Lighting

Proposed Design

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

b. For each lighting fixture, all lighting system components shown or provided for on plans must be

[15] ASHRAE 90.1 2019 Addendum ct https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_ct_20220630.pdf

accounted for including lamps, ballasts, transformers and control devices.

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

- The actual installed fixture wattage determined as described in 90.1 Section 9.1.3.
- 85% of the maximum manufacturer's rated fixture wattage determined as described in 9.1.4.

EXAMPLE 9

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

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

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

e. In spaces where lighting is connected via receptacles and not shown on design documents, lighting power used in the simulation must be equal to the lighting power allowance in Table 9.6.1 for the appropriate space type or as designed, whichever is greater. This provision in Table G3.1 #6 (e), Proposed Building Performance column was added in 90.1 2019 to ensure that spaces where lighting is not specified or only partially specified do not contribute to lighting power savings.

Exception: Dwelling Units and Dormitory Living Quarters

Standard 90.1 defines a dwelling unit as a single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation. Living units that include both a private kitchen/kitchenette and a private bathroom meet this definition. Dwelling units are found in multifamily buildings and in some dormitories and hotels. Credit may be claimed for hard-wired in-unit lighting based on the procedure in the ENERGY STAR Multifamily New Construction Program Guidelines AppG 2016 Version 1 Rev03[13]. The methodology is replicated below for convenience.

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]

The unlit area for which credit cannot be claimed shall be modeled with 0.6 W/ft^2 for dwelling units and as 0.5 W/ft^2 for dormitory living quarters (i.e., as energy neutral).

EXAMPLE 10

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

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

f. Lighting exempt from 90.1

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

Lighting that is subject to this exception may qualify for incentives but must not be combined into one ECM with the regulated lighting. The space-by-space method must be used to establish the baseline for both regulated and un-regulated lighting in such a project. The baseline for unregulated lighting must be established based on the illuminance levels and lighting power density of similar space types that are regulated by Standard 90.1. If the lighting design is required to provide higher illuminance levels compared to those used in IESNA 90.1 lighting models or recommended in IESNA Lighting Handbook, the baseline LPD may be increased in proportion to the increase in the illuminance. Regulated and un-regulated lighting must be captured on separate rows in Table 2 on the Compliance Calculations tab in the DOE/PNNL Compliance Form. An “X” must be input in column G to mark the un-regulated lighting as un-regulated in the table.

g. Temporary Lighting

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

EXAMPLE 11

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

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

h. Lighting controls other than daylighting

Automatic lighting controls are required by Standard 90.1 in most space types (90.1 Section 9.4.1 and Table 9.6.1). Since these provisions are mandatory, where such controls are required (if exceptions to these sections do not apply), they must be specified in the proposed design.

Lighting controls other than daylighting must be modeled by reducing the lighting schedule each hour by the occupancy sensor reduction factors in 90.1 Table G3.7 Occupancy Sensor Reduction column. Based on the footnotes below the table, the occupancy sensor reduction factor must be multiplied by 1.25 for manual-on or partial-auto-on occupancy sensors; for occupancy sensors controlling individual workstation lighting, occupancy sensor reduction factor of 30% must be used.

Projects participating in the ECB program may also document credit for the following automatic lighting controls included in the proposed design that are not required by Section 9.4.1 and Table 9.6.1:

- Automatic full off (90.1 Section 9.4.1 [i]) when either automatic full off or scheduled shutoff is allowed in 90.1 Table 9.6.1 (ADD2): the occupancy sensor reduction factor may be increased by 5%. Example: enclosed office >250 ft^2
- For high end trim or task tuning, the occupancy sensor reduction factor may be increased by

7.5%. The following must be provided to claim this credit:

a. The lighting designer must provide the anticipated degree of turndown that is to be installed in each space with task tuning. This is the basis of savings to be claimed in the energy model. The submittal must list what tuning factors are applied to the space LPD. The tuning factor is to be considered in addition to control factors for occupancy sensors and lighting schedules.

b. The project construction documents must clearly list the intended light level that the systems are to be tuned to (foot candles as measured below the light at a specific height above the floor).

c. The project construction documents must clearly describe lighting controls commissioning requirements and methods for implementing task tuning.

- For lighting in dwelling units that have controls meeting all of the following requirements, an occupancy senor reduction factor of 10% may be used:

  a. Each dwelling unit has a main control by the main entrance that turns off all the lights and all switched receptacles in the dwelling unit.

  b. The main control may have two controls, one for permanently wired lighting and one for switched receptacles.

  c. Where controls are divided the main controls must be clearly identified as “lights master off” and “outlets master off.”

i. Daylighting Controls

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

j. Fixture Sampling

ASHRAE 90.1 Table G3.1 states that in the proposed design model “where a complete lighting system exists, the actual lighting power for each thermal block shall be used in the model.” Following this requirement, use of representative spaces (sampling) for establishing lighting power density in the proposed design is not allowed.

Baseline Design

a. Lighting power must be determined using Table G3.7 Space-by-Space Method and assigned to each modeled thermal block based on space use types within the block. Table G3.8, Building Area Method, may only be used for portions of the building where lighting is not specified and space types are unknown, as with core-and-shell projects.

b. Lighting power cannot be increased to account for decorative lighting. Where specified, such lighting will be modeled in the proposed design but not in the baseline design, resulting in a performance penalty.

c. Where retail display lighting is included in the proposed building design in accordance with Section 9.6.2b, the baseline building design retail display lighting additional power should be equal to the limits established by Section 9.6.2b or same as proposed which ever less (90.1 2019 addendum af[16]).

d. Lighting must be modeled with automatic shutoff controls in buildings >5000 ft^2 and occupancy sensors in employee lunch and break rooms, conference/meeting rooms, and classrooms (not including shop classrooms, laboratory classrooms, and preschool through 12th-grade classrooms).

e. Daylighting controls must not be modeled in the baseline design model.

12. Exterior and Parking Garage Lighting

Exterior and parking garage lighting must be excluded from the energy model. The baseline and proposed kW must be established by filling out Table 1 on the Ext+Parking Garage Lighting tab in the CT ECB Companion Tool. The baseline and proposed electricity kWh consumption must be manually calculated and entered in Table 3 on the Ext+Parking Garage Lighting tab based on the autopopulated baseline and proposed kW values from Table 1 and lighting runtime hours. The baseline and proposed coincident peak demand must also be calculated outside of the energy model and entered manually in Table 4 on Ext+Parking Garage Lighting tab per the methodology described below in Section 12.2.

12.1. Exterior Lighting Power Calculation

ASHRAE 90.1 Table 9.4.2-2 categorizes the exterior lighting power allowances by specific exterior lighting zones and describes the exterior lighting power allowance for different exterior lighting surfaces for each exterior lighting zone and categorizes exterior lighting into tradable and non-tradable surfaces.

Tradable applications include uncovered parking areas, building grounds, building entrances and exits, sales canopies, and outdoor sales areas. The allowed LPD for tradable applications must be multiplied by the associated area or length to determine the baseline power. Only illuminated areas can be included in the baseline allowable wattage calculations.

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[16] ASHRAE 90.1 2019 Addendum af https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_af_bc_cd_db_20201116.pdf

EXAMPLE 12- Exterior Lighting: Tradable vs. Non-Tradable

Q. An office building has a 40,000 ft^2 lighted parking lot and a 3,500 ft^2 lighted façade. The installed power for the parking lot is 2 kW; the installed power for the façade is 400 W. It is determined that the building is located in Zone 3 (All Other Areas) from Table 9.4.3-1. What should the exterior lighting power for the baseline and proposed?

A. The table below shows lighting inputs associated with the baseline and proposed designs this example along with associated calculations. These calculations are automated on the Ext+Parking Garage Lighting tab in the CT ECB Companion Tool.

	Parking Lot		Building Façade	
Surface Area	40,000 ft^2		3,500 ft^2	
Lighting Allowance (Table 9.4.2-2)	0.0.6 W/ft^2		0.15 W/ft^2	
Maximum Allowed Wattage	0.06 W/ft^2 × 40,000 ft^2 = 2.4 kW		0.15W/ ft^2 × 3,500 ft^2 = 525 W	
Base Site Allowance, total per project (Table 9.4.2-2)	500 W		NA	
Allowance Type (Table 9.4.2-2)	Tradable		Non-tradable	
Modeled Wattage	Baseline Model	Proposed Model	Baseline Model	Proposed Model
	2.9 kW	2 kW	400 W	400 W

Non-tradable exterior lighting includes building façades, automated teller machines and night depositories. Non-tradable lighting is a use-it-or-lose-it allowance and must be met individually. Thus, the baseline power for these applications must be the lesser of the specified wattage or the product of the LPD allowance and the associated area or length.

The determination of the baseline kW is automated on the Ext+Parking Garage Lighting tab in the CT ECB Companion Tool.

EXAMPLE 13– Common Mistakes When Calculating Baseline Exterior Lighting Power

1. Including areas of the proposed design that are not illuminated, or incorrectly accounting for partially illuminated areas, when calculating the baseline exterior lighting power. For example, if the proposed design has an uncovered parking lot that has no lighting specified, an exterior lighting allowance for the uncovered parking areas cannot be included in the baseline.
2. Double-counting areas when calculating the baseline exterior lighting power allowance. For example, the baseline lighting allowance for the walkway that crosses an illuminated parking lot can be determined based on the parking lot allowance, or walkway allowance in 90.1 Table 9.4.2-2, but not both. If walkway allowance is used, the walkway area calculated as described in #3 above must be subtracted from the parking lot area used to calculate the parking lot baseline lighting allowance.
3. Claiming baseline lighting for non-tradeable surfaces based on the full allowance in 90.1 Table 9.4.2-2. The baseline non-tradeable lighting kW must be the same as the proposed.

12.2. Coincident Peak Demand Calculation for Exterior and Parking Garage Lighting

Exterior and parking garage lighting coincident peak demand must be calculated separately as described in this section and manually entered in Table 4 on the Ext+Parking Garage Lighting tab in the CT ECB Companion Tool

Coincident peak electric demand, summer, baseline, kW = $(W_{baseline}/1000) \times CFs$

Coincident peak electric demand, winter, baseline, kW = $(W_{baseline}/1000) \times CFw$

Coincident peak electric demand, summer, proposed, kW = $(W_{proposed}/1000) \times CFs$

Coincident peak electric demand, winter, proposed, kW = $(W_{proposed}/1000) \times CFw$

where

$W_{baseline}$ = the baseline Wattage established per 90.1 Table 9.4.2-2 via the Ext+Parking Garage Lighting tab in the CT ECB Companion Tool.

$W_{proposed}$ = the proposed Wattage is the as-designed Wattage.

CFs = Summer coincidence factor (for exterior lighting use 1.5%, for parking garage lighting determine the value using Annex 4 based upon the building type)

CFw = Winter coincidence factor (for exterior lighting use 87.3%, for parking garage lighting determine the value using Annex 4 based upon the building type)

13. Process and Plug Loads

The process and plug loads category includes systems and equipment that affect building energy consumption but are not regulated by ASHRAE Standard 90.1. As a general rule, such loads must be modeled as energy-neutral (identical) in the baseline and proposed design. However, some unregulated systems such as major ENERGY STAR®-labeled appliances may qualify for incentives. Process loads can only be modeled for performance credit if they are not incentivized by any other state or utility program. Process loads that are incentivized by another state or utility program must be modeled as energy neutral (with the baseline matching the proposed design model).

These systems contribute to internal heat gains which impact heating and cooling loads on the HVAC systems. Process and plug loads must be reasonably captured in the models to account for their impact on regulated systems due to these heat gains. Additionally, these loads affect the percentage improvement of the proposed design relative to the baseline (the performance rating), which sets the incentive tier. Hence underestimating or overestimating these loads may place a project into an incorrect incentive tier.

EXAMPLE 14– Common Mistakes in Categorizing Process and Plug Loads

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

Proposed Design

If process and plug loads are not included in any ECMs, they must be kept energy-neutral, and must be modeled the same in the proposed design as in the baseline. If one or more process or plug load is modeled as an ECM, the baseline must be established based on the applicable state, local or national codes. Detailed documentation must be provided, and the assumptions and modeling approach are subject to utility approval. The following calculation methods are pre-approved:

a. Savings from ENERGY STAR appliances should be calculated using the latest version of the appliance calculator published by the EPA on the ENERGY STAR website. Savings given by the calculator should be converted into model inputs exactly. Reported savings should come from model outputs and may differ from the appliance calculator outputs due to interactions with HVAC systems.

b. Savings for automated receptacle controls in addition to those required by 90.1 Section 8.4.2 must be modeled by adjusting modeled equipment schedules per Option 1 or by adjusting proposed equipment power densities using Option 2 as follows:

<u>Baseline Design (Both options):</u>

- EPD_B [W/SF] – equipment power density (EPD) from the Default Power Density column, Space-by-Space Classification for the appropriate space (lower portion of the table) of COMNET Appendix B[4]
- Equipment Schedule - based on the plug load schedule for the appropriate building type of COMNET Appendix C [4]

<u>Proposed Design:</u>

- In thermal blocks where no automatic receptacle controls are specified, EPD and schedule must be modeled the same as in the baseline
- In thermal blocks where automatic receptacle controls are specified, one of the following options may be used to calculate the performance credit:

  Option 1:

  RPC = RC x 10%

  Where,

  RPC = receptable power credit

  EPSpro = EPSbas x (1-RPC)

  RC = percentage of all controlled receptacles where not required by Section 8.4.2.

  EPSbas = baseline equipment power hourly schedule (fraction)

  EPSpro = proposed equipment power hourly schedule (fraction)

  Option 2:

  $EPD_P = EPD_B * (1 - RC * 10\%)$

EPD_P [W/SF] – proposed EPD, modeled with the same schedule as in the baseline

10% – allowed EPD reduction

Exception: With prior Utility approval and proper documentation such as measurements performed on similar completed projects, higher performance credit may be allowed compared to the defaults.

EXAMPLE 15 – Performance Credit for Receptacle Controls

Q. Project involves an office building. How can receptacle control savings be modeled for a thermal block that include private offices and has a scheduled time-of-day operation control on 70% of 125-volt 15- and 20-amp receptacles?

A. Model inputs must be calculated as follows:

Baseline:

EPD_B=1.67 (W/SF) from COMNET Appendix B & C Abstract, App B Modeling Data tab, row 110

Equipment schedule is based on COMNET Appendix B & C Abstract Table C-5 tab.

Proposed:

Section 8.4.2 requires automatic controls on 50% of the receptacles, thus RC=70%-50%=20% (i.e., 20% of the receptables are not required to have controls but have them specified).

Option 1:

RPC = RC x 10% = 20% x 10% = 2% = receptacle power credit

RC = percentage of all controlled receptacles where not required by Section 8.4.2

Each hourly fraction of the proposed receptacle equipment schedule would be multiplied by 0.98 (1-2%) to get a 2% credit during occupied hours.

Option 2:

$EPD_P = EPD_B * (1-RC*10\%)=1.67*(1-20\%*10\%) =1.637$ W/SF

EPD_P modeled with the same schedule as in the baseline.

14. Commercial Refrigeration Equipment

This section describes the method that must be used to calculate the usage of commercial refrigeration equipment. Refrigerators used in residential kitchens or refrigerated vending machines should be treated as described in Section 13.

a. Commercial refrigerators and freezers that have the baseline efficiency prescribed in 90.1 Table G3.10.1 and the refrigerated cases with the baseline efficiency prescribed in 90.1 Table G3.10.2 must be modeled as described in the following bullets. For all other types of refrigeration equipment, the same energy use must be modeled in the baseline and proposed design unless credit is claimed per Section 14f below.

- Baseline energy use (kWh/day) must be as prescribed in 90.1 Table G3.10.1 and G3.10.2 for the specified equipment type and size.
- Proposed energy use must reflect the AHRI 1200 kWh/day rating for the specified equipment from equipment manufacturer and input the information in Table 3 on the “Plug, Process, and Other Loads” tab in the Compliance Form.

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

RL = RP/24

Where:

RL [kW/hr] = refrigeration load,

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

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

d. Self-contained refrigeration creates a space cooling load, which is captured in most simulation tools when the equivalent process load is modeled in a space. If the specified refrigeration equipment has remote condensers, the internal gains to the spaces where equipment is located must be adjusted to reflect amount of heat extracted from the space as appropriate for the specified equipment. The same internal gains adjustment must be used for the baseline design as for the proposed design.

e. The refrigeration power for the walk-in refrigerators and freezers must be calculated using the equation below unless credit is claimed per Section 14f below, depending on the size and features of the specified equipment (e.g. number of glass display doors):

$$P_{WALK\text{-}IN} = (A_{REF} \times PD_{REF} + N_{REF} \times D_{REF}) + (A_{FRZ} \times PD_{FRZ} + N_{FRZ} \times D_{FRZ})$$

where

$P_{WALK\text{-}IN}$ power density for the walk-in refrigerator or freezer, Watt

A_{XXX} the area of the walk-in refrigerator or freezer, ft²

N_{XXX} the number of glass display doors, unitless

PD_{XXX} the power density of the walk-in refrigerator or freezer from Table 14-1, W/ft²

D_{XXX} the power associated with a glass display door for a walk-in refrigerator or freezer, W/door

XXX subscript indicating a walk-in freezer or refrigerator (REF or FRZ)

Table 14-1: Default Power for Walk-in Refrigerators and Freezers

Floor Area	Refrigerator	Freezer
100 ft^2 or less	8.0	16.0
101 ft^2 to 250 ft^2	6.0	12.0
251 ft^2 to 450 ft^2	5.0	9.5
451 ft^2 to 650 ft^2	4.5	8.0
651 ft^2 to 800 ft^2	4.0	7.0
801 ft^2 to 1,000 ft^2	3.5	6.5
More than 1,000 ft^2	3.0	6.0
Additional Power for Each Glass Display Door	105	325

Source: These values are determined using the procedures of the Heatcraft Engineering Manual, Commercial Refrigeration Cooling and Freezing Load Calculations and Reference Guide, August 2006. The energy efficiency ratio (EER) is assumed to be 12.39 for refrigerators and 6.33 for freezers. The specific efficiency is assumed to be 70 for refrigerators and 50 for freezers. Operating temperature is assumed to be 35°F for refrigerators and -10°F for freezers.

f. Credit for refrigerated cases not regulated by 90.1 and/or not covered by Appendix G may be claimed using exceptional calculation methods. Baseline systems and components shall meet or exceed standard practice and be supported by other jurisdictions and/or standards such as USGBC or California Title 24. The baseline and exceptional calculation methods are subject to approval by the Utility and must be classed as unregulated consumption in Table 2 on the Compliance Calculations tab in the DOE/PNNL Compliance Form.

15. Heating, Ventilation and Air Conditioning Systems

15.1. HVAC System Type and Efficiency

Proposed Design

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

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

Equation 1: $COPnfcooling = -0.0076 \times SEER^2 + 0.3796 \times SEER$

Equation 2: $COPnfheating = -0.0296 \times HSPF^2 + 0.7134 \times HSPF$

Where:

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

COPnfheating = Coefficient of Performance (COP) heating efficiency excluding AHRI rating fan power.

EXAMPLE 16 – SEER to COPnfcooling Conversion

Q. If a system in the proposed design has a rated efficiency of SEER 13.0, what are the model inputs for the system efficiency?

A. SEER can be converted to COPnfcooling (i.e., COP no fan cooling) using Equation 2, in this case this results in COPnfcooling = 3.65.

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

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

Where:

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

EER = the rated Energy Efficiency Ratio, at AHRI conditions

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

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

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

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

Where:

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

COP = the rated COP, at ARI conditions.

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

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

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

Baseline Design

a. HVAC System Type

90.1 2019 addendum ab[17] clarified and streamlined the process of determining the baseline HVAC system types. These updated requirements, as modified as shown underlined below, must be followed when documenting performance with the ECB program. Below is a summary of the process based on amended Section G3.1.1.1:

1. Determine the combined gross conditioned and semi-heated floor area for each of the following building area types in the proposed design:

- residential and residential-associated zones
- public assembly
- heating-only storage
- retail
- hospitals
- other nonresidential

2. Classify the nonresidential building area type with the largest combined area as the predominant nonresidential building area type. Add the combined area of any remaining nonresidential building area types with less than 20,000 ft^2 to the combined area of the predominant nonresidential building area type.

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

The amended section G3.1.1.2 includes requirements for determining additional and adjusted baseline HVAC system types.

Table G3.1.1-3 Note 2 shall be amended to read as follows: "The total number of stories in a building, including above-grade and below-grade stories but not including stories solely devoted to parking and stories solely devoted to *residential building* area type as defined in G3.1.1.1(a) #1."

[17] ASHRAE 90.1 2019 Addendum ab
https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_ab_20220727.pdf

Example 17 Baseline System Type for a Mixed-Use Building

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

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

Step 1: Determine the baseline HVAC system types based on building area types following 90.1 addendum ab Section G3.1.1.1

Based on 90.1 2019 Addendum ab definition, any HVAC zone that primarily includes nonresidential spaces designed to serve occupants of residential spaces on a floor where over 75% of the gross conditioned floor area are residential spaces is considered residential-associated. On floors 2-5, hotel guest rooms account for more than 75% of conditioned and semi heated floor area, and all non-residential spaces on these floors are used for the hotel function. Thus, the residential zones on floors 2-5 shall be modeled with baseline System 1 – PTAC following Table G3.1.1-3 and the residential associated spaces on these floors shall be modeled with System 3 – PSZ- AC following 9.1-2019 Addendum ab G3.1.1.2 (f).

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

Step 2: Determine additional and adjusted baseline HVAC system types following 90.1 addendum ab Section G3.1.1.2

Heated only stairwells on the hotel floors and heated only storage on the retail floor are subject to addendum ab Section G3.1.1.2 Exception (c) and will be modeled with System 9 – Heating and Ventilation.

b. Air-side System Efficiency

- Baseline air-side HVAC system efficiency ($COP_{NFCOOLING}$ and $COP_{NFHEATING}$) is determined based on 90.1 Tables G3.5.1, G3.5.2, G3.5.4, and G3.5.5.
- The values provided in the tables depend on the baseline system capacity which must be determined using the simulation sizing runs following 90.1 Section G3.1.2.2.1.
- 90.1 Table G3.1 #7-9 allow modeling multiple HVAC zones that meet the specified criteria as a single thermal block to simplify modeling. To avoid impact of these modeling simplifications on the baseline system efficiency, the baseline efficiencies must be based on the load of individual HVAC zones prior to aggregation into thermal blocks as is allowed in 90.1 Table G3.1 #7 Thermal Blocks – HVAC Zones Designed. When identical floors are grouped in accordance with Section G3.1.1(a)(4), efficiencies in G3.5.1 for the Baseline HVAC System Types 5 or 6 must be based on the cooling equipment capacity of equipment serving a single floor.

c. PTHP Auxiliary Heat

Baseline System 2 – PTHP must be modeled with electric auxiliary heat controlled as required in 90.1 Section G3.1.3.1. The electric auxiliary heat must be locked out in the model at temperatures above 40°F.

When modeling a PTHP, heat pump operation must be allowed in conjunction with auxiliary heat at temperatures of 25°F and above; below 25°F, only auxiliary heat should operate. For example, eQUEST users should set “Minimum HP Heat Temp” to 25°F and “Maximum HP Supp Temp” to 40°F.

15.2. Mechanical Ventilation

Proposed Design

Mechanical ventilation must be modeled as specified, including ventilation delivery method such as via the space conditioning system or a dedicated outdoor air system (DOAS), ventilation controls such as demand control ventilation (DCV), and exhaust air energy recovery.

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

- Automatic controls to shut off fans when outdoor air not required (6.4.3.4.4)
- Garage ventilation capable to automatically stage fans or modulate airflow rates to 50% or less of design capacity based on contaminant levels (6.4.3.4.5)
- DCV for spaces over 500 ft^2 with design occupancy equal or greater than 25 people per 1000 ft^2 (6.4.3.8). If the occupant density in spaces that are typically subject to the DCV requirement is less than the default occupant density listed in ASHRAE 62.1 Table 6-1, making DCV not required, the source for the assumed occupant density must be documented.

Baseline Design: Ventilation Rate

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

a. Following 90.1 Section G3.1.2.6 exception (c), if the minimum outdoor air intake flow in the proposed design exceeds the amount required by the applicable code, then the baseline building design must be modeled to reflect the minimum required ventilation rate and will be less than in the proposed design. There is no over-ventilation penalty for healthcare facilities following ventilation requirements of ASHRAE Standard 170 if deemed necessary by the owner.

b. Zones with air distribution effectiveness Ez>1.0 may be modeled with lower ventilation rate in the proposed design compared to the baseline as described in 90.1 Section G3.1.2.5 Exception (2). This performance credit may apply to designs with displacement ventilation or other techniques that result in ventilation effectiveness greater than 1.0. Projects must use Ventilation Rate Procedures described in ASHRAE Standard 62.1, Section 6.2 to demonstrate the savings.

Baseline Design: Demand Control Ventilation

a. Section 90.1 G3.1.2.5 Exception 1 requires that demand control ventilation (DCV) is modeled in the baseline design for systems serving areas with a design occupancy greater than 100 people per 1,000 ft^2 of floor area and a design outdoor airflow greater than 3000 CFM. In all other cases, DCV is not modeled in the baseline.

b. DCV can be modeled for performance credit when it is not already required to be modeled per

ASHRAE 90.1 2019 Appendix G. Minimum code-required ventilation rates must be used in the baseline model for systems in the proposed design claiming credit for using DCV.

15.3. Fan Systems

Proposed Design

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

Baseline Design

a. The system baseline fan power must be calculated according to Appendix G section G3.1.2.9 and represents the total fan power allowance including supply, return, and exhaust fans, central and zonal. No additional fan power is allowed to be modeled for exhaust fans as the calculated system baseline fan power allowance includes all fans.

b. Baseline fan power allowance must be allocated to supply, return and exhaust in the same proportion as in the proposed design.

c. Baseline fan power allowance may be increased to account for air filtration (based on MERV rating) and sound attenuation when specified for the proposed design. Exhaust air energy recovery adjustment may be used only when energy recovery is modeled in the baseline. Fully ducted return adjustment may only be used when the proposed design is required by code or accreditation standards to be fully ducted is required by applicable code.

d. The preferred method for modeling baseline fan power is by specifying Watt per CFM of air flow in the model, as this avoids the need to adjust fan power whenever flow rates change when evaluating ECMs. However, if a software tool does not allow inputting power per unit flow, the same purpose can be achieved by defining the total static pressure drop (TSP) and overall fan efficiency fraction (including motor, drive, and mechanical efficiencies). If TSP and/or overall fan efficiency are unknown, use Equation 5 to convert from kW/cfm (power per unit flow).

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

If overall fan efficiency fraction $\eta_{overall}$ is unknown, 0.55 default may be used. The accuracy of this estimate does not affect the results of the simulation, since adjusting the efficiency fraction when using Equation 5 will cause an offsetting adjustment in the total static pressure.

Example 18 Fan Power and Cooling Efficiency

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

A. Baseline: According to Table 7.2, the baseline is System 3, Packaged Single Zone with Fossil Fuel Furnace. Baseline thermal blocks are the same as in the Proposed Design. System auto-sizing places the systems in the same capacity range as the proposed units, with a design flow rate of 4,850 CFM each.

The baseline system efficiency from ASHRAE 90.1 Table G3.5.1 for 135 kBtu/hr – 240 kBtu/hr capacity bracket is COPnfcooling=3.4.

To calculate baseline fan power, first determine the total baseline fan power allowance according to section G3.1.2.9. The specified units include MERV 13 filters, exhaust air energy recovery, fully ducted return and sound attenuation that each have fan power pressure drop adjustments available in 90.1 Table 6.5.3.1-2. The return is not required by code to be fully ducted, thus the associated pressure drop adjustment cannot be used for the baseline. Exhaust air energy recovery pressure drop adjustment also cannot be used because the baseline system is modeled without exhaust air energy recovery following G3.1.2.10. Only the MERV 13 adjustment (0.9) and sound attenuation adjustments (0.15) are used as follows:

A = (0.9+0.15) × 4,850 ÷ 4,131 = 1.23 BHP

BHP=0.00094 ×CFM+A=0.00094 ×4850+1.23=5.8 BHP

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

P_FAN=BHP ×746 ÷Fan Motor Efficiency=5.8 ×746 ÷0.895=4,834 W

The final step in determining baseline fan power is to apportion the total system P_{FAN} to supply, return, and exhaust applications, directly proportional to the apportionment in the Proposed Design using the Application Ratios described below. For this example, total proposed fan BHP for each system is 2.8 + 1.1 + 75 / 746 = 4 HP. Total baseline fan power = 4,824 W. Application ratios and their usage in calculating power per unit flow for this example are listed in the table below.

	Proposed Application Ratio	Total Baseline Fan Power W	Baseline Fan Power kW
Supply Fan	2.8 / 4 = 0.7	4,824	0.7 * 4.824 = 3.38
Return Fan	1.1 / 4 = 0.275		0.275 * 4,824 = 1.33
Bathroom Exhaust	(75 / 746) / 4 = 0.025		0.025 * 4,824= 0.121

The baseline kW/CFM should either be entered directly into the modeling tool, or first converted into TSP and efficiency fraction inputs using the equation in Section 7.6.2 (c) . There is no additional allowance for individual exhaust fan – the calculated baseline fan power allowance covers all applications.

Proposed Model: To extract proposed fan power, use equation 7-1. For BHP_{SUPPLY}, take the difference between gross and net cooling c a p a c i t

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

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

15.4. Special Rules for Laboratory Exhaust Systems

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

- Following Addendum ab[17] Section G3.1.1.2 (b), laboratory spaces in buildings having a total laboratory exhaust rate greater than 15,000 CFM must be modeled with baseline systems of type 5 or 7 serving all such spaces. The lab exhaust fan must modeled as constant horsepower (kilowatts) reflecting constant-volume stack discharge with outdoor air bypass.

- Following the exception to Section G3.1.3.13, the baseline systems serving laboratory spaces shall be modeled to reduce the exhaust and makeup air volume during unoccupied periods to the largest of 50% of zone peak air flow, the minimum outdoor air flow rate, or the air flow rate required to comply with applicable codes or accreditation standards. If a project has a minimum flow rate above 50% due to the applicable codes and standards, and this higher rate is modeled in the baseline, the flow cannot be reduced below this required minimum the proposed design.
- Following Section G3.1.2.10 Exception 2, exhaust air energy recovery does not have to be modeled in the baseline unless it is specified for the proposed design.
- Following 90.1 2019 Addendum i[18], HVAC systems serving laboratory HVAC zones with a total laboratory exhaust volume greater than 15,000 cfm should not be modeled with exhaust air energy recovery. Prior to the addendum, a proposed laboratory design with variable flow exhaust and energy recovery would be required to model both heat recovery and variable exhaust in the baseline HVAC system, which misrepresents 90.1 2004 requirements.

15.5. Chiller Performance Curves

Table G3.5.2 prescribes full load efficiency (FL) and part load efficiency (IPLV) for the baseline chillers depending on chiller type and capacity. Similarly, construction documents provide FL and IPLV of the specified equipment. Commonly used simulation tools allow entering chiller full load efficiency and performance curves that determine chiller operation at lower loads, but do not the IPLV input.

Previously, performance curves corresponding to the prescribed baseline chiller IPLV were not provided in 90.1. As a result, modelers often used default curves that differed between simulation tools and did not reflect the intended performance of the baseline chillers. The issue was addressed by 90.1 2019 addendum bd[19] which prescribed the performance curves that must be used for the baseline chillers.

The addendum also requires that where the performance curves for the chillers specified in the proposed design are not available, the provided default performance curves are used based on the specified chiller type. The addendum also prescribes chiller minimum part-load ratio (ratio of load to available capacity at a given simulation time step) and minimum compressor unloading ratio (part-load

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[18] ASHRAE 90.1 2019 Addendum I
https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_i_20201030.pdf

[19] ASHRAE 90.1 2019 Addendum bd
https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/90_1_2019_bd_20220531.pdf

ratio below which the chiller capacity cannot be reduced by unloading and chiller is false loaded) of 0.25. Chiller performance must be modeled as required in [90.1 2019 addendum bd][19].

15.6. Boiler Performance Curves

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

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

For projects with boiler system(s) in the proposed design, modeling parameters must reflect mechanical drawings. Design supply and return water temperatures must be explicitly entered into the simulation tool if the tool can automatically capture their impact on boiler efficiency through performance curves. If the tool is not capable of automatically adjusting efficiency based on entered loop temperatures, efficiency input must be adjusted manually to reflect manufacturer's performance data for the boiler at actual operating conditions. Atmospheric boiler performance curves included in Annex 2 must be modeled for the baseline design. For the proposed design, either the default performance curves included in Annex 2 or the actual performance curves for the specified boilers should be used.

15.6. Special ECB Program Rules for Ventilation in Healthcare Facilities

Minimum flow rates in healthcare facilities are prescribed by ASHRAE Standard 170. Higher rates are permitted if deemed necessary by the owner, thus higher rates may be specified for such facilities without incurring an over-ventilation penalty with pre-approval from the Utility.

All related EEMs for ventilation in healthcare facilities must be approved by the Utility prior to modeling including but not limited to flow control measures such as an advanced air quality control system and heat recovery. The following are other modeling requirements:

- Areas subject to Standard 170 must be modeled with baseline systems of type 5 or 7 serving all such spaces (i.e., the systems only serve areas subject to ASHRAE Standard 170).
- During occupied hours, the baseline design must be modeled at the minimum flow rates required by Standard 170 and the proposed must be modeled with the greater of the as designed flow rates and the minimum flow rates required by Standard 170.
- During unoccupied hours:
    - The baseline systems must be modeled to reduce the flow rates to the largest of 50% of zone peak air flow, the minimum outdoor air flow rate, or the air flow rate required to comply with applicable codes or accreditation standards.
    - The proposed systems must be modeled as designed, except if the project has a minimum flow rate above 50% due to the applicable codes and standards, and this

higher rate is modeled in the baseline, the flow cannot be reduced below this required minimum in the proposed design.

15.7. Special ECB Program Rules for Engine Driven Chillers

Projects with engine driven chillers shall follow the modeling rules in ASHRAE 90.1 2019 and these guidelines. Program administrators may institute exceptions to these rules on a case-by-case basis. It is recommended that project teams contact program administrators if a project includes an engine driven chiller prior to beginning modeling in case exceptions apply.

16. Water Heating

Baseline Design

a. The service hot-water system in the baseline building design is prescribed in Table G3.1.1-2 and is either gas or electric resistance storage central water heater. In mixed use buildings, baseline water heater type must be established separately for each occupancy.

b. Hot water demand in the baseline building design must be typical for building occupancy type. Table 16-1 provides typical hot water use for various types of buildings that should be used to establish baseline hot water energy use which are based on Table 7 from Chapter 50: Service Water Heating of the 2011 ASHRAE Applications Handbook.

   For building types not included in Table 16-1, hot water demand may be established using other information given in Chapter 50: Service Water Heating of the 2011 ASHRAE Applications Handbook, such as Table 10 which provides hot water demand in gallons per hour per fixture for various types of buildings. Hourly demand must be coupled with the appropriate hourly schedules per Section 9[5,4].

Proposed Design

a. Hot water heater type and efficiency must be modeled as specified.

b. How water demand may be lower than in the baseline if the following technologies are specified (Exceptions 1-3 to Table G3.1 #11 (g), Baseline Building Performance column):

   I. Measures that reduce the physical volume of service water required blow the maximum flow rates allowed by applicable code, such as low-flow shower heads and dishwashers.

   II. Measures that reduce the required temperature of service mixed water, by increasing the temperature, or by increasing the temperature of the entering makeup water. Examples include alternative sanitizing technologies for dishwashing and heat recovery to entering makeup water.

   III. Reducing the hot fraction of mixed water to achieve required operational temperature. Examples include shower or laundry heat recovery to incoming cold-water supply, reducing the hot-water fraction required to meet required mixed-water temperature.

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

Technologies demonstrating a reduction in hot water usage should be modeled as reduced hot water demand in the Proposed Design based on Equation 6.

Equation 6: $HWD_{PROP} = HWD_{BASE} * (1 - R)$

Equation 7: $R = \sum(R_A * F_A)$

where

HWD_{BASE} baseline consumption [gal/day]

R % reduction from baseline to proposed.

R_A % reduction in hot water usage for a particular hot water application

F_A hot water usage for the particular application as a fraction of total usage.

Table 16-2 shows R_A and F_A values for common building types and technologies. Values for other technologies must be documented in the modeling submittal. F_A values must reflect realistic run-time based on the number of fixtures specified for the project.

*Table 16-1 Sample Hot-Water Demands and Use for Various Types of Buildings[20]**

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

*Data predates modern low-flow fixtures and appliances, and may be reduced by projects

**Average of men's and women's dormitories

***Categories changed to ranges to avoid the need for interpolation

****Average for different size apartment buildings

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

Table 16-2: F_A and R_A values for calculating reductions in hot water usage

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

*sum of all F_A values must not exceed 100%

17. Special Cases

17.1. Core and Shell Projects

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

17.2. Tenant Space Fit Out Zones

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

17.3. Modeling Existing and Future Components

17.3.1. Future Components

Future components (e.g., unspecified system and components in core and shell projects and future tenant fit-out spaces) must be held energy neutral and must be modeled as minimally complying with ASHRAE Standard 90.1 in the proposed and per the rules of Appendix G in the baseline.

17.3.2. Unmodified Existing Components

Existing components that are not modified or replaced as part of the project scope must be modeled with existing conditions in the proposed design model per the requirements of 90.1 2019 Appendix G and with the baseline established and modeled per Appendix G rules. Examples of unmodified existing components include, but are not limited to, existing envelopes not being renovated as part of the project scope of work, as in tenant fit-out and major renovation projects, and existing central plants in tenant fit-out projects.

17.3.3. Existing Components Being Replaced or Modified

Existing components that are being modified or replaced must be modeled per the requirements of ASHRAE 90.1 Appendix G in the baseline and proposed. This requirement applies to all building components, including the building envelope.

Example 19 – Core and Shell Project

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

A. The following systems and components would be modeled:

1. Building envelope will be modeled as shown on design documents.
2. Lighting power and controls for common spaces where lighting design is completed will be modeled as shown on design documents. For tenant spaces where lighting is not specified, the proposed design will be modeled as minimally compliant with the allowances in Table 9.5.1, Building Area Method (Table G3.1 #6 (c), Proposed Building Performance column). The baseline design for these spaces will be modeled following Table G3.8, Performance Rating Method Lighting Power Densities Using the Building Area Method (90.1 2019 Addendum af). If use type of future tenant spaces is unknown, office occupancy must be assumed (Table G3.1#1 (c), Proposed Building Performance).
3. Thermal blocks in the common areas where air-side HVAC system design is completed will be based on specified HVAC zones and requirements in Table G3.1.#7, Thermal Blocks – HVAC Zones Designed. In tenant spaces where air-side HVAC systems are not yet designed, thermal blocks will be modeled using perimeter/core approach as described in Table G3.1 #8, Thermal Blocks – HVAC Zones Not Designed.
4. The baseline will be modeled with System 7 – VAV with reheat following the regular rules of 90.1 PRM. Proposed design will be modeled with the specified heating and cooling plants. Air-side systems in common spaces will be modeled as shown on design documents. Air-side systems in tenant spaces will be modeled with the same configuration as in the baseline (e.g., one system per floor) but minimally compliant with the applicable prescriptive requirements of 90.1 2019.

17.4. Modeling Similar Buildings

a. To qualify for ECB incentives where modeling is necessary, non-identical buildings must be modeled explicitly. For example, a multifamily complex with ten buildings but only three unique building types may consist of an explicit model of the three buildings representing each building type with a multiplier applied to each building in the modeling software. Alternatively, all ten buildings may be modeled explicitly, depending on the capabilities of the simulation tool.

b. A separate model and report must be generated for each unique location of multiple similar buildings, such as chain retail stores, with the model and documentation matching the design parameters at each location.

Annex 1 Reference Site EUI by End Use

These tables are provided for reference and are based on the energy consumption by end use of the Appendix G PNNL prototype models in Climate Zone 5A minimally compliant with 90.1 2004 (analogous to 90.1 Appendix G baseline) and 90.1 2019. These values are for reference purposes only, modeled baseline and proposed EUIs for the program are not required to match these end use EUI values or be within any specific % margin of error with the exception that per Section 13 projects with a process and plug load site energy intensity more than 20% below the provided values for the baseline must justify the related modeling assumptions in the report.

Table A1.1: Site EUI [kBtu/SF] of Designs Minimally Compliant with ASHRAE 90.1 2004 in CZ 5A

Building Type	Interior Lighting	Exterior Lighting	SHW	Heating	Cooling	Fans	Pumps	Refrigeration	Elevators	Transformers	Process & Plug	Total
High-rise Apartment	3.4	2.6	13.3	25.4	2.1	7.0	0.1	0.0	2.6	0.2	10.9	67.6
Mid-rise Apartment	3.6	2.3	13.3	19.4	2.5	6.7	0.1	0.0	5.2	0.0	10.8	63.8
Hospital	16.3	1.1	5.1	38.7	10.8	14.7	2.3	0.7	6.6	0.3	37.9	134.3
Large Hotel	11.8	2.5	22.3	19.3	5.6	7.8	0.1	0.6	9.6	0.2	26.6	106.4
Small Hotel	11.3	2.3	17.7	11.0	6.2	5.4	0.0	0.0	8.2	0.0	16.0	78.0
Large Office	10.7	1.9	0.9	11.1	3.8	5.2	1.8	0.0	4.6	0.1	27.9	68.0
Medium Office	10.0	4.2	1.0	15.8	2.9	3.1	0.1	0.0	3.2	0.2	10.3	50.7
Small Office	12.1	6.1	1.2	13.4	2.2	7.2	0.0	0.0	0.0	0.0	8.3	50.5
Outpatient Healthcare	14.5	5.5	3.0	28.2	9.9	10.6	0.1	0.0	12.7	0.0	31.9	116.4
Standalone Retail	18.9	4.8	1.1	20.8	4.3	18.1	0.0	0.0	0.0	0.0	7.5	75.4
Strip Mall	26.1	7.5	0.8	22.7	4.8	22.5	0.0	0.0	0.0	0.0	5.4	89.8
Primary School	15.6	1.2	2.0	22.2	3.8	5.0	0.0	1.3	0.0	0.2	18.7	70.0
Secondary School	14.6	1.0	3.3	17.7	3.0	5.7	0.8	0.7	0.8	0.1	12.7	60.4
Warehouse	11.4	2.4	0.2	19.4	0.5	4.7	0.0	0.0	0.0	0.0	2.5	41.1

Table A1.2: Site EUI [kBtu/SF] of Designs Minimally Compliant with ASHRAE 90.1 2019 in CZ 5A

Building Type	Interior Lighting	Exterior Lighting	SHW	Heating	Cooling	Fans	Pumps	Refrigera tion	Elevators	Transfor mers	Process & Plug	Total
High-rise Apartment	1.8	1.4	13.3	10.4	2.0	2.5	0.8	0.0	1.6	0.2	10.9	45.0
Mid-rise Apartment	2.1	0.9	13.3	8.0	1.9	2.5	0.0	0.0	1.9	0.0	10.8	41.4
Hospital	12.2	0.7	5.1	19.5	6.5	12.3	1.1	0.5	3.5	0.3	37.9	99.6
Large Hotel	4.2	1.5	22.1	9.2	4.1	5.1	0.6	0.4	4.8	0.2	26.6	78.9
Small Hotel	3.8	1.1	17.7	8.6	4.5	5.3	0.0	0.0	2.9	0.0	16.0	60.0
Large Office	4.7	0.7	0.9	4.9	3.7	4.3	0.6	0.0	3.5	0.1	27.9	51.3
Medium Office	4.1	0.9	1.0	10.5	2.4	1.5	0.1	0.0	2.1	0.2	10.3	33.1
Small Office	4.5	1.7	1.2	9.3	1.6	2.9	0.0	0.0	0.0	0.0	8.3	29.6
Outpatient Healthcare	9.4	1.4	3.0	26.4	10.2	7.1	0.1	0.0	4.6	0.0	31.9	94.0
Standalone Retail	8.9	1.7	1.1	24.8	2.8	5.5	0.0	0.0	0.0	0.0	7.5	52.3
Strip Mall	15.4	2.5	1.1	28.3	2.7	4.1	0.0	0.0	0.0	0.0	5.4	59.6
Primary School	3.6	0.4	1.9	11.9	3.0	3.7	0.0	0.9	0.0	0.2	18.7	44.3
Secondary School	3.6	0.3	3.1	7.4	3.1	5.0	0.2	0.5	0.5	0.1	12.7	36.5
Warehouse	1.5	1.1	0.2	15.6	0.1	0.6	0.0	0.0	0.0	0.0	2.5	21.6

Annex 2 Boiler Performance Curves

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

Equation 2.1: $Fuel_{parload}=Fuel_{design} * FHeatPLC$

Equation 2.2: $FHeatPLC=a+b*Q_{partload}/Q_{design}+c*Q_{partload}/Q_{design})^2$

Equation 2.3: $FHeatPLC=a+b*Q_{partload}/Q_{design}+c*(Q_{partload}/Q_{design})^2+d * T_{rwt}+ e * T_{rwt}^2 + f * T_{rwt} * Q_{partload}/Q_{design}$

Where:

Fuelpartload = fuel consumption at part-load conditions, in Btu/h for DOE2, W for E+

Fueldesign = fuel consumption at design conditions, in Btu/h for DOE2, W for E+, and

FHeatPLC = fuel heating part-load efficiency curve determined using equation and coefficients in Table A2.1.

Qpartload = *boiler* capacity at part-load conditions, in Btu/h for DOE2, W for E+

Qdesign = *boiler* capacity at design conditions, in Btu/h for DOE2, W for E+

Trwt = return water temperature in F for DOE2; C for E+

a, b, c, d, e, f = coefficients from Table A2.1

Table A2.1: Boiler Performance Equation Form and Coefficients

BEM Tool	Boiler Type	Equation	a	b	c	d	e	f
DOE2	Non-condensing	Eq 2.2	0.082597	0.996764	-0.07936			
	Condensing	Eq 2.3	-0.09439	0.903224	0.01546	0.001598	-6.5E-06	0.001114
E+	Non-condensing	Eq 2.2	0.6267	0.674	-0.3073			
	Condensing	Eq 2.3	1.19381	-0.11083	0.039514	-0.00637	0.000038	0.00083

The coefficients in rows 1,3,4 of Table A2.1 are from California Alternative Calculation Manual (ACM) Appendix 5.7 Equipment performance curves. The coefficients in row 2 of Table A2.1 are from the eQUEST technical documentation.

Annex 3 Commercial and Industrial Hours of Use and EFLH

Table A3.1 shows the typical effective lighting full load hours (EFLH) for different types of facilities without accounting for lighting controls such as occupancy sensors and daylighting. Table A3.1 includes adjustments to account for the reduced lighting runtime due to occupancy sensors, based on ASHRAE 90.1 2013 User's Manual. In addition, modeled lighting runtime will be reduced due to daylighting controls.

The equation below allows estimating typical facility-wide effective full load hours for interior lighting for the proposed design model.

EFLH=Annual_Runtime x OS_Adjustment x Daylighting_Adjustment

Annual_Runtime from Table A3.1; OS_Adjustment from Table A3.2; Daylighting_Adjustment ~ 0.9

The baseline design includes limited lighting occupancy controls and no daylighting controls therefore it is expected that lighting EFLHs would approximately align with the values in Table A3.1 without the adjustment described directly above.

Table A3.1: Annual Runtime[21]

Facility Type	Lighting Hours
Auto-related	2,807
Bakery	5,468
Banks, financial center	3,748
Church	913
College: cafeteria	5,018
College: classes/administrative	4,839
College: dormitory	4,026
Commercial condo	4,026
Convenience store	5,468
Convention center	913
Courthouse	4,181
Dining: bar lounge/leisure	5,018
Dining: cafeteria/fast food	5,018
Dining: family	5,018
Entertainment	1,952
Exercise center	5,836
Fast food restaurant	5,018
Fire station (unmanned)	4,336
Grocery/food store	5,468
Gymnasium	2,586
Hospital	5,413
Health care	5,564
Industrial: 1 Shift	2,897
Industrial: 2 Shift	5,793
Industrial: 3 Shift	8,690
Laundromat	4,056
Library	3,748
Light manufacturer	5,793
Lodging (hotel/motel)	3,112

Facility Type	Lighting Hours
Mall concourse	4,939
Manufacturing facility	5,793
Medical office	3,673
Motion picture theatre	1,954
Multifamily (common areas)	6,388
Museum	3,748
Nursing home	5,840
Office (general office types)	4,098
Office/retail	4,181
Parking garage and lot	6,887
Penitentiary	5,477
Performing arts theatre	913
Police/fire station (24-hr)	8,760
Post office	3,748
Pump station	1,949
Refrigerated warehouse	6,512
Religious building	913
Residential (except nursing homes)	3,066
Restaurant	5,018
Retail	4,939
School/university	2,967
Schools (Jr./Sr. High)	2,967
Schools (preschool/elementary)	2,967
Schools (technical/vocational)	2,967
Small services	3,748
Sports arena	913
Town hall	4,181
Transportation	6,456
Warehouse (not refrigerated)	5,667
Wastewater treatment plant	6,631
Workshop	3,750

[21]] Connecticut’s 2022 Program Savings Document, 19th Edition (2021)

Table A3.2: Occupancy Sensor Adjustment (ASHRAE 90.1 2013 Users' Manual Tables G-D to G-L)

Building Type	**OS_Adjustment**
Assembly	0.87
Health	0.92
Light manufacturing	0.95
Office	0.78
Parking garage	0.77
Restaurant	0.94
Retail	0.95
School	0.77
Warehouse	0.68
Other	0.85

Annex 4 Coincidence Factors for Parking Garage Lighting

Table A4.1: Parking Garage Lighting Coincidence Factors[21]

Building Type	Parking Garage Lighting Coincidence Factor (CF)	
	Summer	Winter
Grocery	90.40%	85.60%
Manufacturing	83%	66.50%
Medical (hospital)	82.50%	69.60%
Multifamily common area	17.00%	100.00%
Large office	70.20%	53.90%
Small office	76.80%	44.10%
Other	86.90%	76.70%
Restaurant	77.50%	77.00%
Retail	98.40%	85.60%
University/college	36.80%	46.00%
Warehouse	89.30%	72.40%
School	59.90%	38.80%
Automotive	68.30%	36.90%
Hotel/motel	40.60%	37.50%
Industrial	83.00%	66.50%
Religious building/convention center	17.00%	9.20%