Whole Building Performance Energy Modeling Guidelines for Connecticut

Version 2.0

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Prepared for Energize Connecticut for use with 2016 CT State Building Code based on ANSI/ASHRAE/IESNA Standard 90.1 2010 by Karpman Consulting.

Contents

1 Purpose

The purpose of the Whole Building Performance Energy Modeling Guidelines is to establish clear, transparent, peer-reviewed modeling policies that improve the accuracy and technical integrity of analyses performed by program participants.

Towards this end, these guidelines aim to fulfill the following objectives:

1. Describe program policies that deviate from the standard approach described in the ANSI/ASHRAE/IESNA Standard 90.1 2010 [1] Appendix G ("Appendix G") modeling protocol.
2. Define program technical policies (such as required assumptions or methodologies) in areas left unregulated or ambiguous by Appendix G (e.g., rules governing heat pump auxiliary heat operation)
3. Reiterate and explain Appendix G rules that are often misapplied or misinterpreted
4. Highlight impactful changes in Appendix G rules since the last version of 90.1
5. Provide examples in order to illustrate all of the above

2 Scope and Applicability

2.1 Program Eligibility

To be eligible for participation in the Whole Building Performance program, a project must include at least 30,000 square feet of conditioned floor area, that is both heated and cooled. Eligible projects must include measures addressing at least two of the following five building systems: Lighting, HVAC, Service Water Heating, Plug and Process Loads, and Building Envelope.

For the purposes of calculating incentives, the project area, in units of square feet, shall be defined as gross conditioned floor area, calculated using the definition of conditioned space found in Section 3 of ASHRAE Standard 90.1 2010 [1].

> EXAMPLE 2-1 – Calculating Project Area
>
> Q. A Whole Building project involves a high-rise multi-family tower with a parking garage on the ground floor. The parking garage includes lighting and exhaust systems but does not meet the ASHRAE Standard 90.1 definition for conditioned space. Should the area of the parking garage be included in the space area reported to the program for the determination of program eligibility and calculation of incentives?
>
> A. Because the parking garage is not considered conditioned space, based on the definition in ASHRAE Standard 90.1, it *cannot* be included in the Project Area reported to the program.

2.2 Applicability of Guidelines

Projects with design requirements to meet IECC 2012 / ASHRAE 90.1 2010 must follow Energy Modeling Guidelines (EMG) v2.x or later, based on the EMG version in effect when the Design Agreement is executed.

Projects required to meet IECC 2009 / ASHRAE 90.1 2007 or earlier codes must use EMG V1.1.

3 General Modeling Approach

3.1 Modeling Protocol

Buildings shall be modeled following ASHRAE/IESNA Standard 90.1-2010 (ASHRAE 90.1, 90.1) [1] Informative Appendix G Performance Rating Method (Appendix G, PRM), and as described in this document or by specific instruction of the Utility responsible to review the results.

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 must not be used in developing energy models except where explicitly permitted in this document.

3.1.1 Appendix G Baseline Model

The baseline shall be modeled according to the rules described in Appendix G. As per Appendix G, the baseline shall not include end uses that do not exist in the proposed building (see Example 3-2).

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 by applying 90.1 Table G 3.1.1 A to these spaces, with the baseline system configuration based on Table G3.1.1 B except with cooling type set to "None".

> Exception: 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 Design 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 tenanats.

Where parameters of the baseline model are not defined by ASHRAE Standard 90.1, they should be modeled matching the proposed design or, if no corresponding parameters exists in the proposed design model, based on modeling best practice (see e.g., COMNET [3]) or typical industry practice.

EXAMPLE 3-1 - No Cooling Specified

Q. A Whole Building project involves a school that includes cooling in the administrative wing but does not include cooling in classrooms (30,000 square feet total area) 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. Should cooling be modeled in 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 or 6, depending on the heating fuel source, but without DX coil. Mechanical spaces should be modeled as unconditioned.

EXAMPLE 3-2 (a) - Unlit Parking Lot

Q. If a building design includes a parking lot that is not lit, what lighting power allowance can be used in the baseline model?

A. If a parking lot in the proposed design is not lit, then the parking lot lighting power allowance cannot be added to the baseline energy consumption.

EXAMPLE 3-2 (b) – Partially Illuminated Parking Lot

Q. If a project includes a parking lot that is designed to be partially illuminated, what lighting power allowance can be used in the baseline model?

A. The parking lot baseline lighting power allowance shall be calculated based on the area designed to be illuminated and meets the recommended illuminance levels based on the photometric study.

3.1.2 Appendix G Proposed Model

The proposed design must be modeled according to the rules described in Appendix G and, generally, must reflect the building components specified in project drawings and specifications.

3.1.3 Performance Rating

The performance rating must be calculated on the basis of source energy, in units of kBtu, using the following site to source multipliers:

Electricity – 2.99
Natural Gas – 1.09
Propane and Fuel Oil – 1.01

3.1.4 Regulated and Unregulated Loads

All energy costs within and associated with the building must be modeled in both the baseline and proposed models, including both regulated and unregulated loads, unless specifically excluded by this document.

3.1.5 Addenda

Addenda to ASHRAE Standard 90.1 2010 may optionally be followed, but must be explicitly referenced in the submittals and must be followed in their entirety. One addendum or several addenda may be used without having to use all addenda.

3.1.6 Mandatory Requirements

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

3.1.7 Software Requirements

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

- eQUEST
- EnergyPlus
- OpenStudio
- Trane TRACE
- Carrier HAP
- IES VE
- Symergy
- DesignBuilder

Other software tools may be approved on a case by case basis.

3.1.8 Exceptional Calculation Methods

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

a. Step-by-step documentation of the Exceptional Calculation Method performed detailed enough to reproduce the results;
b. Copies of all spreadsheets used to perform the calculations;
c. A sensitivity analysis of energy consumption when each of the input parameters is varied from half to double the value assumed;
d. The calculations shall be performed on a time step basis consistent with the simulation program used;
e. The Performance Rating calculated with and without the Exceptional Calculation Method.

At no time shall the total Exceptional Savings constitute more than half of the difference between the baseline building performance and the proposed building performance.

3.2 Modeling Similar Buildings

To qualify for Whole Building program incentives, 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 building types with a multiplier applied to each building type in the modeling software. Alternatively, all ten buildings may be modeled explicitly, depending on the capabilities of the simulation tool. Additionally, a separate model and report must be generated for unique locations of multiple similar buildings, such as chain retail stores, with the model and documentation matching the design parameters of each location.

3.3 District Systems

3.3.1 General Approach

District and campus energy systems must be held energy neutral, and must be modeled as purchased energy (chilled water, hot water, and/or steam) in both the baseline and proposed models.

While district system energy savings are always counted towards determining the performance rating and incentive tier, incentives for district energy system savings (for example, as a result of increased insulation) are only paid if the owner of the district systems pays into the energy efficiency fund. If the owner of the district system does not pay into the energy efficiency fund, incentives are prorated to exclude these savings.

3.3.2 Baseline System Adjustment

Projects that include district and campus energy systems may need to modify the baseline system in order to be able to model purchased energy, as shown in Table B1 of Appendix B. Any system parameters not specifically addressed in Table B1 must be modeled as specified in Appendix G.

3.3.3 Conversion to Electricity and/or Fossil Fuel Usage

Purchased energy usage modeled per 3.3.1 must be converted to electricity and/or fossil fuel usage using the actual district plant efficiency, for which documentation must be included in the project submittal.

If the actual plant efficiency is not known, the following assumed efficiencies must be used:

i. District chilled water generated by electric chiller(s): COP 4.4 chiller efficiency, 5% distribution loss, with an overall system performance of COP 4.2 [19]

ii. District chilled water generated by gas chiller: COP 0.95 chiller efficiency [11], 5% distribution loss [19], with an overall system performance of COP 0.90

iii. District steam generated using conventional boiler technology: 80% boiler efficiency, 7.5% distribution loss, with an overall system performance of 74% [11]

iv. District steam generated using combined heat and power: 107.4% generation efficiency, 7.5% distribution loss, with an overall system performance of 99.3% [11]

v. District steam generated with unknown technology: 84.9% weighted average overall efficiency based on 43% CHP market share [11]

vi. District hot water: 80% boiler efficiency, 2.5% distribution loss, with an overall system performance of 78% [11]

EXAMPLE 3-3 (a) - Converting Central Chiller Plant Savings to Equivalents

Q. A project has a proposed cooling system that utilizes chilled water, and is connected to an existing central campus plant comprised of electric chillers with unknown efficiency. The project includes a lighting ECM that will cause a reduction in the cooling load for the building. An energy simulation is performed for the building. According to the simulation, the lighting ECM saved 65 MMBtu of chilled water, and reduced summer peak chilled water demand by 100 kBtu/hr. How can electrical savings from the reduction in the cooling load be determined?

A. The equivalent electricity savings are calculated as 65,000 ÷ (4.2 × 3.412) = 5,953 kWh and 100 ÷ (4.2 × 3.412) = 9.2 kW

EXAMPLE 3-3 (b) - Converting Central Steam Plant Savings to Equivalents

Q. A proposed HVAC system uses steam from an existing central campus plant that utilizes combined heat and power with an unknown efficiency. The project includes an envelope ECM that reduces steam consumption by 100 MMBtu and peak steam demand by 50 kBtu/hr. How can the equivalent gas savings from the reduction in heating load be determined?

A. The equivalent gas usage savings are calculated as 100 ÷ 0.993 = 101 MMBtu. The equivalent gas demand savings are 50 ÷ 0.993 = 50.4 kBtu/hr

3.4 Oil, Propane, and Non-Firm Gas Customers

Oil and propane customers must follow all the rules included in this document and Appendix G. Oil and propane savings are not eligible for incentives. They should be reported and will contribute towards determining the Performance Rating (and incentive tier), however, incentives will be prorated to exclude oil and propane savings.

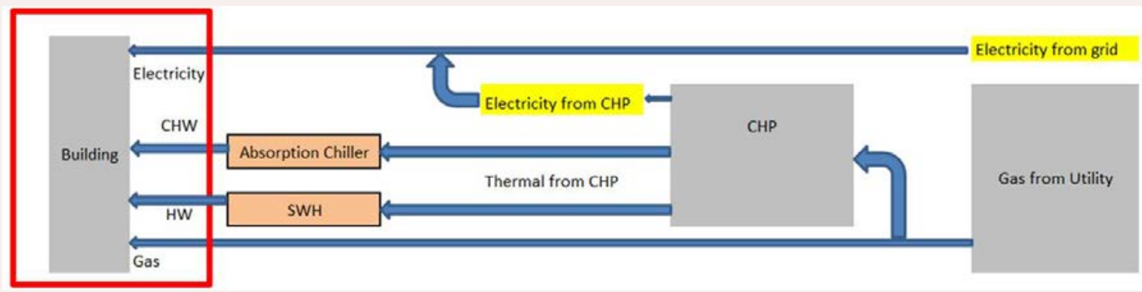
3.5 Renewable Energy Systems and Combined Heat and Power (CHP)

Renewable energy systems, such as photovoltaic solar panels, and CHP are not incentivized under the Whole Building Program and should be excluded from both the baseline and proposed energy models or otherwise modeled as energy neutral. The selected modeling approach must be described on the Modeling Plan Charrette tab of the WBP Report Template.

EXAMPLE 3-4 – Excluding CHP from the Model

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

A. Since CHP cannot contribute toward the incentives the modeled scope should reflect systems within the boundary shown in red in the figure below. Both the baseline and proposed design should be modeled with all electricity purchased from grid, and with purchased chilled water (CHW) and hot water (HW) as applicable to reflect absorption chiller and waste heat recovered to service hot water loop. Baseline HVAC system must be modeled as described in Appendix B for projects that used purchased chilled water for cooling.



3.6 Engine Driven Chillers

Engine driven chillers being incentivized by a separate state funding source shall be modeled as energy neutral.

3.7 Modeling Existing and Future Components

3.7.1 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.

3.7.2 Unmodified Existing Components

Existing components that are not being modified or replaced as part of the project scope must be held energy neutral and must reflect existing conditions. 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. For existing central plants, projects must follow the alternate baseline system map found in Appendix B

EXAMPLE 3-5 – Core and Shell Project

Q. A core and shell project design leaves future tenant space lighting systems and secondary HVAC systems unspecified. A central heating and cooling plant have been designed, with sufficient capacity to serve future tenants. The baseline system for the project is System 7 – VAV w/ HW Reheat. How should the project be modeled?

A. Future components must be modeled as energy neutral, with the proposed design matching the baseline. Where a central plant has been designed, the project can earn credit for the resultant savings in future tenant spaces, but unspecified secondary HVAC systems must be modeled as energy neutral. In this case, proposed model lighting in tenant spaces must match the minimum requirements of ASHRAE Standard 90.1, and the proposed model secondary HVAC systems in the future tenant spaces must be modeled identically to the baseline (System 7 – VAV w/ HW Reheat), but must be served by the proposed central plant.

Note that if the baseline were System 5, which includes DX cooling coils, the project would have had to follow the alternate baseline prescribed in Appendix B for district

3.7.3 Existing Components Being Replaced or Modified

Existing components that are being modified or replaced must be modeled as meeting the minimum requirements of ASHRAE Standard 90.1 in the baseline. This requirement applies to all building components, including the building envelope. For further guidance related to modeling existing building envelopes, refer to section 4.1.1 of this document.

3.8 Demand Reporting

3.8.1 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.

EXAMPLE 3-6 – Demand Reporting

Q. An elementary school is participating in the Whole Building Program. According to the model, 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 peak demand for the project be reported?

A. Although, the building peak occurs in September due to the nature of the project, 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:

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

Thus, reported peak demand must equal 340.4 kW.

3.8.2 Natural Gas Demand

Natural Gas demand savings must be calculated as the difference between the baseline and proposed demand during the coldest day (24 hours) in the weather file used in the simulation, as shown in Table 3-1.

Table 3-1: 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

3.9 Simulated Schedules

Modeled lighting, occupancy, HVAC, and other schedules should not deviate significantly (i.e. have Full Load Hours (FLH) differing by more than 15%) from the schedules in Tables G-E to G-O of the 90.1 – 2010 User's Manual and COMNET Commercial Buildings Energy Modeling Guidelines and Procedures [3] Appendix C, as applicable, unless documentation is available 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 Appendix G rules or the rules set forth in this document, or unless documented in an exceptional calculation method.

3.10 Measure Modeling

Simulation results must be reported at the measure level, including energy usage, electricity peak demand, energy cost, and energy savings for each measure.

3.10.1 Background

In a typical project, 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, since the ASHRAE 90.1 modeling protocol allows performance trade-offs, 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 at 40%, or the proposed lighting power density may exceed the requirements of ASHRAE 90.1 in some or all 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 Whole Building Program, 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 difference 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 by end use must be reported for each Measure.

3.10.2 Measure Granularity

3.10.2.1 Minimum Measure Granularity

At a minimum, differences between the baseline and proposed design models related to lighting systems, building envelope components, plug and process loads, HVAC systems, 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 following Section 2.1.

3.10.2.2 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).

3.10.3 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, building envelope measures shall be modeled first, followed by 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 and is useful in determining baseline HVAC system mapping for projects that have multiple fuel sources as indicated in Section 7.1.1 of this document. Both methods, if performed properly, will produce identical results.

EXAMPLE 3-7 – Measure Modeling Example

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-0.048	U-0.030
	Walls	U-0.064	U-0.052
Lighting	Lighting	Average LPD 1.1	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 centrifugal chillers, COP = 5.55	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, two-speed motor	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

4 Building Envelope

4.1 Baseline Envelope

The baseline envelope shall be modeled as minimally complying with ASHRAE Standard 90.1 Section 5, following all applicable Appendix G rules and as described below.

4.1.1 Baseline Envelope for Existing Buildings

Envelope components that are *not* being modified or replaced as part of the project scope shall be modeled in the baseline design to match existing conditions. If existing conditions are not known, such components may alternatively be modeled as minimally complying with Standard 90.1 [1] Section 5 – Table 5.5. In both cases, unmodified existing envelope components must be modeled as energy neutral (i.e., identically in the baseline and proposed design models).

EXAMPLE 4-1 – Existing Building Envelope

Q. A major renovation project includes a measure where roof insulation is being added to the existing roof. The existing roof includes continuous R-10 insulation. The proposed roof includes continuous R-30 insulation. How should the roof be modeled in the baseline and proposed design models?

A. Because the roof is being modified as part of the project's scope of work, the baseline design must be modeled as meeting the requirements of ASHRAE Standard 90.1 Section 5 Table 5.5 (per 4.1.1 of this document). Thus, the baseline roof must be modeled as insulated entirely above deck, with R-20 continuous insulation.

The proposed design must be modeled as designed (with

Envelope components that *are* being modified or replaced as part of the project scope (beyond merely cosmetic changes) shall be modeled as minimally complying with the prescriptive requirements found in Standard 90.1 Section 5 – Table 5.5 [1] in the baseline design, using the construction type referenced in Appendix G Table G3.1 section 5 [1]. Note that this is contrary to the guidance in Appendix G Table G3.1 section 5 [1], which allows modeling upgraded envelope components as matching the existing conditions in the baseline design.

4.1.2 Exposure Neutral Baseline

The baseline for projects involving renovations and additions must reflect the actual orientation.

The baseline for new construction projects must be the average building consumption for the four exposures, as described in Table G3.1-5.a, Baseline Building Performance column, unless exceptions apply [1].

4.1.3 Doors

Doors that are more than one-half glass are considered fenestration, per Section 3 of ASHRAE 90.1, and shall be modeled with properties required for vertical glazing from ASHRAE 90.1 Table 5-5 in the Baseline Building Design. The entire surface area of such doors must contribute toward baseline window to wall ratio cap.

4.2 Proposed Envelope

Envelope components in the proposed building model shall be modeled in accordance with project drawings and specifications.

4.2.1 Thermal Bridging

Models must take into account thermal bridging effects. For example, steel framing members penetrate cavity insulation and significantly decrease the effective R-value of the assembly. Steel-framed walls must be modeled using the data in ASHRAE Standard 90.1 Appendix A [1]. Thermal bridging due to metal fasteners that penetrate a layer of continuous insulation must likewise be accounted for, as well as shelf angles supporting the façade.

> EXAMPLE 4-2 – Cavity Insulation and Steel Framed Walls
>
> Q. A project has 16” on center steel framed walls with R-13 cavity insulation and R-10 continuous insulation. How should this assembly be modeled?
>
> A. Based on ASHRAE 90.1 Table A3.3, the effective thermal resistance of the R-13 cavity insulation is R-6, thus the overall R-value of the cavity and continuous insulation is 6 + 10 = 16.

4.2.2 Fenestration

Fenestration must be modeled to reflect whole window assembly U-values (including framing) and not the center-of-glass U-value. Acceptable sources for overall fenestration U-value are:

- 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 2013 [9], Chapter 15 Table 4.

4.2.3 HVAC Penetrations

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.

If an insulated cover for the through-wall AC units is specified, the insulated cover is not used every day and must not be included in the model. [20]

Through-wall AC sleeves and PTAC/PTHP penetrations must not be modeled in the Baseline Design.

4.3 Infiltration

The same infiltration rates must be modeled in the baseline and proposed designs, except when whole-building air leakage testing, in accordance with ASTM E779, is specified during design and completed after construction. On such projects, energy savings associated with the reduced air leakage may be modeled as follows:

- the proposed design air leakage rate of the building envelope shall be as measured.
- the baseline air leakage rate shall be 0.4 cfm/ft2 at a fixed building pressure differential of 0.3 in. H2O shall (*I 75Pa*). The leakage is per the total area of the envelope air pressure boundary, as defined for term “S” the formula below.

- the same modeling methodology, and adjustments for weather and building operation must be used in both the proposed design and the baseline design.
- 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) [23]. 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.

The air leakage rate of the building envelope shall be converted to appropriate units for the simulation program using one of the methods described below [24]:

For methods describing infiltration as a function of floor area:
$I_{FLR} = 0.112 \times I_{75Pa} \times S/A_{FLR}$

For methods describing infiltration as a function of exterior wall area,
$I_{EW} = 0.112 \times I_{75Pa} \times S/A_{EW}$

When using the measured air leakage rate of the building envelope at a pressure differential of 0.3 in. H_2O for the proposed design, the air leakage rate shall be calculated as follows:

$I_{75Pa} = Q/S$

where
I_{75Pa} = air leakage rate of the building envelope expressed in cfm/ft^2 at a fixed building pressure differential of 0.3 in. H_2O, or 1.57 psf

Q = volume of air in cfm flowing through the whole building envelope when subjected to an indoor/outdoor pressure differential of 0.3 in. H_2O, or 1.57 psf, in accordance with ASTM E 779

S = total area of the envelope air pressure boundary (expressed in ft^2), including the lowest floor, any below- or above-grade walls, and roof (or ceiling) (including windows and skylights), separating the interior conditioned space from the unconditioned environment measured

I_{FLR} = adjusted air leakage rate (expressed in cfm/ft^2)of the building envelope at a reference wind speed of 10 mph and the total gross floor area

A_{FLR} = total gross floor area, ft^2

I_{EW} = adjusted air leakage rate (expressed in cfm/ft^2) of the building envelope at a reference wind speed of 10 mph and the above ground exterior wall area

A_{EW} = total above-grade exterior wall area, ft^2

4.4 Unique Envelope Assemblies

Unique envelope assemblies, such as projecting balconies, perimeter edges of intermediate floor slabs, concrete floor beams over parking garages, and roof parapets, shall be separately modeled in the Proposed Design, per Appendix G Table G3.1, Section 5(a). A weighted average of the U-factors of these assemblies can also be used.

Projected balconies and perimeter edges of intermediate floor slabs are considered to be a wall, per wall definition in Section 3 of ASHRAE 90.1, and shall be modeled in the Baseline Building Design as having the U-factor required in Table 5-5 for exterior steel-frame walls.

5 Lighting

5.1 Baseline Lighting Power Density Calculation Method

Baseline Lighting Power Density (LPD) must meet requirements in Table 9.6.1 (Building Area Method) or Table 9.6.2 (Space-by-Space method) of ASHRAE 90.1 [1]. The selected table must be used for all spaces in the project, except for mixed use buildings where different tables may be used for each distinct occupancy type. For example, if the three lower floors in a building house retail spaces, and the upper ten floors are multifamily, Table 9.6.1 (Building Area Method) may be used for the retail portion and Table 9.6.2 (Space-by-Space method) may be used for the multifamily portion.

Following 90.1 Section 9.6.4, the baseline lighting power allowances using the space by space method may be increased by 20% for spaces with Room Cavity Ratio (RCR) exceeding thresholds in Table 9.6.1 for that space type.

RCR = 2.5 x Room Cavity Height x Room Perimeter / Room Area

Room Cavity Height = Luminaire mounting height – Work plane

Luminaire mounting height is the ceiling height of the space. For suspended luminaires, the mounting height shall be determined at the height of the suspension cable mounting.

Work plane height is 30” (desk level) for office spaces, and 6”-8” for circulation areas such as hallways and stairwells.

5.2 Lighting in Residential Space

5.2.1 Lighting in Dwelling Units

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. Lighting in dwelling units is not regulated by Standard 90.1 and as a general rule must be modeled as energy neutral in the baseline and proposed design. Credit may be claimed for hard-wired in-unit lighting based on the following procedure:

Baseline: LPD_B = 1.1 W/SF [20][13]

Proposed Design:

i. LPD_B must be used for rooms with no specified hardwired lighting.
ii. Actual installed fixture input wattage must be used for rooms where a complete lighting system is specified and plug-in fixtures will not be installed. This typically includes bathrooms, hallways, closets, and kitchens, but not living rooms or bedrooms. To verify that complete lighting design exists, the luminous efficacy of the specified fixtures (source efficacy), including lamp and ballast, must be obtained from the fixture manufacturer. If the efficacy of the specified fixtures is unknown, LPD_B must be used for the room, and no

performance credit can be documented. To determine if a space has a completed lighting system, use the following formulas:

$L_{MIN} = A_{ILLUM} \times LPD_B \times SE_B$

$L_{DESIGN} = \sum W_{S,i} \times Qnty_i \times SE_{P,i}$ ($_i$ indicates the properties of each unique fixture specified)

If $L_{DESIGN} \geq L_{MIN}$, then space has a complete lighting design and actual installed fixture wattage may be used.

If $L_{DESIGN} < L_{MIN}$, then space has an incomplete lighting design. See (iii) below.

where

L_{MIN}	minimum required lumens of a given space
L_{DESIGN}	specified lumens of a given space
A_{ILLUM}	area of the room illuminated by specified lighting, square feet
LPD_B	baseline lighting power density, W/SF; LPD_B = 1.1 W/SF
$W_{S,i}$	input wattage of each unique specified fixture, Watt
SE_B	luminous efficacy of baseline fixtures, Lm/W; SE_B=50, based on typical for high-efficacy lamps [13]
$SE_{P,i}$	source efficacy of each unique specified fixture, Lm/W

iii. In spaces where the hard-wired lighting is designed to be supplemented with plug-in fixtures or $L_{DESIGN} < L_{MIN}$, such as in bedrooms and living rooms, the luminous efficacy of the specified fixtures (source efficacy), including lamp and ballast, must be obtained from the fixture manufacturer. If the efficacy of the specified fixtures is unknown, LPD_B must be used for the room, and no performance credit can be documented. Otherwise, proposed wattage must be determined as follows:

$A_{ILLUM} = \sum (W_{S,i} \div LPD_B) \times (SE_{P,i} \div SE_B)$

If $A_{ILLUM} > A$ Then $A_{ILLUM} = A$

$W_P = \sum W_{S,i} + (A - A_{ILLUM}) \times LPD_B$

where

W_P	wattage that must be used for the space when calculating proposed LPD
A	total area of the room, square foot

iv. The LPD for each room calculated as described in (i)-(iii) above must be multiplied by the room floor area to obtain the total proposed wattage for the dwelling unit.

5.2.2 Hotel/Motel Guestrooms

In hotel/motel guestrooms, the modeled proposed lighting power density must include both hard-wired and plug-in lighting, such as future fixtures on night stands, desks, and floor lamps. Quantity, type, and wattage of all lighting fixtures must be noted in the project documents and will be verified during post-construction inspection.

5.2.3 Dormitory-living quarters

The same calculation method must be used for dormitory-living quarters as for dwelling units, with

EXAMPLE 5-1 - Dwelling Unit Lighting

Q. A dwelling unit has some spaces with fully specified lighting and some with partially specified lighting. A lighting plan and lighting schedule are shown below. How should the LPD for the proposed designed be determined?

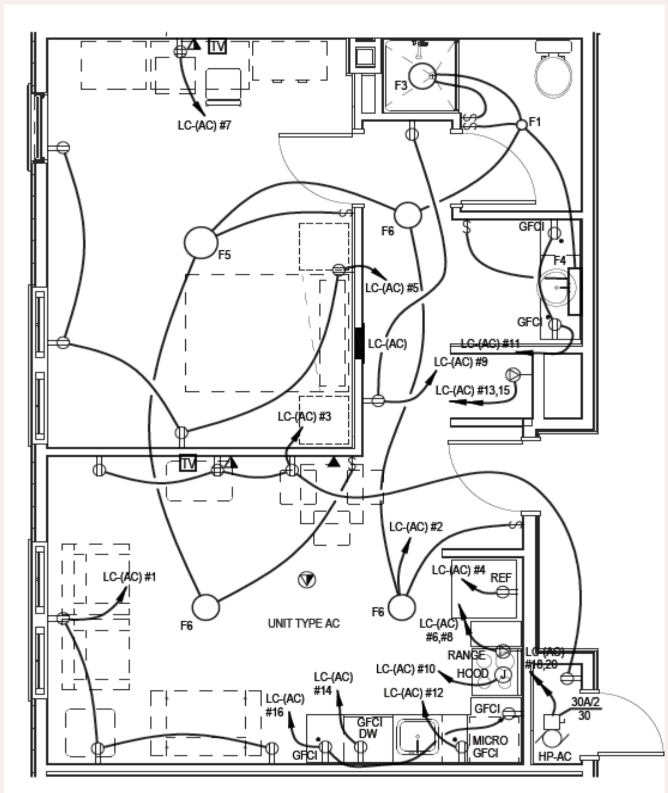


FIGURE 5-1.1 – LIGHTING PLAN

TABLE 5-1.1 – LIGHTING FIXTURE SCHEDULE				
TAG	MOUNTING	LAMPS	MAKE	MODEL #
F1	CEILING MOUNTED	(1) 24W 4 PIN CFL	COOPER SHAPER	260-CFL/1/26-120V-NA-DL
F2	CEILING HUNG	(1) 18W CFL SCREW BASE	FORECAST	F1677-36
F3	CEILING MOUNTED	(1) 26W 4 PIN CFL	KENALL	XMR13FL-PP-MW-26Q-1-DV-SA
F4	WALL MOUNTED	(2) 14W T5	COOPER SHAPER	607-24-T5/2/14-120V-SM-DL
F5	CEILING MOUNTED	(2) 25W 4 PIN CFL	FORECAST	F2080-36U
F6	CEILING MOUNTED	(3) 13W Spiral G24q-1 CFL	MINKA LAVERY	893-84-PL

(CONTINUED ON NEXT PAGE)

the following exceptions:

LPD_B = 1.1 W/SF as per Standard 90.1

SE_B = 61 as per IESNA lighting models

EXAMPLE 5-1 – Dwelling Unit Lighting (continued from previous page)

A. The **baseline** lighting power density for the unit is LPD_B = 1.1 W/SF

The **proposed** lighting wattage is calculated as follows:

Spaces with fully specified lighting: The kitchen area, hallway, bathroom and closet have fully specified lighting. The actual input wattage of the installed lighting fixtures is shown in Table 5-1.2.

L_{MIN} = (150 × 1.1 × 50) = 8,250 lumens

L_{DESIGN} = (28 × 2 × 76.5) + (32 × 1 × 69) + (29 × 1 × 69) = 8,493 lumens

$L_{DESIGN} > L_{MIN}$, therefore space has a complete lighting design

Table 5-1.2 – Proposed LPD in Common Spaces with Fully Specified Lighting

Area (SF)	Fixture Type	No. Fixtures	Fixture Wattage	Fixture Efficacy	Total Watts	Actual Installed Lighting Power	Modeled Proposed Lighting Power
150	F1	1	28	76.5	28	117 W (0.78 W/SF)	117 W (0.78 W/SF)
	F3	1	28	76.5	28		
	F4	1	32	69	32		
	F6	1	29	69	29		

Spaces with partially specified lighting & no luminous efficacy available: The bedroom is subject to the rules related to partial lighting. The modeler was unable to obtain the luminous efficacy for the fixture, thus the default LPD (1.1 W/SF) must be used for the room, as shown in Table 5-1.3

Table 5-1.3 Proposed LPD in Bedroom

Area (SF)	Fixture Type	No. Fixtures	Fixture Wattage	Total Watts	Installed Lighting	Proposed Modeled Lighting
235	F5	1	56	56	56 W (0.24 W/SF)	258.5 W (1.1 W/SF)

Spaces with partially specified lighting & luminous efficacy available: The fixture for the living room is ENERGY STAR® and has an input wattage of 29 Watts with source efficacy of 66.5 Lm/W, based on the EPA website. Using the calculation procedure described in iii above, the total proposed wattage for the room is 184.8 Watts:

Table 5-1.4 Proposed LPD in Living Room w/ Partial Specified Lighting & Luminous Efficacy is Available

Area (SF)	Fixture Type	No. Fixtures	Fixture Wattage	Fixture Efficacy	Total Watts	Installed Lighting	Proposed Modeled Lighting
180	F6	2	29	66.5	58	58 W (0.32 W/SF)	184.8 W (1.03 W/SF)

L_{MIN} = 180 × 1.1 × 50 = 9,900 lumens

L_{DESIGN} = (29× 2 × 66.5) = 3,857 lumens

$L_{DESIGN} < L_{MIN}$, therefore

$A_{ILLUM} = (W_S \div LPD_B) \times (SE_P \div SE_B) = (58 \div 1.1) \times (66.5 \div 50) = 70\ SF$

$W_P = W_S + (A - A_{ILLUM}) \times LPD_B = 58 + (180 - 70) \times 1.1 = 184.8\ W\ (1.03\ W/SF)$

Overall Proposed Lighting Power: The dwelling unit must be modeled with 146 W + 258.5 W + 184.8 W = 589.3 W (1.04 W/SF) in the proposed model.

5.3 Lighting Exempt from Standard 90.1

Section 9.1.1 exception (c) excludes lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation from the scope of the Standard 90.1. 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, as published at http://lpd.ies.org/cgi-bin/lpd/ShowSpaceTypes.pl, the baseline LPD may be increased in proportion to the increase in the illuminance.

EXAMPLE 5-2 – Lighting Exempt from Standard 90.1

Q: A project involves a manufacturing facility that processes milk into dried products, and is under USDA Food Processing Regulations that require 50 foot candles (fc) of light intensity in areas where dairy products are graded or examined for condition and quality, and 30fc at working surfaces in rooms for manufacturing, processing, or packaging dairy products or washing of equipment and utensils. In all other rooms, including storage rooms and coolers, light intensity is required to be at least 5fc. How should the lighting in this project be modeled for NCP?

A. Baseline LPD for offices, stairwells, and other spaces that are not subject to USDA regulations must be established based on 90.1 Table 9.6.1 – Lighting Power Density Using the Space-by-Space Method. This lighting will be included in ECM2. Lighting that is subject to USDA regulations may be modeled as energy-neutral, as any unregulated load, as it is exempt from Standard 90.1. Alternatively, to document incentives for the unregulated lighting, the LPD baseline is established as shown in Table E5-2.1. If specified lighting improves over this baseline, it will be modeled as ECM1.

Table E5-2.1 Exempt Lighting Example

Area	USDA fc Requirement	ECM1: USDA - regulated	ECM2: ASHRAE-regulated	90.1 Table 9.6.1 Space Type Used as the Baseline	Baseline W/SF
Storage	5 min		x	Medium/Bulky Material Storage	0.63
Evaporation	30	x		Low Bay Manufacturing	1.19
Mill	50	x		Detailed Manufacturing	1.29
Corridors	5 min		x	Corridors	0.41
Stairs	5 min		x	Stairway	0.69
Receiving	30	x		Low Bay Manufacturing	1.19
M/E rooms	None		x	Electrical/Mechanical	0.95
Offices	None		x	Office, Enclosed	1.11
Locker Rooms	30 recommended	x		Dressing/Locker/Fitting Room	1.41 (Note 1)

Note 1: LPD for locker rooms in 90.1 Table 9.6.1 is 0.75 W/SF based on the Dressing/Locker/Fitting Room space type. However, this LPD was established based on the target average illuminance level of 16 fc (see IESNA link provided above), which is lower than 30fc recommended for such spaces in USDA regulations. To account for that, the baseline LPD for locker spaces in the project is increased in proportion to the increase in the illuminance, and calculated as 0.75 [W/SF] * 30 [fc] / 16 [fc] =1.41 [W/SF]

5.4 Temporary Lighting

Where temporary or partial lighting is specified for core and shell spaces, lighting wattage in the proposed design must be the same as in the baseline, and determined in accordance with the Building Area Method for the appropriate building type.

5.5 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.

EXAMPLE 5-3 – Temporary Lighting

Q. A 3,000 ft^2 retail space has a temporary lighting setup with a total lighting power of 1,000 W. The permanent lighting system will be designed and installed by the future tenant. How should the baseline and proposed design LPDs be calculated?

A. The baseline LPD must be modeled at 1.5 W/ft^2 based on Table 9.5.1. The proposed design must be modeled with the same LPD as the baseline design. It is incorrect to model the temporary lighting (0.33 W/ft^2) as the proposed design LPD.

5.6 Interior Lighting Controls

5.6.1 Occupancy sensors and timers

Automatic lighting controls are required by Standard 90.1 for classrooms and lecture halls including K-12 classrooms, conference/meeting/training rooms employee lunch/break rooms, storage and supply rooms 50 ft^2 to 1000 ft^2, rooms used for copying and printing, office spaces up to 250 ft^2, restrooms and dressing/locker/fitting rooms (Section 9.4.1.2 [1]). In addition, bi-level controls are required in the parking garages (Section 9.4.1.3) and stairwells (9.4.1.6). Since these are mandatory provision, where such controls are required (if exceptions to these section do not apply), they must be specified in the proposed design and no performance credit is permitted. In all other space types, automatically controlled lighting is not required by Standard 90.1 and controls specified in the proposed design may be modeled for performance credit by reducing the LPD using the power adjustment factors below. Where only some fixtures in a space are controlled by automatic lighting controls, the power adjustment factors shall only be applied to the wattage of the controlled fixtures.

Table 5.6.1-1 Power Adjustment Factors (PAF) for Modeling Automatic Lighting Controls

Automatic Control Device	**Non-24-hour Occupied and < 5,000 ft²**	**Other buildings**
Programmable timing control [3]	10%	0%
Occupant sensor [3]	15%	10%
Occupant sensor and programmable timing controls [3]	15%	10%
B-level controls in hotel and multifamily corridors [3]	20%	20%
Scene controller with timeclock [3]	20%	20%
Key-card controls in hotel guestrooms [8]	30%	30%

90.1 2013 Addendum bw may be used as an alternative to PAF in Table 5.6.1-1 for spaces where occupancy sensors are not required in the baseline.

5.6.2 Daylighting

90.1 Sections 9.4.1.4 & 9.4.1.5 establish the criteria for spaces that require automatic daylighting controls. In spaces where daylighting is required, it must be specified in the proposed design but not modeled in either baseline or proposed design, as the lighting schedules are understood to reflect the mandatory control requirements.

Exception: Mandatory daylighting *may* be explicitly modeled in both the baseline and proposed designs if the proposed design has greater than 40% window to wall ratio.

In all other spaces that are not required to have daylighting controls, daylighting may be modeled explicitly in the proposed and baseline design to demonstrate performance credit. If a simulation tool does not have the capability to model daylighting, a specialized daylighting tool may be used. The savings projected by the external analysis must be incorporated into the whole building simulation tool as an equivalent adjustment to the lighting schedule or lighting power density. The summary outputs from the daylighting software and explanation of how the results were incorporated into the whole building simulation tool must be included in an appendix to the report.

Visual light transmittance of specified windows will affect daylighting savings and must be captured in the tool used to calculate savings and included in the report.

5.7 Exterior Lighting

ASHRAE 90.1 Table 9.4.3.A categorizes the exterior lighting power allowances by specific exterior lighting zones. Table 9.4.3.B describes the exterior lighting power allowance for different exterior lighting surfaces for each exterior lighting zone and categorized 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, as described in Example 3-2.

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.

EXAMPLE 5-4 - Exterior Lighting: Tradable vs. Non-Tradable

Q. An office building has a 40,000 ft² lighted parking lot and a 3,500 ft² lighted façade. The installed power for the parking lot is 3 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 9.4.3A. What exterior lighting power should be modeled in the baseline and proposed design?

A. The table below shows lighting inputs in the baseline and proposed designs for this example along with associated calculations.

	Parking Lot		Building Façade	
Surface Area	40,000 ft^2		3,500 ft^2	
Lighting Allowance (Table 9.4.3B)	0.10 W/ft^2		0.15 W/ft^2	
Maximum Allowed Wattage	0.1 W/ft^2 × 40,000 ft^2 = 4 kW		0.15W/ ft^2 × 3,500 ft^2 = 525 W	
Base Site Allowance, total per project (Table 9.4.3 B)	750 W		NA	
Allowance Type (Table 9.4.6)	Tradable		Non-tradable	
Modeled Wattage	Baseline Model	Proposed Model	Baseline Model	Proposed Model
	4.75 kW	3 kW	400 W	400 W

5.8 Decorative Lighting

Additional interior lighting power allowed by Section 9.6.2 (a) of Standard 90.1 [1] cannot be used to increase the baseline allowance for spaces where decorative lighting is not essential to space function, including but not limited to corridors of office buildings and hotels/motels. Examples of spaces where decorative lighting is permitted include but are not limited to theaters, galleries, and conference centers.

5.9 Interior Lighting Runtime

Modeled interior lighting runtime should be generally aligned with full load hours in Table E1 in Appendix C of this document.

6 Plug and Process Loads

6.1 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).

Process and plug loads must be reasonably captured in the models to account for their impact on regulated systems due to the added internal 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.

6.1.1 Baseline Process and Plug Loads

The typical energy use intensities by end use for different building types based on the Commercial Building Energy Consumption Survey (CBECS) are shown in Appendix A – Table A1 of this document. Projects with a process and plug load site energy intensity more than 20% below what is listed in Table A1 must justify the related modeling assumptions in the report.

6.1.2 Proposed Process and Plug Loads

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 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 proposed equipment schedule (Option 1) or proposed equipment power density (Option 2) as follows:

<u>Baseline Design (Options 1 & 2):</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 [3].
- Equipment Schedule - based on the plug load schedule for the appropriate building type of COMNET Appendix C [3]

<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:

- Separate plug loads into two categories:

$EPD_{P, NC}$ [W/SF] – EPD corresponding to receptacles with no automatic controls, or controls that do not exceed requirements of Section 8.4.2. $EPD_{P,NC}$ must be modeled with the same schedule in the proposed design as in the baseline.

$EPD_{P,NC}=EPD_B*(1-RC)$

RC – percentage of the receptacles in the thermal block with automatic controls beyond minimally required in Section 8.4.2.

$EPD_{P,AC}$ [W/SF] – EPD corresponding to receptacles with the automatic controls that exceed the minimum required by Section 8.4.2

$EPD_{P,AC}=EPD_B*RC$

$EPD_{P,AC}$ must be modeled with the following schedule:

Unoccupied hours (when HVAC System Schedule is Off in COMNET Appendix C for the appropriate building type): zero schedule fraction

Occupied hours: same schedule fraction as in the baseline for time-of-day control that functions as described in Section 8.4.2 (a); schedule fraction reduced by 5% (i.e. multiplied by 0.95) for occupancy sensor controls as described in Section 8.4.2 (b) & (c).

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 prescribed in Options 1 & 2.

EXAMPLE 6-1 – 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, as shown in the Baseline column in the figure below.

Proposed:

Section 8.4.2 requires automatic controls on 50% of the receptacles, thus RC=70%-50%=20%

Option 1:

$EPD_{P,NC}$=EPD_B*(1-RC)=1.67*(1-0.2)=1.34 (W/SF)

$EPD_{P,NC}$ modeled with the same schedule as in the baseline (the Baseline column in the figure).

$EPD_{P,AC}$=1.67*0.2=0.33 (W/SF)

Equipment schedule as shown in "Option 1 Proposed, Controlled" column in the figure. For occupancy sensor control instead of scheduled time of day control, each hourly fraction would be multiplied by 0.95 to get an additional 5% credit during occupied hours.

Table C-5 – Office Occupancy

Hour of Day (Time)	Baseline Schedule for Lighting Receptacle Percent of Maximum Load			Option 1 Proposed, Controlled Schedule for Lighting Receptacle Percent of Maximum Load		
	Wk	Sat	Sun	Wk	Sat	Sun
1 (12-1 am)	5	5	5	0	0	0
2 (1-2 am)	5	5	5	0	0	0
3 (2-3 am)	5	5	5	0	0	0
4 (3-4 am)	5	5	5	0	0	0
5 (4-5 am)	5	5	5	0	0	0
6 (5-6 am)	10	5	5	0	0	0
7 (6-7 am)	10	10	5	10	10	0
8 (7-8 am)	30	10	5	30	10	0
9 (8-9 am)	90	30	5	90	30	0
10 (9-10 am)	90	30	5	90	30	0
11 (10-11 am)	90	30	5	90	30	0
12 (11-12 pm)	90	30	5	90	30	0
13 (12-1 pm)	80	15	5	80	15	0
14 (1-2 pm)	90	15	5	90	15	0
15 (2-3 pm)	90	15	5	90	15	0
16 (3-4 pm)	90	15	5	90	15	0
17 (4-5 pm)	90	15	5	90	15	0
18 (5-6 pm)	50	5	5	50	5	0
19 (6-7 pm)	30	5	5	30	0	0
20 (7-8 pm)	30	5	5	30	0	0
21 (8-9 pm)	20	5	5	20	0	0
22 (9-10 pm)	20	5	5	20	0	0
23 (10-11 pm)	10	5	5	0	0	0
24 (11-12 am)	5	5	5	0	0	0

Option 2:

EPD_P = EPD_B * (1-RC*10%)=1.67*(1-20%*10%) =1.64 W/SF

EPD_P modeled with the same schedule as in the baseline (the Baseline column in the figure).

6.2 Commercial Refrigeration Equipment

This section describes the method that must be used to calculate the usage of commercial refrigeration equipment including walk-in refrigerators and freezers, open refrigerated casework, and closed refrigerated casework. Refrigerators used in residential kitchens or refrigerated vending machines should be treated as described in Section 6.1.

Commercial refrigeration equipment can be modeled following one of the following two methods:

Method 1 (Simplified): Baseline and proposed refrigeration power must be calculated as described in section 6.2.1.1 and modeled in the simulation tool as a process load with a flat load profile. Self-contained systems must be modeled as a process load in the space where they are located. Systems with remote condensers must be modeled as exterior process loads.

For refrigeration systems that reject heat remotely from the space (e.g., supermarket rack systems), the heating load resulting from the refrigeration system must be calculated as described in section 6.2.1.2 and also modeled in both the baseline and proposed models.

Method 2 (Explicit): Refrigeration equipment must be modeled explicitly in the whole building simulation tool. The baseline must be based on the Department of Energy 10 CFR Part 431 [14]. Refrigeration system EER must be based on Table 1 of ASHRAE Standard 1200 – 2013 [15]. The proposed system must be modeled as designed.

The modeling methodology for Method 1 (Simplified) is included in section 6.2.1 below. It is the responsibility of the modeler to develop the modeling methodology for Method 2 (Explicit).

6.2.1 Commercial Refrigeration Equipment Method 1 (Simplified)

6.2.1.1 Refrigeration Power

Refrigeration Power is the average power draw (kW) of the equipment, assuming constant year-round operation. Refrigeration power must be calculated as described in this section.

6.2.1.1.1 Proposed Design

a) The refrigeration power for refrigerated casework must be calculated as the total rated kWh/day of the specified equipment divided by 24 hours/day.
b) The refrigeration power for the walk-in refrigerators and freezers must be calculated using the equation 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 6.2.1-1, 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 6.2.1-1 – Default Power for Walk-in Refrigerators and Freezers [3]

Table 42 – Default Power for Walk-In Refrigerators and Freezers (W/ft²)

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 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.

Floor Area	Refrigerator	Freezer
100 ft² or less	8.0	16.0
101 ft² to 250 ft²	6.0	12.0
251 ft² to 450 ft²	5.0	9.5
451 ft² to 650 ft²	4.5	8.0
651 ft² to 800 ft²	4.0	7.0
801 ft² to 1,000 ft²	3.5	6.5
More than 1,000 ft²	3.0	6.0
Additional Power for each Glass Display Door	105	325
Note:		

c) The total refrigeration power of the proposed design is the sum of the refrigeration power of the casework and walk-in equipment. Exceptional calculation methods may be used to document savings from efficiency improvements in walk-in equipment, provided it is well-documented.

6.2.1.1.2 Baseline Design

a) The energy usage of refrigerated cases must be based on the kWh/day column from Table 6.2.1-2 for the specified equipment divided by 24 hours. Equipment types are defined in Table 6.2.1-3 [14]. Definitions of terms are included below the table, based on Section 431.62 of the DOE Ruling. A definition of the Total Display Area (TDA) in Table 6.2.1-2 can be found in ANSI/AHRI Standard 1200 [15].

Table 6.2.1-2 – Baseline Electricity Consumption of Refrigerated Cases

TABLE I–1—STANDARD LEVELS FOR COMMERCIAL REFRIGERATION EQUIPMENT

Equipment class [2]	Standard level * ** (kWh/day) ***	Equipment class	Standard level * ** (kWh/day)
VOP.RC.M	0.82 × TDA + 4.07	VCT.RC.I	0.66 × TDA + 3.05
SVO.RC.M	0.83 × TDA + 3.18	HCT.RC.M	0.16 × TDA + 0.13
HZO.RC.M	0.35 × TDA + 2.88	HCT.RC.L	0.34 × TDA + 0.26
VOP.RC.L	2.27 × TDA + 6.85	HCT.RC.I	0.4 × TDA + 0.31
HZO.RC.L	0.57 × TDA + 6.88	VCS.RC.M	0.11 × V + 0.26
VCT.RC.M	0.22 × TDA + 1.95	VCS.RC.L	0.23 × V + 0.54
VCT.RC.L	0.56 × TDA + 2.61	VCS.RC.I	0.27 × V + 0.63
SOC.RC.M	0.51 × TDA + 0.11	HCS.RC.M	0.11 × V + 0.26
VOP.SC.M	1.74 × TDA + 4.71	HCS.RC.L	0.23 × V + 0.54
SVO.SC.M	1.73 × TDA + 4.59	HCS.RC.I	0.27 × V + 0.63
HZO.SC.M	0.77 × TDA + 5.55	SOC.RC.L	1.08 × TDA + 0.22
HZO.SC.L	1.92 × TDA + 7.08	SOC.RC.I	1.26 × TDA + 0.26
VCT.SC.I	0.67 × TDA + 3.29	VOP.SC.L	4.37 × TDA + 11.82
VCS.SC.I	0.38 × V + 0.88	VOP.SC.I	5.55 × TDA + 15.02
HCT.SC.I	0.56 × TDA + 0.43	SVO.SC.L	4.34 × TDA + 11.51
SVO.RC.L	2.27 × TDA + 6.85	SVO.SC.I	5.52 × TDA + 14.63
VOP.RC.I	2.89 × TDA + 8.7	HZO.SC.I	2.44 × TDA + 9.
SVO.RC.I	2.89 × TDA + 8.7	SOC.SC.I	1.76 × TDA + 0.36
HZO.RC.I	0.72 × TDA + 8.74	HCS.SC.I	0.38 × V + 0.88

* TDA is the total display area of the case, as measured in the Air-Conditioning and Refrigeration Institute (ARI) Standard 1200–2006, Appendix D.

** V is the volume of the case, as measured in ARI Standard 1200–2006, Appendix C.

*** Kilowatt hours per day.

[2] For this rulemaking, equipment class designations consist of a combination (in sequential order separated by periods) of: (1) An equipment family code (VOP=vertical open, SVO=semivertical open, HZO=horizontal open, VCT=vertical transparent doors, VCS=vertical solid doors, HCT=horizontal transparent doors, HCS=horizontal solid doors, or SOC=service over counter); (2) an operating mode code (RC=remote condensing or SC=self contained); and (3) a rating temperature code (M=medium temperature (38 °F), L=low temperature (0 °F), or I=ice-cream temperature (– 15 °F)). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class. See discussion in section V.A.2 and chapter 3 of the TSD, market and technology assessment, for a more detailed explanation of the equipment class terminology. See Table IV–2 for a list of the equipment classes by category.

Table 6.2.1-3 – Equipment Configuration Definitions [14]

TABLE IV–1—EQUIPMENT CONFIGURATION DEFINITIONS

Equipment family	Description
Vertical Open (VOP)	Equipment without doors and an air-curtain angle ≥0 degrees and <10 degrees from the vertical.
Semivertical Open (SVO)	Equipment without doors and an air-curtain angle ≥10 degrees and <80 degrees from the vertical.
Horizontal Open (HZO)	Equipment without doors and an air-curtain angle ≥80 degrees from the vertical.
Vertical Closed (VC)	Equipment with hinged or sliding doors and a door angle <45 degrees.
Horizontal Closed (HC)	Equipment with hinged or sliding doors and a door angle ≥45 degrees.

Definitions concerning commercial refrigerators, freezers, and refrigerator-freezers [14]:

Air-curtain angle means:

(1) For equipment without doors and without a discharge air grille or discharge air honeycomb, the angle between a vertical line extended down from the highest point on the manufacturer's recommended load limit line and the load limit line itself, when the equipment is viewed in cross-section; and

(2) For all other equipment without doors, the angle formed between a vertical line and the straight line drawn by connecting the point at the inside edge of the discharge air opening with the point at the inside edge of the return air opening, when the equipment is viewed in cross-section.

Door angle means:

(1) For equipment with flat doors, the angle between a vertical line and the line formed by the plane of the door, when the equipment is viewed in cross-section; and

(2) For equipment with curved doors, the angle formed between a vertical line and the straight line drawn by connecting the top and bottom points where the display area glass joins the cabinet, when the equipment is viewed in cross-section.

b) Usage of walk-in refrigerators and freezers must be the same as in the proposed design, unless exceptional calculation methods are used, unless an exceptional calculation method is being employed, in which case the baseline refrigeration power should be calculated per 6.2.1.1.1-b

c) The total refrigeration power of the Baseline Design is the sum of the refrigeration power of the casework and walk-in equipment.

6.2.1.2 Space Loads due to Refrigeration Equipment

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. Refrigeration equipment rejecting heat remotely, such as casework attached to a supermarket parallel rack system, creates a space heating load, which must be modeled separately from the exterior process load that represents the energy consumption of the refrigeration system. This space heating load, *Q*, must be calculated following the procedure described below and modeled in the tool:

$$Q = kW \times COP \times 3.413$$

where

Q The heating load in the space due to the continuous operation of the refrigeration system, kBtu/h.

kW Refrigeration Power, kW

COP The coefficient of performance of the refrigeration system (unitless). COP must be the same in the baseline and proposed models, and equal to 3.6 for refrigerators and 1.8 for freezers. This COP should only be used to determine the heat removed or added to the space, not the refrigeration power or energy.

Note that self-contained refrigeration systems and remote refrigeration systems must be modeled separately.

7 Heating, Ventilation and Air Conditioning

7.1 Alternative Baseline HVAC Systems

7.1.1 Baseline System Type for Hybrid Fossil Fuel/Electric Projects

Applying the baseline HVAC system map of Appendix G Table G3.1.1A to projects that use both electricity and fossil fuel for heating may result in different *predominant* heating sources in the baseline and proposed design models for some projects (fuel switching). To ensure compliance with the program's policy against fuel switching, the following steps must be followed to establish the HVAC baseline for such projects:

a) Establish the baseline HVAC System Type(s) following G3.1.1, including exceptions.

b) Determine the predominant heating source in the proposed design for areas served by each unique baseline system type. The predominant heating source is the fuel that accounts for 50% or more of the total *input* capacity (MBH) of the specified heating equipment, or for 50% or more of the annual heating consumption (MMBtu) based on the proposed design model.

c) If it is found that the predominant heating source in the proposed design is different from the heating source in the baseline, the baseline HVAC system must be determined following Standard 90.1 Figure 11.3.2 and Table 11.3.2A in lieu of Table G3.1.1A. In addition, the following rules apply:

    i. Assume "Air/None" condenser cooling source for all projects except "Nonresidential and More than 5 Floors or > 150,000 ft^2" in conjunction with Figure 11.3.2.

    ii. All applicable Appendix G requirements pertaining to the baseline system type selected based on Figure 11.3.2A, including but not limited to fan and pump power and HVAC system control, must be used in lieu of the footnotes to Table 11.3.2A. If there is no analogous baseline system type in Appendix G, such as with Table 11.3.2A for System 5 - Two Pipe Fan Coil and System 6 – Water Source Heat Pump, un-defined aspects of the baseline must be modeled as minimally complying with the applicable mandatory and prescriptive requirements of Standard 90.1 [1]. Unregulated components must be treated as energy neutral.

    iii. For systems with mixed fuel heating sources, the component(s) that use the secondary heating source type (the one with the smallest total installed input capacity for the spaces served by the system) shall be modeled with the same heating source in the *baseline,* and the primary heating source type shall be used in Figure 11.3.2 to determine baseline system type.

7.1.1.1 Dedicated Outdoor Air System (DOAS) Exception

When an electrically heated system, such as a heat pump, provides space conditioning and a fossil fuel dedicated outside air system conditions ventilation air, follow the procedure described in 7.1.1 (c) above, which directs modelers to the system map found in Standard 90.1 Section 11 [1] to determine the baseline system. The following requirements also apply:

i. Baseline fan power must be determined per G3.1.2.9 [1], based on the supply air flow rates of the space conditioning systems in the proposed design, and then apportioned to the baseline DOAS and space conditioning systems in the same proportion as the proposed design.
ii. For the baseline DOAS system, a constant volume system must be modeled in the baseline.
iii. The baseline DOAS must be modeled with the same temperature control strategy as the proposed design.

EXAMPLE 7-1 – Alternative HVAC Baseline for Fuel-Switching Projects

Scenario 1:

Q. A dormitory has a WSHP system with ventilation provided by gas-fired rooftop unit. The proposed design model shows that gas accounts for 90% of the annual heating energy, including heating of ventilation air. What is the baseline HVAC system for the project?

A. Gas is the predominant heating fuel in the proposed design. The Appendix G baseline for the project is System 1 - PTAC. Since the predominant heating source in the proposed design is the same as in the Appendix G baseline, the baseline does not have to be modified. It is expected that most, if not all, projects with WSHPs will use the standard Appendix G baseline.

Scenario 2:

Q. A 75,000 SF three story office building is served by VAV systems with gas-fired furnaces in the central air-handling units and electric resistance reheat coils. Perimeter spaces have electric baseboards. Ventilation to some spaces is provided by a dedicated gas-fired make-up air unit. The combined input capacity of electric re-heat coils and baseboards exceeds the combined input capacity of all gas-fired heating equipment. What is the baseline HVAC system for the project?

A. The predominant heating fuel in the proposed design is electricity. The Appendix G baseline for the project is System 5, with heating provided by a hot-water fossil fuel boiler. Following Section 7.1.1 of this document, the baseline HVAC system type must be determined based on Figure 11.3.2, “Air/None” condenser cooling source, “Electric Resistance” heating, and “All Other” system type. Based on these criteria, the baseline for the proposed VAV system is Section 11 System 3 - Packaged VAV with parallel fan-powered boxes. Based on the rule (iii) above for systems with mixed fuels, the central heating coils in the baseline VAV systems will be modeled with gas heating. Fan power and other HVAC system attributes will be based on the requirements for Appendix G System 6. The baseline system type for the gas-fired dedicated make-up air unit specified in the proposed design will be established following a similar procedure.

Scenario 3:

Q. A 50,000 SF, six-story college building is served by VRF heat pumps, with ventilation provided by gas-fired rooftop units. The input heating capacity of the specified VRF system is less than the input capacity of the gas-fired rooftop units. What is the baseline HVAC system for the project?

A. Gas is the predominant heating fuel. The Appendix G baseline for the project, System 7 – VAV with reheat, also uses gas for heating. However, per the exception described in 7.1.1.1, the Section 11 system map must be used. As a result, Section 11 – System 9 (Packaged Rooftop Heat Pump) must be modeled in place of the VRF systems in the baseline, and Section 11 – System 11 (Packaged Rooftop Air Conditioner) must be modeled in place of the DOAS systems in the baseline. Per 7.1.1.1, the DOAS system will be a constant volume unit with the same temperature control strategy as the proposed design.

7.1.2 Non-Electric Chillers

Projects with absorption or engine-driven chillers in the proposed design must use a non-electric chiller in the baseline using the following mapping based on Table 11.3.2C [1]:

<u>100 tons or less:</u>	reciprocation, single-effect absorption chiller
<u>Over 100 tons but less than 300 tons:</u>	screw, double-effect absorption chiller
<u>300 tons or more:</u>	centrifugal, double-effect absorption chiller

The baseline chiller must comply with efficiency requirements in ASHRAE 90.1 Section 6 and use the same energy source as the chiller in the proposed design. For example, if the proposed chiller uses district steam, purchased steam must be modeled as the cooling energy source in both the baseline and proposed models. The baseline system type for such projects must be based on the Table B1 in Appendix B. All applicable rules of Appendix G must otherwise be followed. This exception is due to the program policy against incentivizing fuel-switching.

Where chiller fuel source is mixed, the system in the Baseline Design model shall have chillers with the same fuel types and with the same proportional capacity as the proposed building. Chiller sequencing in the baseline shall match the sequencing in the proposed design as nearly as possible.

7.1.3 Baseline System Type for Electrically Heated Buildings

The baseline for electrically heated buildings must be submitted to the utility for pre-approval by filling out the Modeling Plan Charrette tab of the WBP Report Template V2.0, and may be modified by the utility from the Appendix G baseline.

7.2 Ventilation Control

7.2.1 Baseline Demand Control Ventilation (DCV)

Mandatory Section 6.4.3.9 of Standard 90.1 [1] requires that demand control ventilation (DCV) is specified for spaces larger than 500 ft^2 and with a design occupancy greater than 40 people per 1,000 ft^2 of floor area and served by systems with one or more of the following (unless exceptions to 6.4.3.9 apply):

- an air-side economizer
- automatic modulating control of the outdoor air damper or
- a design outdoor airflow greater than 3000 CFM

Due to this requirement, spaces such as auditoriums, conference rooms, lecture halls, and multipurpose rooms must typically have demand control ventilation in the Baseline Design. This requirement is mandatory. Thus, in order to comply with ASHRAE 90.1 and to qualify for program incentives, the proposed design must also have demand control ventilation unless exceptions to Section 6.4.3.9 apply.

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.

7.2.2 Baseline Ventilation Rates when DCV Is Modeled in the Proposed Design

Demand Control Ventilation (DCV) can be modeled for performance credit when it is not already required by ASHRAE 90.1 2010. When DCV is modeled for performance credit, ASHRAE 62.1-2010 ventilation rates or the ventilation requirements of applicable local code (whichever is greater) must be used in the baseline model for systems in the proposed design claiming credit for using DCV.

7.2.3 Ventilation Effectiveness Credit

Zones with air distribution effectiveness $E_z > 1.0$ may be modeled with lower ventilation rate in the proposed design compared to the baseline as described in 90.1 Section G3.1.2.6 Exception (b) [1], and may qualify for the performance credit. This credit may apply to proposed designs with displacement ventilation or other techniques that have a ventilation effectiveness greater than 1.0. Such projects must use Ventilation Rate Procedures described in ASHRAE Standard 62.1, Section 6.2 to demonstrate the savings.

7.2.4 Over-ventilation Penalty

Following 90.1 Section G3.1.2.6 exception (c), if the minimum outdoor air intake flow in the proposed design is provided in excess of the amount required by the 2016 CT State Building Code (2012 International Mechanical Code) or other mandated minimum ventilation requirements, then the baseline building design shall be modeled to reflect the minimum required ventilation rate, that will be less than in the proposed design.

Exception: Health care facilities are not subject to over-ventilation penalty as described in Section 6.2.6.

7.2.5 Laboratory Exhaust Systems

This section summarizes the relevant 90.1 Appendix G rules. However, the program requires that the baseline is based on 90.1 Appendix G or the standard practice, whichever is more stringent, thus all EEMs related to the laboratory exhaust systems must be approved by the utility before modeling.

Following G3.1.1 Exception (c), laboratory spaces in a building having a total laboratory exhaust rate greater than 5000 CFM must be modeled with baseline systems of type 5 or 7 serving individual spaces (i.e. single zone VAV).

Following the exception to Section G3.1.3.13, the baseline systems serving laboratory spaces shall be modeled to reduce the exhaust and makeup air volume during unoccupied periods to the largest of 50% of zone peak air flow, the minimum outdoor air flow rate, or the air flow rate required to comply with applicable codes or accreditation standards.

If project has a minimum flow rate above 50% due to the applicable codes and standards, and this higher rate is modeled in the baseline, the flow cannot be reduced below this required minimum in a measure.

Following 90.1 Section G3.1.2.11, 6.5.6 Exception (a), and 6.5.7.2 (b), the baseline laboratory exhaust system in many projects will not have energy recovery, however projects that include an energy recovery EEM must receive approval from the Utility for a baseline without energy recovery prior to modeling.

7.2.6 Ventilation in Healthcare Facilities

Minimum flow rates in healthcare facilities are prescribed by ASHRAE Standard 170. Section 7 of the standard allows higher rates if deemed necessary by the owner, thus higher rates may be specified for such facilities without incurring over-ventilation penalty.

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 a starting point for discussion:

a. For the areas subject to Standard 170, Systems 5 or 7 serving individual spaces (i.e. single zone VAV) must be modeled in the baseline.
b. During occupied hours, the baseline and proposed design must be modeled at the minimum flow rates required by Standard 170
c. 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.

7.3 Fan System Operation

Fan systems that provide outside air to the building shall operate continuously whenever the building is occupied, and cycle on and off to maintain the setback temperature when the building is unoccupied, per G3.1.2.4 [1] and Table G3.1 #4. In unoccupied mode, outside air must be shut off per 6.4.3.4.3 of ASHRAE Standard 90.1 [1]. These requirements apply to both the baseline and proposed design models.

7.4 Fan Control for Baseline Systems 3 and 4

Baseline systems 3 and 4 shall always be modeled with constant-volume fans, including in cases where 6.4.3.10 requires single-zone VAV control. Proposed systems shall meet 6.4.3.10.

7.5 Baseline Heat Pump Auxiliary Heat

Baseline System 2 – PTHP and System 4 – PSZ-HP must be modeled with electric auxiliary heat controlled as required by G3.1.3.1 [17].

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. When modeling a PSZ-HP, heat pump operation must be allowed in conjunction with the auxiliary heat at temperatures of 10°F and above; below 10°F, only auxiliary heat should operate.

For example, when modeling a PTHP, eQUEST users should set “Minimum HP Heat Temp” to 25°F and “Maximum HP Supp Temp” to 40°F.

7.6 Fan Power

7.6.1 Extracting Supply Fan Power from Efficiency Ratings

Based on Appendix G section G3.1.2.1, where efficiency ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately.

7.6.1.1 Extracting Fan Power – Proposed Design

When AHRI rated supply fan power has been obtained from the manufacturer, the following equation should be used for extracting supply fan power from cooling EER:

$$EER_{ADJ} = \frac{Q_{T,RATED} + BHP_{SUPPLY} * 2.545}{\frac{Q_{T,RATED}}{EER} - BHP_{SUPPLY} * .7457}$$ (Equation 7-1)

where

EER_{ADJ}	is the adjusted Energy Efficiency Ratio with fan power removed, to be used for simulation purposes
EER	is the rated Energy Efficiency Ratio, at ARI conditions
$Q_{T,RATED}$	is the ARI rated total cooling capacity of the unit (net capacity) in kbtu/h
BHP_{SUPPLY}	is the supply fan brake horsepower (bhp) at ARI rating conditions. For the purposes of these calculations, BHP includes losses of the fan motor and drive.

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

$$COP_{ADJ} = \frac{Q_{T,RATED} - BHP_{SUPPLY} * 2.545}{\frac{Q_{T,RATED}}{COP} - BHP_{SUPPLY} * 2.545}$$ (Equation 7-2)

where

COP_{ADJ}	is the adjusted COP with fan power removed, to be used for simulation purposes
COP	is the rated COP, at ARI conditions
$Q_{T,RATED}$	is the ARI rated total heating capacity of the unit (net capacity) in kbtu/h
BHP_{SUPPLY}	is 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

Manufacturers often publish both gross and net AHRI capacities, and the difference between these two figures is equal to the fan power.

If the actual supply fan BHP is not available from the manufacturer, then fan power must be extracted from the proposed systems in the manner described in §7.6.1.2.

7.6.1.2 Extracting Fan Power – Baseline Design

Per G3.1.2.1 [1], "where efficiency ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately."

For baseline systems 1, 2, 3, 4, 5, and 6, calculate the minimum $COP_{NFCOOLING}$ and $COP_{NFHEATING}$ from the rated efficiencies from tables 6.8.1A, 6.8.1B, and 6.8.1D using equations 7-3 through 7-7 below. Where both part-load and full-load ratings are given in tables 6.8.1A, 6.8.1B, or 6.8.1D, use the full load rating.

$$COP_{NFCOOLING} = 7.84E\text{-}8 \times EER \times Q + 0.338 \times EER$$ (Equation 7-3)

$COP_{NFCOOLING} = 0.0076 \times SEER^2 + 0.3796 \times SEER$ (Equation 7-4)

$COP_{NFHEATING} = 1.48E\text{-}7 \times COP_{47} \times Q + 1.062 \times COP_{47}$ (Equation 7-5)

$COP_{NFHEATING} = -0.026 \times HSPF^2 + 0.7134 \times HSPF$ (Equation 7-6)

where

$COP_{NFCOOLING}$	is the adjusted cooling COP with fan power removed, to be used for simulation purposes
$COP_{NFHEATING}$	is the adjusted heating COP with fan power removed
Q	is the AHRI rated total cooling capacity of the unit (net capacity) in btu/h*

*When using equations 7-3 and 7-5 to calculate $COP_{NFCOOLING}$ and $COP_{NFHEATING}$ in conjunction with tables 6.8.1A and 6.8.1B [1], Q shall be capped at the lower capacity of the highest capacity bracket for the applicable equipment type.

When using equations 7-3 and 7-5 to calculate $COP_{NFCOOLING}$ and $COP_{NFHEATING}$ in conjunction with Table 6.8.1D [1] (PTAC and PTHP systems), Q shall be capped at 15,000 btu/h and shall be no less than 7,000 btu/h.

EXAMPLE 7-3 – Extracting Fan Power for Large Baseline Systems

Q. A single baseline System 5 is being modeled for a large, one-story elementary school, and the auto-sized capacity is 1,400,000 btu/h. How should $COP_{NFCOOLING}$ be calculated?

A. Per table 6.8.1A [1], the baseline EER is 9.5. Equation 7-3 must be used to extract fan power. When using Equation 7-3, Q (capacity) must be capped at the lower end of the highest capacity range (in this case, 760,000 btu/h). As a result, equation 7-3 is evaluated as follows:

$$COP_{NFCOOLING} = 7.848 * 10^{-8} * EER * Q + 0.338 * EER = 7.848 * 10^{-8} * 9.5 * 760{,}000 + 0.338 * 9.5 = 3.27$$

It's expected that this cap will most affect baseline systems 5 and 6 (both are packaged VAV systems that are modeled with one system per floor), particularly in large one and two story buildings.

For the purposes of calculating $COP_{NFCOOLING}$ and $COP_{NFHEATING}$ for the baseline model, Q need only be within the 20% of the modeled system capacity (it is not required that Q exactly match the modeled capacity). This is to prevent the need for recalculating $COP_{NFCOOLING}$ and $COP_{NFHEATING}$ numerous times during the modeling process.

7.6.2 Baseline System Fan Power

a. The system baseline fan power must be calculated according to Appendix G section G3.1.2.9, and represents the total fan power allowance including supply, return, and exhaust fans, central and zonal.

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

c. The preferred method for modeling baseline fan power is by specifying Watt per CFM of air flow in the model, as this avoids the need to adjust fan power whenever flow rates change when evaluating ECMs. However, if a software tool does not allow inputting power per unit flow, the same purpose can be achieved by defining the total static pressure drop (TSP) and overall fan efficiency fraction (including motor, drive, and mechanical efficiencies). If TSP and/or overall fan efficiency are unknown, use equation 7-7 to convert from kW/cfm (power per unit flow).

$$Power_{kW/CFM} = \frac{TSP_{in.wg}}{8520 \times \eta_{overall}} \qquad \text{(Equation 7-7)}$$

If overall fan efficiency fraction $\eta_{overall}$ is unknown, 0.55 can be used. The accuracy of this estimate does not affect the results of the simulation, since adjusting the efficiency fraction when using equation 7-7 will cause an offsetting adjustment in the total static pressure.

7.7 SEER to EER Conversion

If the HVAC system efficiency for the proposed design is given as SEER, the EER rating is not available from manufacture's data, and the approved simulation tool does not automatically perform SEER to EER conversion, the equivalent EER for the model must be calculated as follows [7]:

> EXAMPLE 7-4 – SEER to EER Conversion
>
> Q. If a system in the proposed design has a rated efficiency of SEER 13.0, what are the inputs for the system efficiency?
>
> A. SEER can be converted to EER using the appropriate equation in section 0, in this case resulting in an EER 11.2.

EER = -0.02 × SEER^2 + 1.12 × SEER

Similarly, HSPF must be converted to COP as follows [3]:

All Single Package Equipment	COP = 0.2778 × HSPF + 0.9667
All Split Systems	COP = 0.4813 × HSPF - 0.2606

This equation does not apply if the fan power extraction equations 7.6.1.2 are being used for the proposed system (in cases where rated supply fan BHP was not obtained from the manufacturer), because the equations in 7.6.1.2 already perform the requisite unit conversion.

7.8 Baseline Chilled Water Pump Power

Section G3.1.3.10 requires that baseline building design pump power is modeled as 22 W/gpm. This represents the *total* for the primary plus secondary chilled water loop, and not the power of each loop [18]. The pump power allowance must be apportioned to the primary and secondary loops as follows:

Primary Loop Pump Power	7 W/GPM
Secondary Loop Pump Power	15 W/GPM

EXAMPLE 7-5 – 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 G3.1.1A, 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 2010 Table 6.8.1A is 10.8 EER. This rating includes supply fan power, which needs to be removed from the descriptor using Equation 7.3. The adjusted COP of 3.81 should be modeled in the baseline.

$$COP_{ADJ} = 7.84 \times 10^{-8} \times\ 10.9\ \times\ 144{,}000\ +\ 0.338\ \times\ 10.9 = 3.81$$

To calculate baseline fan power, first determine total baseline fan power allowance according to section G3.1.2.9.

$$\mathrm{A}\ =\ (.5\ +\ .15\ +\ .9)\ \times\ 4{,}850\ \div\ 4{,}131\ =\ 1.82$$

$$BHP = 0.00094\ \times CFM + A = 0.00094\ \times 4850 + 1.8 = 6.4$$

$$P_{FAN} = BHP\ \times 746\ \div Fan\ Motor\ Efficiency = 6.4\ \times 746\ \div 0917 = 5{,}207\ W$$

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 = 5,207 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	Baseline Flow CFM	Baseline kW/CFM
Supply Fan	2.8 / 4 = 0.7	5,207	0.7 * 5,207 = 3.71	4,850	.000765
Return Fan	1.1 / 4 = 0.275		0.275 * 5,207 = 1.46	4,365	.000334
Bathroom Exhaust	(75 / 746) / 4 = 0.025		0.025 * 5,207= 0.133	200	.000665

This calculation need only be performed once, for the fully configured Baseline Design, and should not be redone for individual ECM runs. The result of this calculation, the Baseline kW/CFM column, should either be entered directly into the modeling tool, or first converted into TSP and efficiency fraction inputs using equation 7-7. Thermodynamically equivalent approaches that use modified versions of the concepts and equations outlined above are also acceptable. Note that no additional allowance for individual exhaust fans is provided by the standard – the calculated baseline fan power allowance covers all applications.

Proposed Model: To extract proposed fan power, use equation 7-1. For BHP_{SUPPLY}, take the difference between gross and net cooling capacities and convert to HP. For this example, equation 4.1 simplifies as follows:

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

Had the gross capacity at AHRI rating conditions been unavailable, we would have had to resort to equation 7-3, which would have yielded an adjusted EER of 13.7.

8 Water Heating

8.1 Baseline Hot Water Demand

Hot water demand in the Baseline Building Design shall be determined based on average daily hot water usage indicated in Table 8.1-1 below, based on Table 7 from Chapter 50: Service Water Heating of the 2011 ASHRAE Applications Handbook.

For building types not included in Table 8.1-1, 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, such as those listed in [2] and [3].

8.2 Proposed Hot Water Demand

Technologies demonstrating a reduction in hot water usage can be modeled as reduced hot water demand in the Proposed Design based on Equation 8.1.

$$HWD_{PROP} = HWD_{BASE} * (1 - R) \qquad \text{(Equation 8.1)}$$

$$R = \sum(R_A * F_A) \qquad \text{(Equation 8.2)}$$

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 8.1-2 shows R_A and F_A values for common building types and technologies. Values for other technologies must be documented in the modeling submittal. F_A values must reflect realistic run-time based on the number of fixtures specified for the project. See Example 8-1.

Table 8.1-1 - Hot-Water Demands and Use for Various Types of Buildings*

Type of Building	Average Daily Usage
Dormitories**	12.7 Gal/Student
Motels***	
40 units or less	20 Gal/Unit
40-80 units	14 Gal/Unit
80 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	.6 gal/student
Junior and senior high school	1.8 gal/student

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

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

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

****Average for different size apartment buildings

Table 8.1-2 - F_A and R_A values for calculating reductions in hot water usage

Application/ Technology	F_A	R_A	Notes
Low flow faucets (residential)	10% [21]	1-FR/2.5	FR = average flow rate of installed faucets (GPM); 2.5 GPM = EPAct maximum
Low flow showerheads (residential)	54% [21]	1-FR/2.5	FR = average flow rate of installed showerheads (GPM); 2.5 GPM = EPAct Maximum
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
Low flow faucets (commercial)	Estimate	1-FR/2.5	FR = average flow rate of installed faucets (GPM); 2.5 GPM = EPAct maximum
Low flow showerheads (commercial)	Estimate	1-FR/2.5	FR = average flow rate of installed showerheads (GPM); 2.5 GPM = EPAct Maximum

*sum of all F_A values must not exceed 100%

9 References

[1] ANSI/ASHRAE/IESNA Standard 90.1 -2010 Energy Standard for Buildings Except Low-Rise Residential Buildings

[2] 90.1-2010 User's Manual

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

[4] "Reducing Barriers to Use of High Efficiency Lighting System", Lighting Research Center, RPI. Final report: March 2002 to January 2003, sponsored by US Department Of Energy.

[5] An analysis of the energy and cost savings potential of occupancy sensors for commercial lighting systems. Bill VonNeida, Dorene Maniccia, Allan Tweed; Lighting Research Center School of Architecture Rensselaer Polytechnic Institute and US Environmental Protection Agency Energy Star Buildings Program.

[6] Non-residential Alternative Calculation Method (ACM) Approval Manual for the 2005 Building Energy Efficiency Standards for Residential and non-residential Buildings. California Energy Commission, October 2004.

[7] Building America House Simulation Protocols, Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory, Revised October 2010.

[8] Emerging Energy-Saving Technologies and Practices for the Building Sector as of 2004, October 2004, H. Sachs, S. Nadel, J. Thorne Amann, M. Tuazon, and E. Mendelsohn : ACEEE, L. Rainer: Davis Energy Group, G. Todesco, D. Shipley, and M. Adhlaar: Marbek Resource Consultants

[9] 2013 ASHRAE Handbook Fundamentals IP, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

[10] ASHRAE Guideline 14-2002, Measurement of Energy and Demand Savings.

[11] ENERGY STAR Portfolio Manager Technical Reference: Source Energy https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf

[12] ANSI/ASHRAE/IESNA Standard 90.1 -2010 Energy Standard for Buildings Except Low-Rise Residential Buildings

[13] International Energy Conservation Construction Code, 2010.

[14] Department of Energy 10 CFR Part 431 Energy Conservation Program for Commercial and Industrial Equipment; Final Rule, January 9, 2009 http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/cre_final_rule.pdf

[15] ASHI/AHRI Standard 1200 (I-P) 2010 Standard for Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets http://www.ahrinet.org/App_Content/ahri/files/standards%20pdfs/ANSI%20standards%20pdfs/ANSI.AHRI%20Standard%201200%20%28IP%29%20-%202010.pdf

[16] Connecticut Program Savings Document, 10th Edition (2015)

[17] Interpretation 90.1-2007-09 – January 22, 2012 (Refers to the requirements presented in ANSI/ASHRAE/IESNA Standard 90.1-2007, Section G3.1.3.1, regarding heat pump operation.)

[18] Interpretation 90.1-2007-14 – December 11, 2012 (Refers to the requirements presented in ANSI/ASHRAE/IESNA Standard 90.1-2007, Section G3.1.3.10, regarding Chilled-Water Pumps (System 7 & 8).)

[19] Treatment of District or Campus Thermal Energy in LEED V2 and LEED 2009 – Design & Construction (August 13, 2010)

[20] Energy Star Multifamily High-Rise Program – Simulation Guidelines V1.0, Revision 03 (January 2015)

[21] Hwang et al., "Residential Appliance Data, Assumptions and Methodology for End-Use Forecasting with EPRI-REEPS 2.1." (1994)

[22] ANSI/ASHRAE/IESNA Standard 90.1-2007 – 2008 Supplement (accessed on 3/29/2016 at https://www.ashrae.org/File%20Library/docLib/Public/20090317_90_1_2007_supplement.pdf)

[23] Infiltration Modeling Guidelines for Commercial Building Energy Analysis, K Gowri, D Winiarski, R Jarnagin, September 2009 PNNL-18898

[24] ANSI/ASHRAE/IESNA Standard 90.1 -2013 Energy Standard for Buildings Except Low-Rise Residential Buildings

Appendix A: Typical Energy by End Use in Commercial Buildings

Table A1 – CBEC Typical Energy by End Use by Building Type (kbtu/ft^2)

	Space Heating	Cooling	Ventilation	Water Heating	Lighting	Process & Plug	Total
Education	39.4	8.0	8.4	5.8	11.5	10.1	83.2
Food Sales	28.9	9.8	5.9	2.9	36.7	115.6	199.8
Food Service	43.1	17.4	14.8	40.4	25.4	117.1	258.2
Health Care	70.4	14.1	13.3	30.2	33.1	26.6	187.7
Inpatient	91.8	18.6	20.0	48.4	40.1	30.4	249.3
Outpatient	38.1	7.2	3.3	2.5	22.6	20.6	94.3
Lodging	22.2	4.9	2.7	31.4	24.3	13.7	99.2
Retail (Other Than Mall).................	24.8	5.9	3.7	1.1	25.7	12.7	73.9
Office	32.8	8.9	5.2	2.0	23.1	20.9	92.9
Public Assembly	49.7	9.6	15.9	1.0	7.0	9.5	92.7
Public Order and Safety	49.9	8.9	9.5	14.0	16.5	16.9	115.7
Religious Worship	26.2	2.9	1.4	0.8	4.4	7.7	43.4
Service	35.9	3.8	6.0	1.0	15.6	14.6	76.9
Warehouse and Storage	19.3	1.3	2.0	0.6	13.1	9.0	45.3
Other	79.4	10.5	6.1	2.1	34.1	27.8	160.0
Vacant	14.4	0.6	0.4	0.1	1.7	3.1	20.3

Table A2 – Energy Consumption of PNNL Prototype Models Compliant with 90.1 2010, kBtu/SF

	Light.Int	Light.Ext	SHW	Heat	Humidfy	Cool	Ht.Rej	Fans	Ht.Rcvy	Pumps	Refrig	Elevator	Txfmr	Cook	Data.Ctr	Equip	Total
Highrise Apt	3.8	1.8	13.2	13.4	0.0	4.4	0.2	6.8	0.0	0.6	0.0	1.8	0.2	0.0	0.0	10.9	57.2
Midrise Apt	3.8	1.1	11.7	12.3	0.0	3.4	0.0	6.1	0.0	0.0	0.0	3.5	0.0	0.0	0.0	10.8	52.7
Hospital	14.1	0.8	5.1	34.9	5.3	8.9	1.7	11.6	0.9	2.3	1.0	9.9	0.4	17.0	0.0	21.0	134.9
Large Hotel	9.8	1.8	17.5	12.7	0.0	10.3	0.0	6.5	1.4	0.6	0.8	7.4	0.3	19.8	0.0	7.4	96.3
Small Hotel	2.6	0.4	0.0	1.8	0.0	1.6	0.0	1.8	0.0	0.0	0.0	1.6	0.0	0.0	0.0	2.2	12.0
Large Office	7.2	1.3	1.1	8.8	3.0	5.6	0.6	4.3	0.0	1.0	0.0	3.6	0.2	0.0	28.4	10.2	75.3
Medium Office	6.7	1.9	1.4	10.0	0.0	4.6	0.0	1.5	0.0	0.0	0.0	2.9	0.3	0.0	0.0	10.5	39.8
Small Office	9.2	2.1	3.1	3.1	0.0	3.1	0.0	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5	32.9
Clinic	12.5	2.6	2.9	22.3	3.1	17.9	0.0	9.3	0.0	0.3	0.0	14.8	0.0	0.0	0.0	32.0	117.8
Fast food	13.1	5.9	75.3	218.6	0.0	14.2	0.0	36.2	0.0	0.0	40.6	0.0	0.0	269.5	0.0	0.0	673.5
Restaurant	13.1	5.7	72.4	138.7	0.0	11.6	0.0	22.4	0.0	0.1	18.2	0.0	0.0	152.9	0.0	0.0	435.1
RetailStore	17.1	2.4	3.7	10.8	0.0	4.6	0.0	8.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	7.5	55.7
Strip Mall	22.9	3.0	2.7	24.1	0.0	4.4	0.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	69.7
Preschool	10.1	0.6	2.0	14.7	0.0	6.2	0.0	5.1	1.4	0.0	1.7	0.0	0.3	6.5	0.0	13.9	62.6
Secondary school	9.5	0.5	3.1	5.0	0.0	7.4	0.0	4.7	1.3	0.3	0.9	0.3	0.2	4.1	0.0	9.5	46.9
Warehouse	6.0	1.5	0.5	13.1	0.0	0.1	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	24.2

Appendix B: District Heating/Cooling

Table B1 – Revisions to Appendix G System Map for Projects Utilizing District Heating/Cooling Systems

ASHRAE App G Baseline System Type			District Energy System Used in Proposed Design		
			District Cooling Only	**District Heating Only**	**District Heating & Cooling**
Change from Appendix G Baseline	System 1	->	CV 4-pipe Fan Coil w/ HW Boiler Heat (FCU)	No Change	CV 4-pipe FCU
	System 2	->	Use 90.1 Section 11 System Map, Figure 11.3.2 & Table 11.3.2A with notes		
	System 3	->	2-pipe CV AHU w/ Fossil Fuel Furnace	PSZ-AC w/district heating	4-pipe CV AHU
	System 4	->	Use 90.1 Section 11 System Map, Figure 11.3.2 & Table 11.3.2A with notes		
	System 5	->	Change to System 7	No Change	Change to System 7
	System 6	->	Change to System 8		
	System 7	->	No Change	No Change	No Change
	System 8	->	No Change		
	System 9	->		Use 90.1 Section 11 System Map, Figure 11.3.2 & Table 11.3.2A with notes	
	System 10	->		Use 90.1 Section 11 System Map, Figure 11.3.2 & Table 11.3.2A with notes	

Appendix C: Commercial and Industrial Hours of Use and EFLH

Facility Type	Lighting Hours
Auto Related	4,056
Bakery	2,854
Banks, Financial Centers	3,748
Church	1,955
College - Cafeteria	6,376
College - Classes/Administrative	2,586
College - Dormitory	3,066
Commercial Condos	4,055
Convenience Stores	6,376
Convention Center	1,954
Court House	3,748
Dining: Bar Lounge/Leisure	4,182
Dining: Cafeteria / Fast Food	6,456
Dining: Family	4,182
Entertainment	1,952
Exercise Center	5,836
Fast Food Restaurants	6,376
Fire Station (Unmanned)	1,953
Food Stores	4,055
Gymnasium	2,586
Hospitals	7,674
Hospitals / Health Care	7,666
Industrial - 1 Shift	2,857
Industrial - 2 Shift	4,730
Industrial - 3 Shift	6,631
Laundromats	4,056
Library	3,748
Light Manufacturers	2,857
Lodging (Hotels/Motels)	3,064

Facility Type	Lighting Hours
Mall Concourse	4,833
Manufacturing Facility	2,857
Medical Offices	3,748
Motion Picture Theatre	1,954
Multi-Family (Common Areas)	7,665
Museum	3,748
Nursing Homes	5,840
Office (General Office Types)	3,748
Office/Retail	3,748
Parking Garages & Lots	4,368
Penitentiary	5,477
Performing Arts Theatre	2,586
Police / Fire Stations (24 Hr)	7,665
Post Office	3,748
Pump Stations	1,949
Refrigerated Warehouse	2,602
Religious Building	1,955
Residential (Except Nursing Homes)	3,066
Restaurants	4,182
Retail	4,057
School / University (Ref [1])	2,187
Schools (Jr./Sr. High) (Ref [1])	2,187
Schools (Preschool/Elementary) (Ref [1])	2,187
Schools (Technical/Vocational) (Ref [1])	2,187
Small Services	3,750
Sports Arena	1,954
Town Hall	3,748
Transportation	6,456
Warehouse (Not Refrigerated)	2,602
Waste Water Treatment Plant	6,631

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