Energy Conscious Blueprint (ECB) Energy Modeling Guidelines for Connecticut

Version 3.3

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Prepared for Energize CT for use with 2018 CT State Building Code based on ANSI/ASHRAE/IESNA Standard 90.1 2013 by Karpman Consulting.

Contents

1 Purpose

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

1. Describe program policies that deviate from ANSI/ASHRAE/IESNA Standard 90.1 2013 Appendix G (“90.1 Appendix G”) modeling protocol in order to reflect Connecticut standard construction practices and the incentive program funding rules.
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 to illustrate all of the above

2 Applicability

2.1 Applicability of Guidelines

Projects with design requirements to meet IECC 2015 / ASHRAE 90.1 2013 must follow Energy Modeling Guidelines (EMG) v3.x or later, based on the EMG version in effect when the Design Agreement is executed.

Projects required to meet IECC 2012 / ASHRAE 90.1 2010 or earlier codes must use EMG V2.0.

3 General Modeling Approach

3.1 Modeling Protocol

Buildings shall be modeled following ASHRAE/IESNA Standard 90.1-2013 (ASHRAE 90.1, 90.1) Normative 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 Section C407 Total Building Performance 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 modified by this document.

- As per Appendix G, the baseline shall not include end uses that do not exist in the proposed building (see Example 3-1).
- 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 Table 7.1 to these spaces but with no cooling modeled..

  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 Building Performance column, even if no cooling is specified, to account for impact of envelope, lighting, etc. on the cooling energy associated with room air conditioners that will be installed by tenanats.

EXAMPLE 3-2 - No Cooling Specified

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

A. Cooling should not be modeled in spaces where cooling is not included in the proposed design. Thus, both the mechanical rooms and the classrooms *should not* be modeled with cooling in the baseline. Classrooms should be modeled with System 5 - PVAVS (based on Table 7.1) but without DX coil. Mechanical spaces should be modeled with the same system type as specified in the proposed design.

- Where parameters of the baseline model are not defined by ASHRAE Standard 90.1, they should be modeled matching the proposed design. If no corresponding parameters exist in the proposed design model, the baseline must be based on modeling best practice (see e.g., COMNET [3] or the Performance Rating Method Reference Manual (PRM RM) [7]) or typical industry practice, and is subject to Utility approval.

3.1.2 Appendix G Proposed Model

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

3.1.3 Performance Rating

For projects engaged in the legacy Whole Building Performance program, the performance rating must be calculated on the basis of source energy. For projects participating through the ECB Path 1 and 2 programs, performance rating must be calculated on the basis of site energy usage index (EUI), in units of kBtu per square foot, using the following conversion factors shown in Table 3-1.

Table 3-1: Energy Conversion Factors

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

For projects qualifying based on site EUI, EUI is defined as a measure of a building's gross annual energy consumption relative to its gross square footage. Gross square footage excludes parking garages and penthouse square footage, as these are not conditioned space. EUI calculations will exclude exterior lighting loads (parking garages/lots) and associated loads in the garage space (i.e. exhaust fans). If there are enclosed spaces in garages with equipment loads (i.e. unit heaters in elevator lobbies), these loads and SQFT will be included in the building EUI.

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 Mandatory Requirements

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

3.1.6 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 ECB Path 1 and 2 programs:

- eQUEST
- Trane TRACE

Other software tools may be approved by Utility on a case by case basis. The modeling approach for any non-typical measures must be coordinated with Utility.

3.1.7 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 ECB Path 1 and 2 programs, 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 ECB incentives where modeling is necessary, non-identical buildings must be modeled explicitly. For example, a multifamily complex with ten buildings but only three unique building types may consist of an explicit model of the three 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 each unique location of multiple similar buildings, such as chain retail stores, with the model and documentation matching the design parameters at 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, as described in 90.1 G3.1.1.1, G3.1.1.2, G3.1.1.3 and Section 7 of this document.

While district system energy savings are always counted towards determining the performance rating and incentive tier, incentives for district energy system savings (for example, due to increased insulation) are only paid if the owner of the district systems pays into the energy efficiency (EE) fund. If the owner of the district system does not pay into the energy efficiency fund, incentives are prorated to exclude these savings. For district energy projects, where the district system <u>does not</u> pay into the EE fund, the modeler should select “district steam heating”, "district hot water", and/or "district cooling", as applicable, in the Energy Model Report Template in Table 12.1. Where the district system <u>does</u> pay into the EE fund refer to section 3.3.2 for guidance regarding the conversion to electricity and/or fossil fuel usage.

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

3.3.2 Conversion to Electricity and/or Fossil Fuel Usage

Purchased energy usage, where the owner of the district systems pays into the energy efficiency fund 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
ii. District chilled water generated by gas chiller: COP 0.95 chiller efficiency, 5% distribution loss, 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%
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%.
v. District steam generated with unknown technology: 84.9% weighted average overall efficiency based on 43% CHP market share
vi. District hot water: 80% boiler efficiency, 2.5% distribution loss, with an overall system performance of 78%

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.

For projects that use electricity and other energy sources generated by district CHP, the methodology

> **EXAMPLE 3-4 - Converting Modeled Energy Savings to the Equivalent Savings of Purchased Fuels for Which Owner Pays into the Energy Efficiency Fund on Projects That Use District CHP.**
>
> **Q:** District plant includes CHP that runs on natural gas, absorption chillers and boilers that utilize CHP waste heat when available, with supplement electricity purchased from grid. The owner of the district plant pays into the energy efficiency fund for purchased natural gas and electricity. How will this affect energy savings used to calculate project incentives?
>
> **A:** Modeled savings are converted to the equivalent reduction in the purchased electricity and natural gas and are subject to utility approval.
>
> a. Modeled electricity savings are treated as savings of electricity purchased from grid. (If the district plant in the example did not use purchased electricity as back-up, electricity saving would have been converted to the equivalent reduction in natural gas used by the CHP.
>
> b. Modeled chilled water savings are converted to equivalent savings of purchased fuels used by district chiller plant, excluding the periods when chilled water is generated with the CHP waste steam. Analysis of the district CHW plant load profile indicated that the CHW savings at outdoor temperatures over 85F qualify for incentives.
>
> c. Modeled steam savings are converted to equivalent savings of purchased fuels used by district plant. Reduction in utilization of CHP waste steam does not qualify for incentives. Analysis of waste steam availability indicated that it accounts for 10% of savings, thus 90% of the modeled steam savings are converted to equivalent reduction in purchased fuels.

for converting modeled energy savings to the equivalent savings of fuels for which the owner of the district systems pays into the energy efficiency fund is subject to utility approval and follows the general principal described in EMG Section 3.5.

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 with the exception that fossil fuel systems shall be modeled using the same fuel type in the baseline as is specified in the proposed design.

Propane and oil-fired equipment does not qualify for any incentives even when it improves over the minimum code requirements. For example, incentives are not available for a propane-fired boiler with an efficiency that exceeds the minimum requirements of 90.1-2013.

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

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

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

Energy savings offset by the CHP recovered waste heat cannot contribute toward incentives. If the baseline load exceeds CHP waste heat capacity, the corresponding baseline system shall be modeled based on the energy source used as the backup energy source, and savings in the energy use of that system may be modeled. The selected modeling approach must be described on the Modeling Plan Charrette tab of the Energy Model Report Template.

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 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 Section 3.3.

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 be modeled with the baseline System 7 and as described in EMG Section 3.3.1.

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 EMG Section 4.1.1.

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 Energy Conscious Blueprint 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) ÷ 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 3-2.

Table 3-2: 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 occupancy, HVAC, and other schedules should not deviate significantly (i.e. have Effective Full Load Hours (EFLH) differing by more than 15%) from the schedules in Tables G-D to G-M of the 90.1 – 2013 User's Manual [2], COMNET Commercial Buildings Energy Modeling Guidelines and Procedures Appendix C – Default Schedules [3], 90.1 Section C3.5.5.3 Schedules and Internal Loads [13], or, for multifamily buildings, the ENERGY STAR Multifamily New Construction Program Simulation Guidelines [9], as applicable, unless documentation is available substantiating the modeled schedules. Modeled interior lighting runtime should not deviate significantly (i.e. have EFLH differing by more than 15%) from the EFLH calculated as described in Appendix B of this document unless documentation is provided substantiating the modeled schedules.

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

Schedules must be modeled identically in the baseline and proposed design models, unless otherwise permitted by 90. 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 ECB Path 1 and 2 programs, the proposed model must be developed incrementally using multiple Measures, so that the impact of individual systems on the performance of the proposed design can be reported. This requirement will help to support and expedite the program's quality control process.

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

Annual energy consumption by end use must be reported for each Measure.

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-0.032	U-0.030
	Walls	U-0.055	U-0.052
Lighting	Lighting	Average LPD 0.82	Average LPD 0.8
HVAC	HVAC System Type	System 7 – VAV w/ HW Reheat; System 3 – PSZ in assembly spaces w/ energy recovery;	Chilled beams and CV dedicated outdoor air system with energy recovery; SZ VAV air handlers in assembly spaces w/ DCV
	Chiller Efficiency	Two water-cooled centrifugal chillers >600 tons, 0.585 kW/ton full load, 0.380 IPLV	Two frictionless (magnetic bearing) centrifugal chillers, COP = 6.0, IPLV = 10.1
	Chilled Water Loop Pump Energy and Control	Primary/Secondary (one-speed/VFD), 35 kW total pump energy	Primary/Secondary, (VFD/VFD), 39 kW total pump energy
	Cooling Tower	One axial fan cooling tower, 40.2 gpm/hp, variable speed motors	One two-cell axial fan cooling tower, 44.1 gpm/hp, variable speed motors
	Condenser Loop Pump Energy and Control	Total pump energy 34 kW, constant speed, constant volume	Total pump energy 30 kW, constant speed, constant volume
	Boiler Efficiency	Two natural-draft boilers, 80% Efficient	Two condensing boilers, 95% efficient
	Hot Water Loop Pump Energy and Control	11 kW total pump energy, VFD	15 kW total pump energy, VFD

How should this project be broken into measures?

A. Minimum Required Measure Granularity

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.

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

Baseline – ASHRAE 90.1 baseline run

Measure 1 – ASHRAE 90.1 baseline run + Proposed Roof

Measure 2 – Measure 1 + Proposed Wall

Measure 3 – Measure 2 + Proposed Lighting

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

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

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

Measure 7 – Measure 6 + Proposed Chillers

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

Measure 9 – Measure 8 + Proposed Cooling Tower

Measure 10 – Measure 9 + Proposed CW Pump Power

Measure 11 – Measure 10 + Condensing Boilers

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

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 0 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-35 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-30 continuous insulation.
>
> The proposed design must be modeled as designed (with R-35 continuous insulation).

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 defined in Appendix G Table G3.1 section 5.b Baseline Building Performance column.

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.

4.1.4 Window Area

The baseline vertical fenestration areas for new buildings and additions shall equal that in the proposed design or 40% of gross above grade wall area, whichever is smaller, and shall be distributed on each face of the building in the same proportions in the proposed design. The fenestration area for an existing building shall equal the existing fenestration area prior to the proposed work and shall be distributed on each face of the building in the same proportions as the existing building.

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-factor. 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 ECB Path 1 and 2 simulation tool used for the project based on known thermal properties and dimensions of the framing and glazing
- ASHRAE Fundamentals 2021, Chapter 15 Table 4.
- If both summer and winter U-factors are available, winter U-factor must be modeled as it reflects the testing conditions of NFRC 100 referenced in 90.1 Section 5.8.2.3.

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.

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) [7]. 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. The conversions used by the common simulation tools are automated on the Opaque Assemblies tab of the reporting template.

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 9.5.1 (Building Area Method) or Table 9.6.1 (Space-by-Space method) of ASHRAE 90.1. 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 9.5.1 (Building Area Method) may be used for the retail portion and Table 9.6.1 (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 Proposed Lighting Power Density Calculation Method

The modeled proposed lighting power shall be based on the greater of the following:

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

5.3 Lighting in Residential Space

5.3.1 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 = 0.75 W/SF

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; $LPD_B = 0.75$ 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 $SE_{P,i}$ 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.

5.3.2 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 nightstands, 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. $LPD_B = 0.91$ W/SF as per Standard 90.1

5.3.3 Dormitory-living quarters

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

$LPD_B = 0.38$ W/SF as per Standard 90.1

$SE_B = 61$ as per IESNA lighting models

5.4 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 or recommended in IESNA Lighting Handbook, the baseline LPD may be increased in proportion to the increase in the illuminance.

5.5 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.

5.6 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 5-2 – 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 1.26 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.

5.7 Interior Lighting Controls

5.7.1 Occupancy sensors, timers and other automatic controls except for daylighting

Automatic lighting controls are required by Standard 90.1 in most space types (90.1 Section 9.4.1 and Table 9.6.1). Since these are mandatory provision, where such controls are required (if exceptions to these sections do not apply), they must be specified in the proposed design and no performance credit is permitted. The modeled lighting schedules for the baseline and proposed design must reflect the same reduced runtime due to occupancy sensors, as described in EMG Section 3.9 and EMG Appendix B.

Performance credit may be claimed for the automatic lighting controls included in the proposed design but not required by Section 9.4.1 and Table 9.6.1, or when a more efficient control method is used among the compliance options allowed in Table 9.6.1. Examples of credit opportunities are provided below.

1. Occupancy sensor controls in spaces where automatic controls are not required based on 90.1 Section 9.4.1 (including exceptions) and Table 9.6.1 shall be modeled as 10% reduction in LPD or lighting runtime hours.
2. Occupancy sensors controlling the downlight component of workstation specific luminaires with continuous dimming to off capabilities listed in 90.1 Table 9.6.3 may be modeled by dividing the lighting schedule each hour or the LPD by the factor $(1 + \sum CF)$, where $\sum CF$ is the sum of all applicable control factors (CF) per Section 9.6.3 and Table 9.6.3.
3. Manual ON (90.1 Section 9.4.1.1[b]) or Partial Automatic ON (90.1 Section 9.4.1.1[c]) when neither is required in 90.1 Table 9.6.1 (ADD1) shall be modeled as 5% reduction in LPD or lighting runtime hours.
   Examples: Public corridors, lobbies, restrooms, stairways, storage rooms <50ft^2, dormitory-living quarters, certain spaces in healthcare facilities

4. Automatic full off (90.1 Section 9.4.1 [i]) when either automatic full off or scheduled shutoff is allowed in 90.1 Table 9.6.1 (ADD2): 5% reduction in LPD or lighting runtime hours.
   Example: enclosed office >250 ft^2
5. For high end trim (the task tuning), a maximum reduction of 15% to the LPD or lighting runtime hours may be modeled. The following must be provided to claim this credit [11]:
   a. The lighting designer must provide the anticipated degree of turndown that is to be installed in each space with task tuning. This is the basis of savings to be claimed in the energy model. The submittal must list what tuning factors are applied to the space LPD. The tuning factor is to be considered in addition to control factors for occupancy sensors and lighting schedules.
   b. The project construction documents must clearly list the intended light level that the systems are to be tuned to (foot candles as measured below the light at a specific height above the floor).
   c. The project construction documents must clearly describe lighting controls commissioning requirements and methods for implementing task tuning.

5.7.2 Daylighting

Proposed Design

Automatic daylight responsive controls are required for most spaces with vertical fenestration and skylights as described in 90.1 Section 9.4.1 and Table 9.6.1. These controls must be specified in the proposed design modeled directly in the building simulation or through schedule adjustments determined by a separate approved analysis.

Examples where daylighting controls qualify as performance credit include dormitory living quarters and in spaces meeting exceptions to Section 9.4.1.1(e) and (f), such as retail spaces or spaces with lower fenestration area.

The summary outputs from the daylighting software and explanation of how the results were incorporated into the ECB Path 1 and 2 simulation tool must be included in an appendix to the report. Modeling and schedule adjustments shall be applied only to the fixtures for which daylight controls are specified.

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.

Baseline Design

Daylighting controls required by Section 9.4.1 shall be modeled using the same methodology as in the proposed design.

5.8 Exterior and Parking Garage Lighting

Exterior and parking garage lighting must be excluded from the energy model. The baseline and proposed energy consumption must be calculated outside of the simulation tool and entered manually in the last two rows in Table 12.7 in the Energy Model Report Template using the 90.1 2013 Appendix G methodologies for establishing the baseline and proposed energy consumption. The baseline and proposed coincident peak demand must also be calculated outside of the energy model and entered manually in Tables 12.13a and 12.13b in the Energy Model Report Template per the methodology described below in Section 5.8.2.

5.8.1 Baseline and Proposed Exterior Lighting Power Calculation

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 categorizes exterior lighting into tradable and non-tradable surfaces.

Tradable applications include uncovered parking areas, building grounds, building entrances and exits, sales canopies, and outdoor sales areas. The allowed LPD for tradable applications must be multiplied by the associated area or length to determine the baseline power. Only illuminated areas can be included in the baseline allowable wattage calculations, as described in Example 3-1.

EXAMPLE 5-3 - 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.

<table>
<tr><th></th><th colspan="2">Parking Lot</th><th colspan="2">Building Façade</th></tr>
<tr><td>Surface Area</td><td colspan="2">40,000 ft²</td><td colspan="2">3,500 ft²</td></tr>
<tr><td>Lighting Allowance (Table 9.4.2-2)</td><td colspan="2">0.10 W/ft²</td><td colspan="2">0.15 W/ft²</td></tr>
<tr><td>Maximum Allowed Wattage</td><td colspan="2">0.1 W/ft² × 40,000 ft² = 4 kW</td><td colspan="2">0.15W/ ft² × 3,500 ft² = 525 W</td></tr>
<tr><td>Base Site Allowance, total per project (Table 9.4.2-2)</td><td colspan="2">750 W</td><td colspan="2">NA</td></tr>
<tr><td>Allowance Type (Table 9.4.2-2)</td><td colspan="2">Tradable</td><td colspan="2">Non-tradable</td></tr>
<tr><td rowspan="2">Modeled Wattage</td><td>Baseline Model</td><td>Proposed Model</td><td>Baseline Model</td><td>Proposed Model</td></tr>
<tr><td>4.75 kW</td><td>3 kW</td><td>400 W</td><td>400 W</td></tr>
</table>

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.

5.8.2 Baseline and Proposed Coincident Peak Demand Calculation for Exterior and Parking Garage Lighting

Exterior and parking garage lighting coincident peak demand must be calculated separately as described in this section and manually entered in Tables 12.13a and 12.13b in the Energy Model Report Template.

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

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

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

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

where

$W_{baseline}$ = the baseline Wattage established per the rules of 90.1 2013 Appendix G.

$W_{proposed}$ = the proposed Wattage established per the rules of 90.1 2013 Appendix G (i.e. the as-designed Wattage).

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

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

5.9 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.

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 are shown in Appendix A of this document. Projects with a process and plug load site energy intensity more than 20% below the provided values 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 the appliance calculator outputs due to interactions with HVAC systems.

b) Savings for automated receptacle controls in addition to those required by 90.1 Section 8.4.2 must be modeled by adjusting proposed equipment schedule (Option 1) or proposed equipment power density (Option 2) as follows:

Baseline Design (Options 1 & 2):

- 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]

Proposed Design:

- 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 ECB Path 1 and 2 simulation tool. The baseline must be based on the Department of Energy 10 CFR Part 431. Refrigeration system EER must be based on Table 1 of ASHRAE Standard 1200 – 2013. 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 0

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

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

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 refrigerators and freezers regulated in 90.1 2013 must be based on the kWh/day column from 90.1 2013 Table 6.8.1-12 and 6.8.1-13 for the specified equipment divided by 24 hours.
b) Usage of walk-in refrigerators and freezers must be the same as in the proposed design, unless exceptional calculation methods are used, 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:

For Self-Contained Units:

$Q = kW \times 3.412$

where

Q The rate of heat removal from the space due to the continuous operation of the refrigeration system (kBtu/h). A negative number means that heat is being removed from the space; a positive number means that heat is being added.

kW Refrigeration Power, kW

For Units with Remote Condensers:

$Q = Refload * Credit$

where

Refload = refrigeration load per design documents

Credit = refrigeration credit, 0.13 for reach-ins and 0.32 for open units (credit for cooling, penalty for heating)

7 Heating, Ventilation and Air Conditioning

7.1 Baseline HVAC System Type

The baseline HVAC system requirements described in this section supersede the corresponding rules of 90.1 Appendix G. The changes were made to align the modeled baseline with Connecticut standard design practice, and to ensure that the same fuels are used for heating and cooling in the baseline as in the proposed design. For cases not described below, please contact the program for specific guidance.

The baseline HVAC system type must be determined using one of the following options:

Option A: The same system types as in the proposed design, but with the heating and cooling efficiency minimally compliant with Standard 90.1, to allow claiming credit for better than code heating and cooling efficiency. Projects may still claim credit for ancillary features that exceed minimum code requirements including but not limited to exhaust air energy recovery, demand control ventilation, reduced fan energy and others following the rules in 90.1 Appendix G and this section.

Option B: Based on Table 7.1, to allow claiming credit for more efficient system type specified in the proposed design compared to Connecticut standard practice.

Option C: Alternative baseline system types representative of the standard Connecticut design practice for new facilitates of the similar type and size. The alternative baseline must be pre-approved by Utility based on substantiating documentation provided by the applicant.

The selected approach must be used for all systems in the proposed design.

Table 7.1: Baseline HVAC System Type, General

Design Building or System Category	Design HVAC System Fuels		
	100% Gas Heating	100% Electric Heating	Hybrid Gas + Electric
Hotel	System 1 - PTAC	System 2 - PTHP	Same as proposed, see Table 7.2
Other Residential	System 1 - PTAC	System 2 - ASHP	
Schools < 150,000 ft^2	System 5 – Packaged VAV with reheat	System 4 - VRF	
Schools >=150,000 ft^2	System 7 – VAV with reheat	System 4 - VRF	
Non-Res and 3 floors or fewer and <25,000 ft^2	System 3 - PSZ-AC	System 4 - VRF	
Non-Res, 4-5 Floors & <25,000 ft^2 or <=5 floors & 25,000-150,000 ft^2.	System 5 – Packaged VAV with reheat	Must use Option A or C	
Non-Res >5 floors or >150,000 ft2 and all hospitals	System 7 –VAV with reheat	Must use Option A or C	
Heated-only	System 9	System 10	
Retail & 2 floors fewer	System 3 - PSZ-AC	System 4 - VRF	

Table 7.2: Baseline HVAC System Type for Hybrid Systems in the Proposed Design

Proposed HVAC Design	Baseline HVAC
Gas heating Dedicated Outdoor Air System (DOAS) (via furnace or HW boiler) + electric space heating (PTHP, VRF, or geothermal heat pump)	System 3 PSZ-AC DOAS + space heating and cooling system from Table 7.1, 100% Electric Heating column
Gas heating DOAS (Furnace or HW boiler) + water-source heat pump (WSHP); WSHP providing heating, cooling and ventilation	Use Table 7.1 100% gas heating column for the appropriate building type
Gas heating VAV (Furnace or HW boiler) + electric reheat coils	Gas furnace VAV + electric reheat coils

Notes:

1. System 3 and System 4 shall be modeled as constant volume or variable volume, to meet requirements of 90.1 Section 6.5.3.2.1. If modeled as variable volume, then the baseline fan power shall be determined following Table G3.1.2.10, Variable Volume System 5-8 column. If modeled as constant volume, then the baseline fan power shall be determined following Table G3.1.2.10, Constant Volume System 3-4 column.

2. System 2 - ASHP shall be modeled with heating and cooling efficiencies prescribed in 90.1 Table 6.8.1-2. The prescribed heating efficiency at low temperatures must be captured in the model.

3. System 4 - VRF shall be modeled with heating and cooling efficiencies prescribed in 90.1 Table 6.8.1-10 for VRF air-cooled heat pumps without heat recovery. The prescribed heating efficiency at low temperatures must be captured in the model.

4. Section G3.1.1 Exception 1 shall be revised as follows: Use additional system type(s) for non-predominant conditions (i.e., residential/nonresidential or heating source) <u>regardless of conditioned floor area for that non-predominant condition</u>.

5. Section G3.1.1 Exception 8 shall be stroke out and hospitals shall follow Tables 7.1 and 7.2.

6. Where the baseline and proposed designs include a DOAS that provides ventilation air and a second HVAC system providing heating and cooling, as prescribed in Table 7.2, the HVAC systems' operating schedules shall be the same in the baseline and proposed design, including DOAS running continuously during occupied hours and off during unoccupied hours, and the secondary system cycling with load.

EXAMPLE 7-1 – Baseline HVAC System Mapping for a School

Q. A 100,000 ft² school has ductless VRF air-cooled heat pumps providing heating and cooling to each classroom and cycling with load. Ventilation to classrooms is provide by a gas-fired DOAS. Corridors are served by a gas-fired roof-top unit (RTU). Library and gym are each served by VRF heat pump that run continuously when school is occupied providing heating, cooling and ventilation. How should the baseline HVAC be modeled?

A1. The baseline HVAC shall be modeled as follows based on the EMG Table 7.2:

Classrooms:

a. VRF air cooled heat pumps in each classroom providing heating and cooling (System 4 – VRF)
   - cooling capacity >=135,000 Btu/h and <240,000 Btu/hr based on the baseline space heating and cooling loads in the corresponding HVAC zones
   - cooling efficiency 10.6 EER / 11.8 IEER, heating efficiency 3.2 COPh @ 47F db / 43F wb outdoor air and 2.05 COPh at 17F db / 15F wb outdoor air (90.1 Table 6.8.1-10).
   - Fans shall cycle with load to maintain temperature setpoints
   - All other HVAC system parameters based on 90.1 2013 Appendix and EMG requirements for System 4
   - Fan power shall not be modeled explicitly, per exception to EMG Section 7.6.1.

b. Gas-fired RTU providing ventilation (System 3 – PSZ – AC DOAS)
   - Heating and cooling capacity based on the baseline ventilation load in the HVAC zones served by the DOAS system
   - OA CFM based on EMG Section 7.3.3 and Section 7.3.4 (e.g., penalty for over-ventilation)
   - Design CFM equal to OA CFM
   - Heating efficiency based on 90.1 Table 6.8.1-5; cooling efficiency based on 90.1 Table 6.8.1-1
   - energy recovery with 50% recovery effectiveness as defined in 90.1 6.5.6.1 and provision to bypass or control the energy recovery system to permit economizer operation (G3.1.2.11)
   - fans run continuously when school is occupied and shut off during unoccupied hours; fan control as required by 90.1 Section 6.5.3.2.1.
   - fan power based on 90.1 Section G3.1.2.10 System 3
   - fan power must be excluded from efficiency ratings and fans must be explicitly modeled (EMG Section 7.6.1)

Corridors:

c. Gas-fire RTU providing heating, cooling and ventilation (System 3 – PSZ-AC)
   - Heating and cooling capacity based on the baseline heating, cooling and ventilation load
   - Design airflow determined based on 90.1 G3.1.2.9.1
   - OA CFM based on EMG Section 7.3.3 and Section 7.3.4 (e.g., penalty for over-ventilation)
   - Heating efficiency based on 90.1 Table 6.8.1-5; cooling efficiency based on 90.1 Table 6.8.1-1
   - Exhaust air energy recovery with 50% recovery effectiveness if required in 90.1 6.5.6.1 with provision to permit economizer operation (G3.1.2.11)
   - Economizer with controls based on Table G3.1.2.8
   - Fans run continuously when school is occupied; fan control as required by 90.1 Section 6.5.3.2.1;
   - Fan power based on 90.1 Section G3.1.2.10 System 3
   - Fan power must be excluded from efficiency ratings and fans must be explicitly modeled (EMG Section 7.6.1)
   -

Library and Gym

d. VRF air-cooled heat pumps providing heating, cooling and ventilation (System 4 – VRF)
   - cooling capacity >240,000 Btu/hr based on the baseline model
   - cooling efficiency 9.5 EER/10.6 IEER, heating efficiency 3.2 COPh @ 47F db / 43F wb outdoor air and 2.05 COPh at 17F db / 15F wb outdoor air (90.1 Table 6.8.1-10).
   - Design airflow determined based on 90.1 G3.1.2.9.1
   - OA CFM based on EMG Section 7.3.3 and Section 7.3.4 (e.g., penalty for over-ventilation)
   - exhaust air energy recovery with provision to permit economizer operation based on G3.1.2.11
   - fans run continuously when school is occupied; fan control as required by 90.1 Section 6.5.3.2.1;
   - fan power based on 90.1 Section G3.1.2.10 System 4
   - fan power must be excluded from efficiency ratings and fans must be explicitly modeled (EMG Section 7.6.1)

EXAMPLE 7-2 – Baseline HVAC System Mapping for a Multifamily Project

Q. Proposed design is a multifamily building with air-to-air VRF heat recovery units providing heating and cooling to apartments. In-unit energy recovery ventilators provide ventilation. Gas-fired RTU with DX cooling serves corridors. Storage, mechanical rooms and stairwells have electric resistance space heaters. How should the baseline HVAC be modeled?

A. The baseline HVAC is modeled as follows based on the EMG Section 7.1 Option B:

Apartments: System 2 – ASHP

- cooling capacity >=65,000 Btu/h and <135,000 Bth/h based on the baseline model
- cooling efficiency 10.8 EER / 12.01 IEER, heating efficiency 3.3 COPh @ 47F db / 43F wb outdoor air and 2.25 COPh at 17F db / 15F wb outdoor air (90.1 Table 6.8.1-2).
- Units run continuously providing heating, cooling and ventilation
- fan power based on 90.1 Section G3.1.2.10 System 2 (0.3 W/CFM)
- All other HVAC system parameters as described in 90.1 2013 Appendix G and EMG for System 2

Corridors: System 3 – PSZ AC, packaged rooftop air conditioner

- As described in 90.1 2013 Appendix G and EMG for System 3

Storage, mechanical rooms and stairwells: System 10, warm air electric resistance constant volume furnace

- As described in 90.1 2013 Appendix G and EMG for System 10

7.2 Baseline and Proposed Chillers

7.2.1 Baseline Chillers

For the Baseline Systems 7 and 8, chiller full load efficiency shall be equal to the values specified in 90.1 Table 6.8.1-3 Path B, Effective 1/1/2015 column, for the chiller type and capacity determined following 90.1 Table G3.1.3.7. For the baseline screw chillers, use the values in 90.1 Table 6.8.1-3 for the positive displacement chillers. Baseline chiller performance curves shall reflect Path B performance and modeled using the capacity and efficiency curves provided in the EMG Appendix C.

7.2.2 Proposed Chillers

Proposed chillers shall be modeled as follows:

Option 1: Chillers that meet or improve over Path B IPLV in Table 6.8.1-3 for the appropriate chiller type may be modeling using the appropriate Path B performance curves in EMG Appendix C.

Option 2: Chillers that do not meet Path B IPLV in Table 6.8.1-3 for the appropriate chiller type may be modeled using Path A performance curves in EMG Appendix C

Option 3: Model custom performance curves developed based on the manufacturer’s data. Documentation on development of the custom curves must be included in the submittal and is subject to Utility approval.

7.2.3 Absorption Chillers

Projects with absorption chillers in the proposed design must model an absorption chiller in the baseline using the following mapping based on 90.1 Table 11.3.2C:

<u>100 tons or less:</u>	reciprocating, 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. 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.

7.3.2 Engine Driven Chillers

Engine driven chillers in the proposed design must be modeled as energy neutral, with the same chiller type, efficiency and capacity modeled in the baseline and proposed designs. Engine driven chillers are rebated through a separate state program.

7.3 Ventilation Control

7.3.1 Baseline Demand Control Ventilation (DCV)

Mandatory Section 6.4.3.8 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 or equal to 25 people per 1,000 ft^2 of floor area and served by systems with one or more of the following (unless exceptions to 6.4.3.8 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.

7.3.2 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 2013. Ventilation rates provided in the CT Mechanical Code or other applicable local code (whichever is greater) must be used in the baseline model for systems in the proposed design claiming credit for using DCV.

7.3.3 Ventilation Effectiveness Credit

Zones with air distribution effectiveness Ez>1.0 may be modeled with lower ventilation rate in the proposed design compared to the baseline as described in 90.1 Section G3.1.2.6 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.

7.3.4 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 (2015 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.

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

7.3.5 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.

7.3.6 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 an over-ventilation penalty with pre-approval from the Utility.

All related EEMs for Ventilation in Healthcare Facilities must be approved by the Utility prior to modeling including but not limited to flow control measures such as an advanced air quality control system and heat recovery. The following are 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 design must be modeled at the minimum flow rates required by Standard 170 and the proposed must be modeled with the greater of the as designed flow rates and the minimum flow rates required by Standard 170.

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.

7.4 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 90.1 G3.1.2.4 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. These requirements apply to both the baseline and proposed design models.

7.5 Baseline PTHP Auxiliary Heat

Baseline System 2 – PTHP must be modeled with electric auxiliary heat controlled as required in 90.1 Section G3.1.3.1.

The electric auxiliary heat must be locked out in the model at temperatures above 40°F.

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

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.

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

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:

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

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 AHRI rating conditions. For the purposes of these calculations, BHP includes losses of the fan motor and drive.

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

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

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 90.1 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."

For baseline systems 1, 2, 3, 4, 5, and 6, calculate the minimum $COP_{NFCOOLING}$ and $COP_{NFHEATING}$ from the rated efficiencies from tables 6.8.1-1 through 6.8.1-4 as described in 90.1 G3.1.2.1. When calculating $COP_{NFCOOLING}$ and $COP_{NFHEATING}$ in conjunction with 90.1 Tables 6.8.1-1 through 6.8.1-2 Q shall be capped at the lower capacity of the highest capacity bracket for the applicable equipment type.

When calculate $COP_{NFCOOLING}$ and $COP_{NFHEATING}$ in conjunction with 90.1 Table 6.8.1-4 (PTAC and PTHP systems), Q shall be based on the load of individual HVAC zones prior to aggregation into thermal blocks allowed in 90.1 Table G3.1 #9 Thermal Blocks – Multifamily Residential 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 except as described in Section 7.1, 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 7-3 – 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.

$$EER = -0.02 \times SEER^2 + 1.12 \times SEER$$

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

All Single Package Equipment	$COP = 0.2778 \times HSPF + 0.9667$
All Split Systems	$COP = 0.4813 \times HSPF - 0.2606$

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. 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 7-4 – Fan Power and Cooling Efficiency

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

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

The baseline system efficiency from ASHRAE 90.1 2013 Table 6.8.1A is 10.8 EER. This rating includes supply fan power, which needs to be removed. The adjusted $COP_{NFCOOLING}$ of 3.81 should be modeled in the baseline.

$$COP_{NFCOOLING} = 7.84 \times 10^{-8} \times 10.8 \times 144{,}000 + 0.338 \times 10.9 = 3.81$$

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 Heater Type

a. The service hot-water system in the baseline building design shall use the same energy source as the corresponding system in the proposed design and shall match the minimum efficiency requirements in 90.1 2013 Section 7.4.2 or Federal Regulation §430.32 [10], whichever is more stringent.
Where the energy source is electricity, the heating method shall be electrical resistance or heat pump, as required by the Federal Regulation §430.32

b. Where no service hot-water system exists or has been specified but the building will have service hot-water loads, the baseline and proposed design must be modeled with the same electric service water heating system(s) of type and efficiency based on 8.1 (a). For buildings that will have no service hot-water loads, no service hot-water heating shall be modeled.

c. Where a combined system has been specified to meet both space heating and service water heating loads, the baseline building system shall use separate systems meeting the minimum efficiency requirements applicable to each system individually.

d. For large, 24-hour-per-day facilities that meet the prescriptive criteria for use of condenser heat recovery systems described in Section 6.5.6.2, a system meeting the requirements of that section shall be included in the baseline building design regardless of the exceptions to Section 6.5.6.2. If a condenser heat recovery system meeting the requirements described in Section 6.5.6.2 cannot be modeled, the requirement for including such a system in the actual building shall be met as a prescriptive requirement in accordance with Section 6.5.6.2, and no heat-recovery system shall be included in the proposed or baseline building designs.

8.2 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].

8.3 Multifamily Buildings with Electric Resistance Storage Water Heaters

Multifamily buildings with electric resistance storage water heaters in the proposed design must meet the following requirements [9]:

- Energy factor (EF) of at least 0.95 (UEF ≥ 0.93),
- Hot water piping insulation of R-4 $ft^2h°F/Btu$ or better
- ENERGY STAR certified dishwashers and clothes washers
- WaterSense® certified bathroom faucets/aerators and showerheads, and kitchen faucets maximum flow of 2.0 gpm.

8.4 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.

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

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

Load Type	F_A*	R_A	Notes
Low flow faucets	Residential: 10% [12] Commercial: estimate	1-FR/MAF	FR = average flow rate of installed faucets (GPM); MAF= maximum allows flow rate based on 2015 International Plumbing Code [8] MAF=0.8 for private lavatories MAF=0.4 for public lavatories MAF=1.75 for other residential sinks (e.g. kitchen) MAF=3 for service sinks
Low flow showerheads	Residential: 54% [12] Commercial: estimate	1-FR/2.5	FR = average flow rate of installed showerheads (GPM); 2.5 GPM = From Table 604.3 [8]
Energy Star Appliances	$\frac{APPL_{BASE}}{HWD_{BASE}}$	WS	$APPL_{BASE}$ = Baseline water usage for the appliance from the Energy Star Calculator, in the same units as HWD_{BASE}; WS = % Water Savings from the Energy Star Calculator

*sum of all F_A values must not exceed 100%

9 References

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

[2] ANSI/ASHRAE/IESNA Standard 90.1-2013 User's Manual

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

[4] Connecticut's 2022 Program Savings Document, 19th Edition (2021)

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

[6] Guidelines for Integrated, Heat Pump Water Heaters in Multifamily Buildings July 2018

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

[8] 2015 International Plumbing Code https://codes.iccsafe.org/public/document/code/550/9793989

[9] ENERGY STAR Multifamily New Construction Program Simulation Guidelines – Appendix G 90.1 – 2016 Version 1, Revision 02, October 2020 https://www.energystar.gov/sites/default/files/asset/document/ENERGY_STAR_MFNC_Simulation_Guidelines_AppG2016_Version_1_Rev02_v2.pdf

[10] Federal Regulations §430.32 https://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8

[11] Mass Save Hourly Simulation Guidelines v2.2

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

[13] 90.1 Section C3.5.5.3 Schedules and Internal Loads, http://sspc901.ashraepcs.org/documents.php.

[14] PNNL 2013EndUseTables_2014jun20.xls for buildings compliant with 90.1 2013

Appendix A: Site EUI [kBtu/SF] by End Use in Commercial Buildings [14]*

	Interior Lighting	Exterior Lighting	SHW	Heating	Cooling	Fans	Pumps	Process & Plug	Total
Highrise Apt	3	2	13	12	4	7	1	13	54
Midrise Apt	3	1	12	11	3	6	0	14	50
Hospital	14	1	5	31	13	12	2	49	127
Large Hotel	7	2	17	14	8	7	1	35	90
Small Hotel	7	1	14	8	5	6	0	21	63
Large Office	6	1	1	9	9	4	1	42	74
Medium Office	6	2	1	8	4	1	0	14	36
Small Office	8	2	3	2	2	3	0	8	29
Outpatient Healthcare	12	3	3	24	19	9	0	47	116
Standalone Retail	19	4	4	19	7	13	0	7	73
Strip Mall	20	3	3	22	4	6	0	5	63
Primary School	9	1	2	15	5	6	0	20	57
Secondary School	8	1	3	4	5	5	0	14	40
Warehouse	6	2	0	10	0	0	0	2	22

*These values are for reference purposes only, modeled baseline EUIs for the program are not required to match these end use EUI values or be within any specific % margin of error with the exception that per Section 6.1.1 projects with a process and plug load site energy intensity more than 20% below the provided values must justify the related modeling assumptions in the report.

Appendix B: Commercial and Industrial Hours of Use and EFLH

Table B1 shows the typical effective lighting full load hours (EFLH) for different types of facilities without accounting for lighting controls such as occupancy sensors and daylighting. Table B2 includes adjustments to account for the reduced lighting runtime due to occupancy sensors, based on ASHRAE 90.1 2013 User's Manual. In addition, modeled lighting runtime will be reduced due to daylighting controls.

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

EFLH=Annual_Runtime x OS_Adjustment x Daylighting_Adjustment

Annual_Runtime from Table B1; OS_Adjustment from Table B2; Daylighting_Adjustment ~ 0.9

Table B1: Annual Runtime [4]

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

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

Table B2: Occupancy Sensor Adjustment (ASHRAE 90.1 2013 Users' Manual Tables G-D to G-L)

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

Appendix C: Chiller Performance Curves

Table C1: Path A Water-Cooled Chillers

Chiller Type	Pos Displacement	Centrifugal	Pos Displacement	Centrifugal	Pos Displacement	Centrifugal
Capacity	All	All	All	All	All	All
Keyword	Cap-fCHWT&ECT		EIR-fCHWT&ECT		EIR-fPLR&dT	
Curve Type	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic
a	0.446797	-0.497373	0.713992	1.153615	0.276804	0.279696
b	0.014742	-0.009561	-0.006193	-0.030679	0.270373	0.573757
c	0.000134	-0.000596	0.000149	0.000306	0.372745	0.256905
d	0.000440	0.043521	0.003066	0.006709	0.004819	-0.005807
e	-0.000015	-0.000584	0.000168	0.000053	-0.000156	0.000146
f	-0.000085	0.000960	-0.000267	-0.000093	0.002607	-0.003530

Table C2: Path B Water-Cooled Chillers

Chiller Type	Positive Displacement	Centrifugal			Positive Displacement	Centrifugal			Positive Displacement	Centrifugal		
Capacity	All	<300 ton	300-600 ton	>600 ton	All	<300 ton	300-600 ton	>600 ton	All	<300 ton	300-600 ton	>600 ton
Keyword	Cap-fCHWT&ECT				EIR-fCHWT&ECT				EIR-fPLR&dT			
Curve Type	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic	BiQuadratic
a	0.334128	0.180980	0.363958	-0.455204	0.766809	0.873114	0.974318	0.367023	-0.201206	0.009922	-0.036012	-0.089543
b	0.021015	0.031844	0.045022	0.031347	-0.024317	-0.025208	-0.004632	0.012466	1.093914	0.054002	0.557792	0.320911
c	-0.000102	-0.000154	-0.000274	-0.000057	0.000262	0.000369	0.000048	-0.000069	0.111286	0.918455	0.488242	0.739345
d	-0.001407	0.009566	-0.002028	0.020383	0.007411	0.018292	-0.002013	0.005934	0.004386	0.010597	0.003829	0.009538
e	-0.000029	-0.000135	-0.000088	-0.000153	0.000118	0.000047	0.000159	0.000082	0.000000	-0.000034	0.000037	0.000016
f	0.000071	-0.000053	-0.000012	-0.000127	-0.000182	-0.000358	-0.000212	-0.000227	-0.004460	-0.008770	-0.005296	-0.008207

Appendix D: Coincidence Factors for Parking Garage Lighting

Table D1: Parking Garage Lighting Coincidence Factors [4]

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