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# ANSI/ASHRAE/IES Standard 90.1-2010 Performance Rating Method Reference Manual

**May 2016**

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the U.S. Department of Energy  
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Pacific Northwest National Laboratory  
Richland, Washington 99352

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## Acronyms and Abbreviations

ACH	air changes per hour
AFUE	annual fuel utilization efficiency
AHRI	Air-Conditioning, Heating and Refrigeration Institute
AHU	air handling unit
ANSI	American National Standards Institute
ARI	Air-conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing Materials
BDL	building design language
C-factor	thermal conductance
CCF	centum cubic feet
CRRC	Cool Roof Rating Council
CFA	conditioned floor area
cfm	cubic feet per minute
CHP	combined heat and power
CHW	chilled water
COMNET	Commercial Energy Services Network
COP	coefficient of performance
DCV	demand controlled ventilation
DDC	dynamic demand control
DOAS	dedicated outdoor air system
DV	displacement ventilation
DOE	U.S. Department of Energy
DX	direct expansion
EA	effective aperture
$E_c$	combustion efficiency
EF	energy factor
EER	energy efficiency ratio
EFLH	equivalent full load hours
EIA	Energy Information Administration
EILP	exterior installed lighting power
EIR	energy input ratio
ERV	energy recovery ventilator
$E_t$	thermal efficiency
F-factor	heat transfer coefficient of a slab edge unit of perimeter length

FPLR	function of part load ratio
FT	function of temperature
HSPF	heating seasonal performance factor
HVAC	heating, ventilation, and air conditioning
HW	hot water
IES	Illuminating Engineering Society
ILPA	interior lighting power allowance
kBtu/hr	thousand British thermal units per hour
LPD	lighting power density
MBH	thousand British thermal units per hour
MCF	thousand cubic feet
MBtu	thousand British thermal units per hour
MJ	megajoule
MMBtu	million British thermal units per hour
NAECA	National Appliance Energy Conservation Act
NFRC	National Fenestration Rating Council
OA	outdoor air
OAT	outdoor air temperature
PAF	power adjustment factor
PFP	parallel fan powered
PIU	powered induction unit
PLF	part-load fraction
PNNL	Pacific Northwest National Laboratory
PSZ-AC	packaged single zone air conditioner
PTAC	packaged terminal air conditioner
PTHP	packaged terminal heat pump
PRM	Performance Rating Method
PVAV	packaged variable air volume
RCR	room cavity ratio
RDP	relative daylight potential
SAT	supply air temperature
SEER	seasonal energy efficiency ratio
SHGC	solar heat gain coefficient
SO	source orientation
SRR	skylight roof ratio
SSPC	Standing Standard Project Committee
TOU	time of use
U-factor	thermal transmittance

UFAD	underfloor air distribution system
UMLH	unmet load hours
VAV	variable air volume
VRP	ventilation rate procedure
VT	visible light transmittance
W	watt
w.c.	water column
WSHP	water source heat pump
WWR	window-to-wall ratio

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# 1.0 Overview

## 1.1 Purpose

This document is intended to be a reference manual for the Appendix G Performance Rating Method (PRM) of ANSI/ASHRAE/IES Standard 90.1-2010 (Standard 90.1-2010). The PRM is used to rate the energy efficiency of commercial and high-rise residential buildings with designs that exceed the requirements of Standard 90.1. The procedures and processes described in this manual are designed to provide consistency and accuracy by filling in gaps and providing additional details needed by users of the PRM. Note that this document has been created independently from ASHRAE and Standing Standard Project Committee (SSPC) 90.1 and is neither sanctioned nor approved by either of those entities.

Potential users of this manual include energy modelers, software developers, and implementers of “beyond code” energy programs. Energy modelers using ASHRAE Standard 90.1-2010 for beyond code programs can use this document as a reference manual for interpreting requirements of the PRM. Software developers of tools for automated creation of the baseline model can use this reference manual as a guideline for developing the rules for the baseline model. Requirements for software using the PRM are specified in Standard 90.1-2010, Appendix G, Section G2.2.

## 1.2 Organization

This document is organized into five chapters, as described below.

Chapter	Description
1.0 Overview	The purpose, organization, content, and intent of the manual (this chapter).
2.0 General Modeling Procedures	An overview of the modeling process, outlining the modeling rules and assumptions that are implemented in the same way for both the baseline building and the proposed design, and procedures for determining system types and equipment sizes.
3.0 Building Descriptors Reference	The acceptable range of inputs for the proposed design and a specification for the baseline building.
4.0 Energy Price Data	Process for defining state average and custom utility rates.
5.0 Reporting	Standard output reports required to be generated from a software tool to meet Standard 90.1-2010 PRM reporting requirements.

This document references COMNET (COMNET, 2011) for several appendices containing reference material that support definition of the baseline building.

## 1.3 Type of Project Submittal

The type of project could be any one of the following:

- New building
- Additions to an existing building
- Alterations of an existing building

## **1.4 Climate Zones**

In accordance to Section G2.3 of Standard 90.1-2010, the simulation program is required to perform the simulation using hourly values of climatic data, such as temperature and humidity from representative climatic data, for the site in which the proposed design is to be located.

For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the construction site. The selected weather data are required to be approved by the rating authority.

## 2.0 General Modeling Procedures

### 2.1 General Requirements for Data from the User

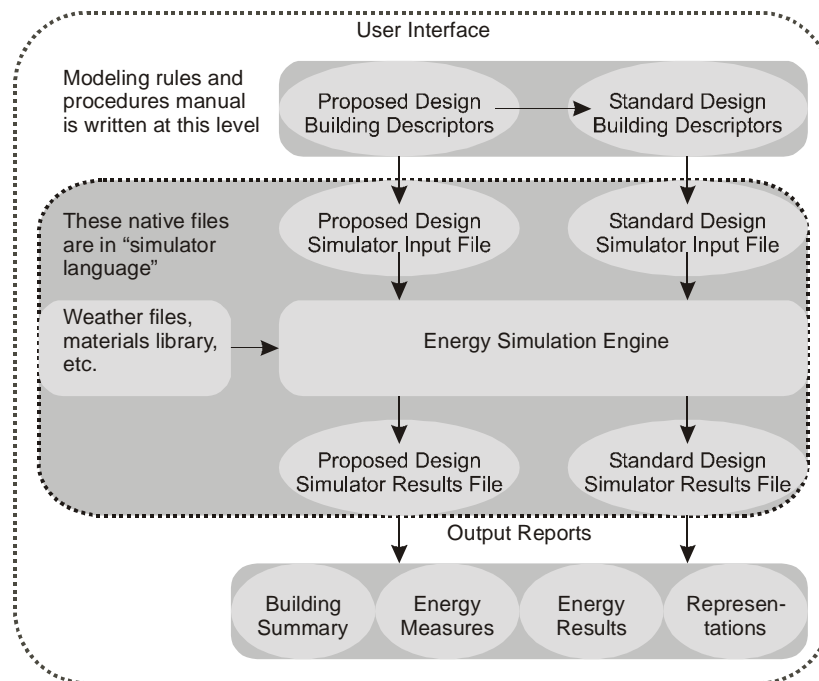
#### 2.1.1 General

This document lists the building descriptors that are used in the simulation. Users must provide valid data for all descriptors that do not have defaults specified and that apply to parts of the building that must be modeled.

#### 2.1.2 Definition of Building Descriptors

Building descriptors provide information about the proposed design and the baseline building. In this chapter, the building descriptors are discussed in the generic terms of engineering drawings and specifications. By using generic building descriptors, this manual avoids bias toward any particular energy simulation engine. The building descriptors in this chapter are compatible with commonly used simulation software.

Each energy simulation program has its own way of accepting building information. EnergyPlus, for instance, uses a comma delimited data file called an IDF file. DOE-2 uses BDL (building design language) to accept information. It is the software's responsibility to translate the generic terms used in this chapter into the "native language" of the simulation program. Figure 1 illustrates the flow of information.



**Figure 1.** Information Flow

### **2.1.3 Building Envelope Descriptions**

The user shall provide accurate descriptions for all building envelope assemblies including exterior walls, windows, doors, roofs, exterior floors, slab-on-grade floors, below grade walls, and below grade floors. The user shall provide data for all of the required descriptors listed in Section 3.4 of this document that correspond with these assemblies. However, the following exception applies:

- Exterior surfaces whose azimuth orientation and tilt differ by no more than 45° and are otherwise the same may be described as a single surface or described using multipliers. This specification would permit a circular form to be described as an octagon.

### **2.1.4 Treatment of Descriptors Not Fully Addressed by this Document**

The goal of this document is to provide input and rating rules covering a full range of energy-related features encountered in commercial buildings. However, this goal is unlikely to ever be achieved due to the many features that must be covered and the continuous evolution of building materials and technologies. Building systems or components not described in this document shall be modeled in the baseline building as meeting the mandatory and prescriptive requirements of Standard 90.1, Sections 5 through 10. If there are no mandatory or prescriptive requirements for a system or component not described in this document, it shall be modeled in the baseline building the same as in the proposed building.

When the simulation program does not model a design, material, or device of the proposed design, an exceptional calculation method shall be used if approved by the rating authority. Refer to Section 5.1.3.5 of this document for requirements related to reporting of savings from exceptional calculation methods.

### **2.1.5 Space Use Classification**

Space use classifications determine the default or prescribed occupant density, occupant activity level, receptacle power, service water heating, lighting load, area-based minimum outdoor ventilation air, daylighting setpoints, and operating schedules used in the analysis. Process loads and refrigeration loads are also provided for applicable space types. The user shall designate space use classifications that best match the uses for which the building or individual spaces within the building are being designed.

Space use classifications shall use either the building area method or space-by-space method, but the two types of categories shall not be combined within a single analysis. The building area method assigns assumptions based on average values within typical buildings of the designated type. The building area method is recommended when detailed space planning information is unavailable. More than one building area category may be used in a building if it is a mixed-use facility.

The space-by-space method uses the area categories in the baseline building, which were developed for lighting requirements. The space-by-space method requires area category entry of floor area and space use designations. The space-by-space method can be used whenever design information is available with the necessary detail.

The user may override the default assumptions for some building descriptors dependent on the space use classification with supporting documentation. Details are provided in Section 3.3.1 of this manual.

## 2.2 Thermal Blocks, HVAC Zones, and Space Functions

### 2.2.1 Definitions

A Heating Ventilation and Air Conditioning (HVAC) *zone* is a space or collection of spaces within a building having space conditioning requirements that are similar enough to be maintained with a single thermal controlling device. An HVAC zone is a thermal and not a geometric concept: spaces need not be contiguous to be combined within a single HVAC zone. However, daylighting requirements may prevent combining non-contiguous spaces into a single HVAC zone.

A *space* is a subcomponent of an HVAC zone that has values identified for lighting, outdoor air ventilation, occupancy, receptacle loads, and hot water consumption requirements. A space could be conditioned, semi-heated, or unconditioned. An HVAC zone may contain more than one space type.

Similar HVAC zones can be combined into a single thermal block provided they

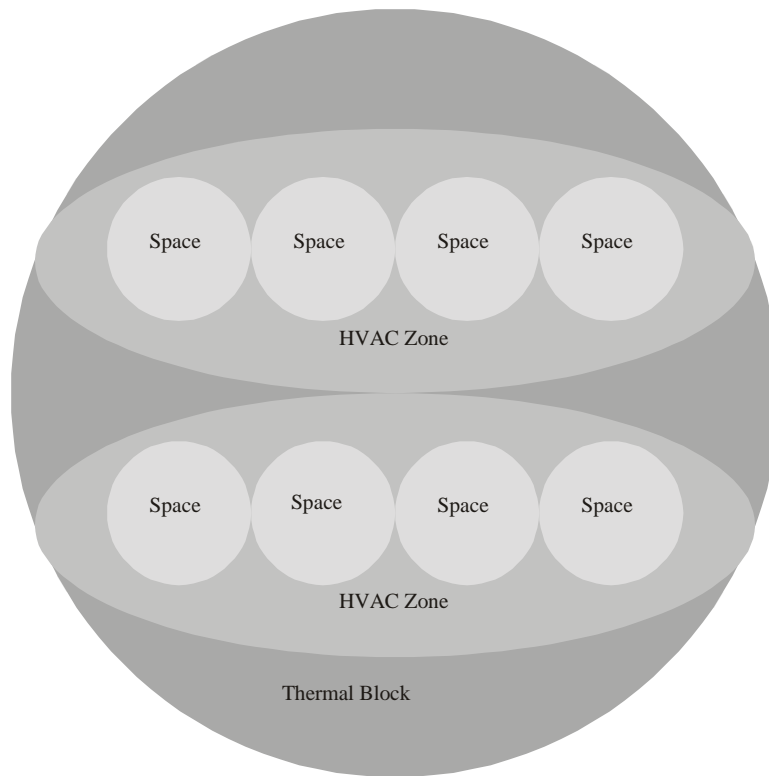
- a. are served by the same type of HVAC system
- b. consist of a similar distribution of space types
- c. have the same occupancy, equipment, lighting, and thermostat schedules and setpoints
- d. are adjacent to opaque walls only, or if adjacent to glazed walls, their orientation differs by less than 45°.

Residential spaces shall be modeled using at least one thermal block per dwelling unit, except that those units facing the same orientations may be combined into one thermal block. Corner units and units with roof or floor loads shall only be combined with units sharing these features.

Where the HVAC zones and systems have not yet been designed, thermal blocks shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following guidelines:

- a. Separate thermal blocks shall be assumed for interior and perimeter spaces. Interior spaces shall be those located greater than 15 ft from an exterior wall. Perimeter spaces shall be those located within 15 ft of an exterior wall.
- b. Separate thermal blocks shall be assumed for spaces adjacent to glazed exterior walls; a separate zone shall be provided for each orientation, except that orientations that differ by less than 45° may be considered the same orientation. Each zone shall include all floor area that is 15 ft or less from a glazed perimeter wall, except that floor area within 15 ft of glazed perimeter walls having more than one orientation shall be divided proportionately between zones.
- c. Separate thermal blocks shall be assumed for spaces having floors that are in contact with the ground or exposed to ambient conditions from zones that do not share these features.
- d. Separate thermal blocks shall be assumed for spaces having exterior ceiling or roof assemblies from zones that do not share these features.

Figure 2 shows the hierarchy of *space functions* and *HVAC zones*.



**Figure 2.** Hierarchy of Space, HVAC Zones, and Thermal Block

## 2.3 Software Modeling Requirements for Zones

### 2.3.1 Required Zone Modeling Capabilities

For use with the PRM of Standard 90.1-2010, software shall accept input for and be capable of modeling a minimum of 10 thermal zones, each with its own control of temperature. The simulation program shall be able to either (1) directly determine the proposed building performance and baseline building performance or (2) produce hourly reports of energy use by an energy source suitable for determining the proposed building performance and baseline building performance using a separate calculation engine. The simulation program shall be capable of performing design load calculations to determine required HVAC equipment capacities and air and water flow rates in accordance with generally accepted engineering standards and handbooks (for example, ASHRAE Handbook—Fundamentals).

### 2.3.2 Modeling Requirements for Unconditioned Spaces

An *unconditioned space* is an enclosed space that is neither directly nor indirectly conditioned. These are either (1) spaces that have neither a heating nor a cooling system or (2) spaces that are not cooled and have a heating system smaller than 3.4 Btu/h-ft<sup>2</sup> (10 W/m<sup>2</sup>). Examples include stairways, warehouses, unoccupied adjacent tenant spaces, and attached sunspaces. Ventilated parking garages, attics, and crawlspaces are defined by Standard 90.1-2010 as unenclosed spaces and are not considered as

unconditioned spaces. Modeling requirements for ventilated parking garages, attics, and crawlspaces are documented in the section below.

Unconditioned spaces shall be modeled if they are part of the permitted space. All applicable envelope information shall be specified in a similar manner to conditioned space. If the unconditioned space is not a part of the permitted space, the space may be explicitly modeled or its impact on the permitted space may be approximated by modeling the space as outdoor space and turning off solar gains to the demising wall that separates the permitted space from the adjacent unconditioned space. The baseline envelope of conditioned, semi-heated, or plenum space adjacent to any other “unconditioned” enclosed space would be semi-exterior. Fenestration on these surfaces would be included in the fenestration area calculations for semi-exterior surfaces. For unconditioned spaces that are explicitly modeled, all internal gains and operational loads (occupants, water heating, receptacle, lighting and process loads) shall be modeled as designed if known or as specified in COMNET Appendix B (COMNET, 2011) if unknown.

Return air plenums are considered indirectly conditioned spaces and shall be modeled with equipment, lighting power, and occupant loads at zero. Where recessed lights are used, heat from lights can be modeled to be transferred to the plenum.

Indirectly conditioned spaces can be either occupiable or not occupiable. For spaces that are not occupiable (such as plenums), lighting, receptacle, and occupant loads shall be zero. Indirectly conditioned zones will not have thermostat setpoint schedules. The allocation of zones into conditioned, indirectly-conditioned, and unconditioned zones shall be the same in baseline and proposed building models.

Unconditioned spaces may not be located in the same thermal zone as conditioned spaces. Conditioned spaces and indirectly conditioned spaces may be located in the same zone; when this occurs, the indirectly conditioned spaces will assume the space temperature schedule of the conditioned space.

### 2.3.3 Modeling Requirements for Parking Garages, Attics, and Crawlspace

Space types such as ventilated parking garage, attics, and crawlspace are defined by Standard 90.1-2010 as unenclosed spaces, and for the purposes of envelope requirements, envelope components adjacent to them are treated as exterior surfaces. Therefore, the following rules apply:

	Baseline	Proposed
Envelope	Demising Walls: The baseline envelope for spaces (conditioned, semi-heated, and plenum) adjacent to unenclosed spaces would be considered exterior and modeled with the baseline exterior envelope requirements.	As designed
	Exterior Walls: Surfaces separating unenclosed spaces from the exterior would be modeled to be the same as the proposed building.	As designed
	All Other Surfaces: All other surfaces, except those classified as ‘Semi-Exterior’ or ‘Exterior’ will be modeled to be the same as proposed.	As designed
	Window-to-Wall Ratio (WWR) Calculation for Unconditioned Space: As designed	As designed
	Skylight Roof Ratio (SRR) Calculation: Only exterior roofs are included in the calculation of skylight area.	As designed
Lighting	The lighting power allowance for attics and crawlspace will be 0 W/ft <sup>2</sup> for the baseline building unless the space is used as a storage or mechanical room, in which case the lighting power density (LPD) would be the value defined in Table 9.6.1 of Standard 90.1-2010. The lighting power allowance for parking garages is defined in Table 9.5.1 of Standard 90.1-2010.	As designed
HVAC System	Ventilated parking garages, attics, and crawlspace will always be excluded from the floor area used to determine the baseline HVAC system. If these unenclosed spaces have space conditioning or a mechanical ventilation system, the systems are assumed to be the same in both proposed and baseline models.	As designed

### 2.3.4 Space Use Classification Considerations

Section 2.1.5 of this document defines the two methods for assigning space functions for spaces within zones. If the building area method is used, each thermal zone must be assigned to one and only one complete building type. Space function inputs and how they translate to thermal zone and HVAC system analysis assumptions are defined by the following rules:

- **Schedule Group:** 12 different schedule groups are defined in COMNET Appendix C (COMNET, 2011) for the Standard 90.1-2010 PRM. Each schedule group defines building-specific hourly profiles for thermostat setpoints, HVAC system availability, occupancy, lighting, etc. The schedules of operation can be entered by the user or defaulted to the values defined in COMNET Appendix C (COMNET, 2011).
- **Space Functions:** Each building space is assigned one *space function*. Design internal loads and other space function input assumptions, including the assigned schedule group described above, can be



input by the user or can be defaulted to the values defined in COMNET Appendix B (COMNET, 2011).

- **HVAC Zones:** The makeup of spaces in thermal zones shall match the proposed building design. If HVAC zones have not yet been designed, they shall be determined in accordance with Section 3.2.1. Where HVAC zones include different space types, peak internal loads and other design inputs for the HVAC zone are determined by weight-averaging the space function design inputs by floor area. Thermal zone schedules are based on the schedule group of the predominant space function (by floor area) included in the thermal zone.

## 2.4 Unmet Load Hours

This manual uses the term *unmet load hours* (UMLH) as a criterion for sizing equipment, for qualifying natural ventilation systems, and for other purposes. The concept of UMLH applies to individual thermal zones but is summed for hours whenever any thermal zone in the building has unmet loads. For a thermal zone, it represents the number of hours during a year when the HVAC system serving the thermal zone is unable to maintain the setpoint temperatures for heating and/or cooling. During periods of unmet loads, the space temperature drifts above the cooling setpoint or below the heating setpoint. A thermal zone is considered to have an unmet load hour if the space temperature is below the heating temperature setpoint or above the cooling temperature setpoint by more than 50% of the temperature control throttling range. *Unmet load hours* for the *proposed design* or *baseline building designs* shall not exceed 300 (of the 8760 hours simulated). Alternatively, *unmet load hours* exceeding these limits may be accepted at the discretion of the *rating authority* provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads.

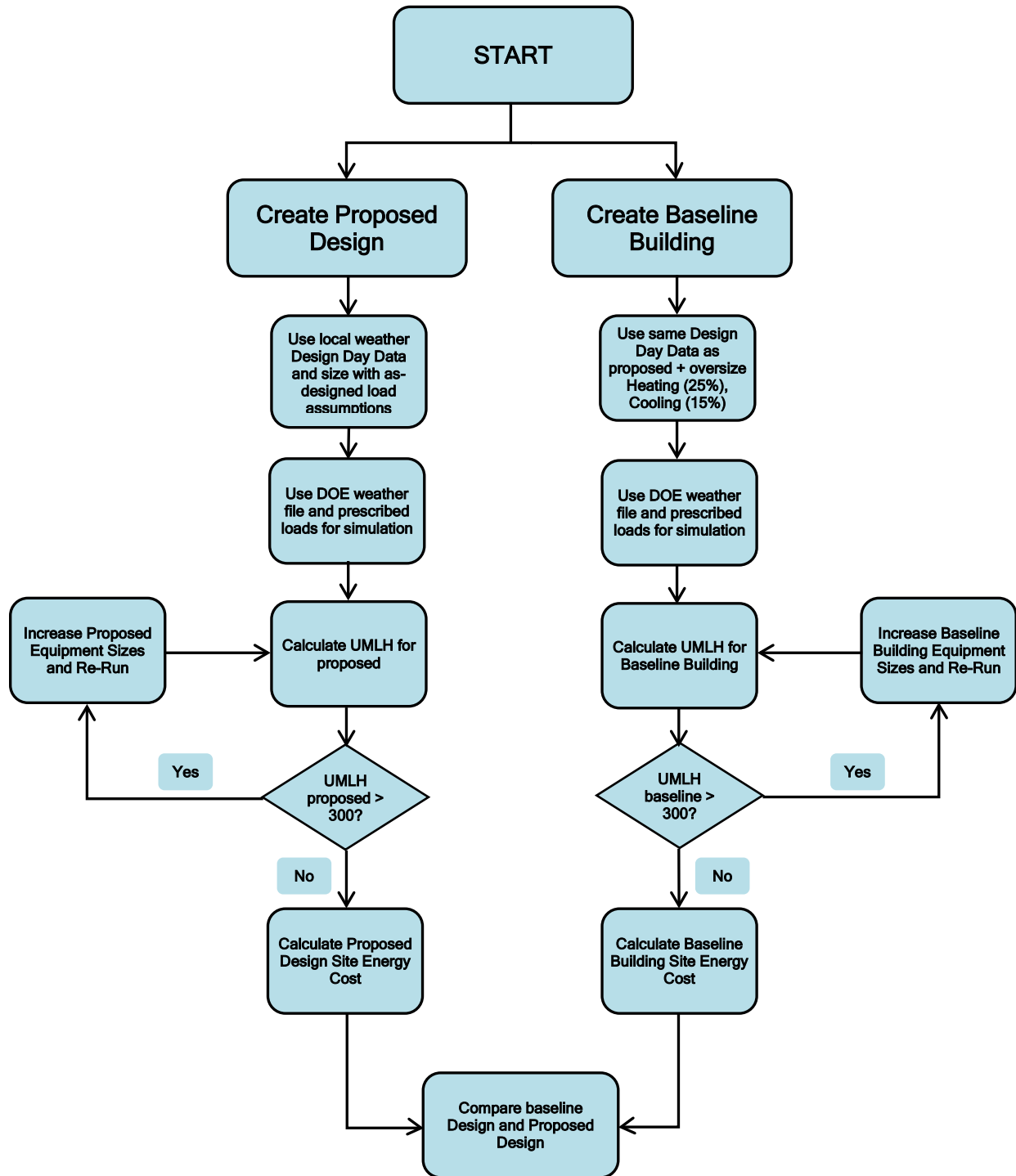
One hour with unmet loads in one or more thermal zones counts as a single unmet load hour for the building.

UMLH can occur because fans, airflows, coils, furnaces, air conditioners, or other equipment is undersized. UMLH can also occur due to user errors, including mismatches between the thermostat setpoint schedules and HVAC operating schedules, or from other input errors. The term, as used in this manual, only addresses undersized equipment. It is the user's responsibility to address other causes of UMLH in the proposed design. There can be many reasons for UMLH; the following list is a starting point to help identify the reasons:

- The thermostat schedules should agree with schedules of HVAC system operation, occupant schedules, miscellaneous equipment schedules, outside air ventilation schedules, and other schedules of operation that could affect the HVAC system's ability to meet loads in the thermal block.
- The inputs for internal gains, occupants, and outside air ventilation should be reasonable and consistent with the intended operation of the building.
- The simulated operation of controls can be examined to determine if primary or secondary heating or cooling equipment (pumps, coils, boilers, etc.) is activated. The control scheme for secondary equipment should be verified.

## 2.5 Calculation Procedures

The general calculation procedure is illustrated in Figure 3. The proposed design energy cost is compared to the baseline building.



**Figure 3.** Calculation Process for Standard 90.1-2010 Performance Using Performance Rating Method

1. The process begins with a detailed description of the proposed design. Information is required to be provided in enough detail to enable an estimate of annual energy use for a typical weather year. This information includes the building envelope, the lighting systems, the HVAC systems, the water heating systems, and other important energy-using systems. This collection of information is referred to in this manual as *building descriptors*. Details on the building descriptors are provided in Chapter 2.
2. If the values of occupant density, equipment power density, ventilation rates, and water heating loads for the proposed building are not known, defaults based on the building type shall be used. Each building descriptor shall be either a user-defined input or the default value for that input where a default is available.
3. The next step is to simulate the proposed design to determine how well the heating and cooling loads are being satisfied. The indicator is the total number of UMLH. Test the number of UMLH and proceed only if the hours are less than or equal to 300 for the year of the proposed design simulation.
4. If the UMLH are greater than 300 for the year, then the user adjusts the proposed building simulation model to reduce the UMLH to less than or equal to 300. There can be several reasons for a high number of UMLH, including incorrectly sized heating and/or cooling equipment, and incorrect schedules for fan availability of heating and cooling availability. It is up to the designer to adjust equipment sizes as necessary; in some cases adjusting the zone airflows may solve the unmet load issue. See Sections 2.4 and 2.6 for discussion on how UMLHs can be reduced.
5. If the UMLH are less than or equal to 300, then the final simulation is performed. If no changes are made in the model, the simulation from step 3 may be considered final. These calculations produce the results that are compared to the baseline building, which is calculated in steps 7 through 16.
6. The next steps relate to the creation of the baseline building model. The baseline building is created following the rules in this manual. It has the same floor area, number of floors, and spatial configuration as the proposed design; however, systems and components are modified to be in minimum compliance with Standard 90.1-2010 PRM. The HVAC systems for the baseline building are established according to rules in this manual and depend on the primary building activity (residential or non-residential), the floor area, and the number of stories. See Section 3.1.
7. Sizing calculations are performed for the baseline building, and heating equipment is oversized by 25% and cooling equipment by 15%. A sizing run is done for each of the four orientations, and system properties (efficiency, controls, etc.) are specified based on equipment size determined through the corresponding sizing run.
8. The baseline building is simulated to determine the number of UMLH. This is the same as the process performed for the proposed design in step 3.
9. The number of UMLH for the baseline building is then tested to see if they are greater than 300. This is unlikely since the heating and cooling equipment is oversized by 15% for cooling and 25% for heating in step 7.
10. If the UMLH are greater than 300, then steps need to be taken to reduce the unmet hours to less than or equal to 300. See Sections 2.4 and 2.6 for discussion on how UMLHs can be reduced.
11. Once the tests on UMLH are satisfied, the energy consumption of the baseline building is calculated. If the tests on unmet hours are satisfied the first time through, this step is the same as step 9.
12. Finally, the proposed design annual site energy cost and baseline building annual site energy cost are compared for performance rating.

## 2.6 HVAC Capacity Requirements and Sizing

To ensure that the simulated space-conditioning loads are adequately met, adequate capacity must be available in each component of the HVAC system (e.g., supply-airflow rates, cooling coils, chillers, and cooling towers). If any component of the system is incapable of adequate performance, the simulation program will report UMLH, which need to be addressed following the steps in Section 2.5. Adequate capacities are required in the simulations of both the proposed design and the baseline building. If the equipment capacity is not sufficient to meet demands, then UMLH are evaluated at the building level by looking at the UMLH for each thermal zone being modeled. One hour with unmet loads in one or more thermal zones counts as a single unmet load hour for the building. Therefore, the UMLH for the building will never be less than the worst thermal zone. The subsections below describe the procedures that shall be followed to ensure that both the baseline and proposed building models are simulated with adequate space-conditioning capacities.

### 2.6.1 Specifying HVAC Capacities for the Proposed Design

If loads are not met for more than 300 hours, the software shall require the user to change the proposed design building description to bring the UMLH equal to or below 300. This process might not be automated by the software, in which case the user is required to modify the design model to bring the UMLH within acceptable limits. Two tests must be met:

- Space loads must be satisfied and space temperatures in all zones must be maintained within one half of the throttling range (1°F with a 2°F throttling range; for simulation using EnergyPlus, the reporting tolerances would be set as 1°F to simulate a throttling range of 2°F) of the scheduled heating or cooling thermostat setpoints. This criterion may be exceeded for no more than 300 hours for a typical year.
- System loads must be satisfied: Plant equipment must have adequate capacity to satisfy the HVAC system loads. This criterion may be exceeded for no more than 300 hours for a typical year.

Equipment sizes for the proposed design shall be entered into the model by the energy analyst and shall agree with the equipment sizes specified in the construction documents. When the simulations of these actual systems indicate that specified space conditions are not being adequately maintained in one or more thermal zone(s), the user shall be prompted to modify equipment sizes or zones as necessary.

### 2.6.2 Sizing Equipment in the Baseline Building

Equipment in the baseline building is automatically oversized by the program (25% for heating and 15% for cooling). Equipment is sized using design day data and weather files for the building location. These are discussed in Section 3.1.5 of this manual.

Oversizing would be carried out at the zone level, where the sizing parameters would be applied to the zone design cooling airflow rates and zone loads. The system sizing calculations would sum the zone design airflow rates to obtain a system level airflow rate. The design conditions and the outdoor airflow rate would be used by the simulation program to calculate a design mixed air temperature. The temperature plus the design supply air temperatures (SATs) would allow for the calculation of system design heating and cooling capacities. The sizing option would be specified as “Coincident,” which

specifies that the central system airflow rate will be sized on the sum of the coincident zone airflow rates. There would be no oversizing factor specified at the system level or the central plant level.

If the automatic oversizing percentage is not sufficient to meet demands, then UMLH are evaluated at the building level by looking at the UMLH for each thermal zone being modeled. One hour with unmet loads in one or more thermal zones counts as a single unmet load hour for the building. Therefore, the UMLH for the building will never be less than the worst thermal zone.

1. The first step would be to determine if the UMLH are high (>300) for the proposed building design as well as the baseline building. If that is the case, the issue is usually related to fan operation, HVAC availability, and occupancy schedules where the HVAC system has an incorrectly specified schedule that makes it unavailable during occupied hours. Optimal start controls can also help eliminate UMLH during startup times. Since the same schedules are used for the baseline design, UMLH are seen in the baseline building as well. Other user inputs that could cause UMLH include incorrectly specified zone minimum airflows, which could result in unmet heating load hours. In this case, the software is required to notify the user and ask the user to verify schedules of operation. If a space is being conditioned via transfer air, it might be that the temperature of the transfer air is not sufficient to meet space conditioning requirements.
2. If this is not the case and UMLH are seen only with the baseline design, the software tool is required to incrementally increase system airflows and equipment capacities, following the steps outlined below.
3. In the case where UMLH for cooling are a bigger problem, the equipment in the baseline building model is resized by first increasing the design airflow of all zones with significant UMLH (greater than 150 for an individual zone) by 10%, increasing the design airflow of all zones with some UMLH (between 50 and 150) by 5%. Then, the equipment capacity for the system(s) serving the affected zones is increased to handle the increased zone loads. For the central plant, the chiller(s) and towers are resized proportionally to handle the increased system loads.
4. In the case where UMLH for heating are a bigger problem, the same procedure is followed, with zone airflows resized first, then heating secondary equipment capacity and then boiler capacity as necessary. The capacity of the boiler or furnace shall be increased in proportion to capacities of coils required to meet the increased airflows at the baseline supply air. For heat pumps, the capacity of the coil is increased so that the additional load is not met by auxiliary heat.

### **2.6.3 Handling Proposed Design with No HVAC Equipment**

Standard 90.1-2010 PRM doesn't address models with no HVAC system. Portions of a building with no heating or cooling system would be simulated to be unconditioned for the baseline as well.

### **2.6.4 Handling Semi-Heated Spaces for Proposed Design**

Semi-heated spaces are documented under Section 3.2.1 of this manual.

## **2.7 Ventilation Requirements**

Refer to Section 3.5.5.5 of this manual for ventilation requirements.

## 3.0 Building Descriptors Reference

### 3.1 Overview

This chapter specifies the rules that apply to the proposed design and to the baseline building for each building descriptor.

#### 3.1.1 HVAC System Map

The HVAC system in the baseline building depends on the primary building activity, the number of floors, conditioned floor area, and the energy source used for heating in the proposed design. Details about these systems are provided in subsequent sections.

For many of the building descriptors there is a one-to-one relationship between the proposed design and the baseline building; for example, every wall in the proposed design has a corresponding wall in the baseline building. However, for HVAC systems, this one-to-one relationship generally does not hold. The HVAC systems serving the proposed design and the baseline building may be completely different, each with different components, etc.

The HVAC system in the baseline building shall be selected from Table 1, HVAC System Map, and be based on building type, number of floors, conditioned floor area, and heating source. The selected system shall conform to the descriptions in Table 2, HVAC System Descriptions. For systems 1, 2, 3, 4, 9, and 10, each thermal zone shall be modeled with its own HVAC system. For systems 5, 6, 7, and 8, each floor shall be modeled with a separate HVAC system. Floors with identical thermal zones can be grouped for modeling purposes. The baseline building heating source is electric if the proposed building has electric heat. In the case of fossil fuel heating, the baseline building uses the same fuel as the proposed building. In the case of a fossil/electric hybrid, the baseline building uses fossil fuel for heating.

**Table 1. HVAC System Map**

Building Type	Fossil Fuel, Fossil/Electric Hybrid, and Purchased Heat	Electric and Other
Residential	System 1—Packaged Terminal Air Conditioner (PTAC)	System 2—Packaged Terminal Heat Pump (PTHP)
Nonresidential and 3 floors or less and <25,000 ft <sup>2</sup>	System 3—Packaged Single Zone-Air Conditioner (PSZ-AC)	System 4—Packaged Single Zone-Heat Pump (PSZ-HP)
Nonresidential and 4 or 5 floors and <25,000 ft <sup>2</sup> or 5 floors or less and 25,000 ft <sup>2</sup> to 150,000 ft <sup>2</sup>	System 5—Packaged Variable Air Volume (PVAV) with Reheat	System 6—PVAV with Parallel Fan Powered (PFP) Boxes
Nonresidential and more than 5 floors or >150,000 ft <sup>2</sup>	System 7—Variable Air Volume (VAV) with Reheat	System 8—VAV with PFP Boxes
Heated only storage	System 9—Heating and Ventilation	System 10—Heating and Ventilation

**Table 2. HVAC System Descriptions**

System No.	System Type	Fan Control	Cooling Type	Heating Type
1 – PTAC	Package terminal air conditioner	Constant volume	Direct expansion	Hot water fossil fuel boiler
2 – PTHP	Packaged terminal heat pump	Constant volume	Direct expansion	Electric heat pump
3 – PSZ AC	Packaged roof top air conditioner	Constant volume	Direct expansion	Fossil fuel furnace
4 – PSZ HP	Packaged roof top heat pump	Constant volume	Direct expansion	Electric heat pump
5 – PVAV Reheat	Packaged rooftop VAV with reheat	Variable volume	Direct expansion	Hot water fossil fuel boiler
6 – Packaged VAV with PFP Boxes	Packaged rooftop VAV with PFP boxes and reheat	Variable volume	Direct expansion	Electric resistance
7 – VAV with Reheat	Rooftop VAV with reheat	Variable volume	Chilled water	Hot water fossil fuel boiler
8 – VAV with PFP Boxes	VAV with parallel fan-powered boxes and reheat	Variable volume	Chilled water	Electric resistance
9 – Heating and Ventilation	Warm air furnace, gas fired	Constant volume	None	Fossil fuel furnace
10 – Heating and Ventilation	Warm air furnace, electric	Constant volume	None	Electric resistance

### 3.1.1.1 Exceptions to HVAC System Requirements

There are several important exceptions to the HVAC mapping rules that apply to spaces with unusual internal heat gains, different schedules, special pressurization requirements, or unique outside air needs. Where attributes make a building eligible for more than one baseline system type, use the predominant condition to determine the system type for the entire building except as noted in exceptions below.

#### a. Mixed Residential and Non-Residential Buildings:

The HVAC system is determined separately for buildings with both residential and non-residential spaces as well as different heating sources. Additional system type(s) are required to be used if the non-predominant conditions (for either use type or heating source) apply to more than 20,000 ft<sup>2</sup> of conditioned floor area.

Residential building types include dormitory, hotel, motel, and multifamily. Residential space types include guest rooms, living quarters, private living space, and sleeping quarters. Other building and space types including common areas associated with residential buildings are considered nonresidential.

#### b. Internal Loads:

This exception is triggered for spaces with peak thermal loads that differ by more than 10 Btu/h-ft<sup>2</sup> (31.5 W/m<sup>2</sup>) from the average of other spaces served by the system or when the weekly operating hours of the HVAC system are different by more than 40 hours; such as computer rooms or guard stations. The baseline system for such spaces would be system type 3 or 4, depending on the heating source for the main building.



Example: For a floor with spaces with peak thermal loads specified as 6 Btu/h-ft<sup>2</sup>, 14 Btu/h-ft<sup>2</sup>, 24 Btu/h-ft<sup>2</sup>, and 34 Btu/h-ft<sup>2</sup>, the average of all spaces is 19.5 Btu/h-ft<sup>2</sup>. Space 4 would be subject to the exception since its peak thermal loads differ by more than 10 Btu/h-ft<sup>2</sup> and the baseline system for this space would be system type 3 or 4.

When multiple proposed systems with schedules varying for less than 40 hours are combined into a single baseline system as a whole floor variable air volume (VAV), the baseline system fan schedule is defined to include the earliest start hour and latest end hour, so that all spaces are designated to have HVAC system availability. Section 3.6.2.2 has more details regarding HVAC availability.

c. Laboratory Spaces:

A separate baseline building system shall serve laboratory spaces or a group of laboratories with an exhaust system designed for 5,000 cubic feet per minute (cfm) or more of air movement. The baseline system serving laboratory spaces shall be system 5 (PVAV with hot water reheat) or 7 (VAV with hot water reheat). The PVAV or VAV system must be capable of reducing the exhaust and makeup air volume to 50% of design values during unoccupied periods. This exception requires VAV for both the supply fan and the exhaust system. Electric resistance heat would replace hydronic heat for baseline systems 5 and 7 when the proposed building uses all electric heat.

d. Kitchens:

Baseline building systems that serve kitchens with an exhaust hood airflow rate greater than 5,000 cfm shall use baseline system 5 or 7. System 7 will be used for baseline buildings with chilled water plants. Electric resistance heat would replace hydronic heat for baseline systems 5 and 7 when the proposed building uses all electric heat.

e. Heating only Systems:

Thermal zones designed with heating only systems serving storage rooms, stairwells, vestibules, electrical/mechanical rooms, and restrooms not exhausting or transferring air from mechanically cooled thermal zones in the proposed design shall use system type 9 or 10 in the baseline building design. If a space type doesn't fall in the list of "storage, stairwells, vestibules, electrical/mechanical rooms or restrooms," then, despite being heated only, it would be modeled as heated and cooled.

f. Baseline System 9, 10:

If the baseline HVAC system type is 9 or 10, all spaces that are mechanically cooled in the proposed building design shall be assigned to a separate baseline system determined by using the area and heating source of the mechanically cooled spaces.

These special systems serve just the spaces that trigger the exceptions. The rest of the building/floor is served by the baseline building HVAC system as indicated in Table 1.

### **3.1.1.2 Process for Determining the Baseline System**

This section provides guidance for determining the baseline HVAC system for a proposed design to address all requirements and exceptions specified in Section 3.1.1. Appendix A of this manual provides a flowchart for baseline HVAC system determination process.

1. **Step 1: Determine Predominant and Non-Predominant Occupancy Type**

Section 3.1.1.1, Exception (a) defines the baseline system rules for occupancy types. The occupancy type with greater conditioned floor area (CFA) is defined as the “predominant occupancy” and the other occupancy type is defined as the “non-predominant occupancy”. If the CFA of the non-predominant occupancy exceeds 20,000 ft<sup>2</sup>, a separate baseline system is to be defined for the non-predominant occupancy.

**Determine Predominant Occupancy Type**

IF,  $Area_{NonRes} > Area_{Res}$   
Then, Predominant Occupancy = "NonResidential"  
Else, Predominant Occupancy = "Residential"

Where,

$Area_{cond}$  = Total Conditioned Floor Area  
 $Area_{Res}$  = Total Residential Conditioned Floor Area  
 $Area_{NonRes}$  = Total Non-Residential Conditioned Floor Area

**Determine Occupancy Exception Area**

IF, Predominant Occupancy = "NonResidential"  
AND  $Area_{Res} > 20,000 \text{ ft}^2$   
THEN  $Area_{OccExc} = Area_{Res}$   
AND NonPredominantOccupancy = 'Residential'  
ELSE  $Area_{OccExc} = 0 \text{ ft}^2$   
IF, Predominant Occupancy = "Residential"  
AND  $Area_{NonRes} > 20,000 \text{ ft}^2$   
THEN  $Area_{OccExc} = Area_{NonRes}$   
AND NonPredominantOccupancy = 'NonResidential'  
ELSE  $Area_{OccExc} = 0 \text{ ft}^2$   
Where,  
 $Area_{OccExc}$  = Occupancy Exception Area

2. **Step 2: Determine Predominant Fuel Type**

For each predominant and non-predominant occupancy type, the fuel source exception area needs to be calculated by first determining the predominant fuel type and then calculating the fuel source exception area. The fuel source type serving the greater CFA is defined as the “predominant fuel source,” and if the CFA of the non-predominant fuel source is  $>20,000 \text{ ft}^2$ , it qualifies for the fuel source exception and a separate baseline system is defined for the fuel source exception area.

In scenarios where both gas and electricity are used as a heating source for the proposed system—for example, in the case of water loop heat pumps, which might be served by a gas-fired boiler, or a specific building with gas-fired dedicated outdoor air systems (DOAS) and all electric terminal units for heating—both electric and gas are counted toward the area served by the respective fuel type. Proposed building designs with systems like these are considered “hybrid” systems and map to the fossil-fuel baseline.

For Predominant Occupancy = “NonResidential”

IF,  $\text{Area}_{\text{NonResFF}} > \text{Area}_{\text{NonResElec}}$   
THEN Predominant Fuel Source = “Fossil Fuel”  
ELSE Predominant Fuel Source = “Electric”

For Predominant Occupancy = “Residential”

IF,  $\text{Area}_{\text{ResFF}} > \text{Area}_{\text{ResElec}}$   
THEN Predominant Fuel Source = “Fossil Fuel”  
ELSE Predominant Fuel Source = “Electric”

Where,

$\text{Area}_{\text{NonResFF}}$  = Non Residential Conditioned Floor Area with Fossil Fuel Heating  
 $\text{Area}_{\text{NonResElec}}$  = Non Residential Conditioned Floor Area with Electric Heating  
 $\text{Area}_{\text{ResFF}}$  = Residential Conditioned Floor Area with Fossil Fuel Heating  
 $\text{Area}_{\text{ResElec}}$  = Residential Conditioned Floor Area with Electric Heating

Determine Fuel Source Exception Area

IF, Predominant Occupancy = "NonResidential", Predominant Fuel Source = “Fossil Fuel”  
AND  $\text{Area}_{\text{NonResElec}} > 20,000 \text{ ft}^2$   
THEN,  $\text{Area}_{\text{FuelSrcExc}} = \text{Area}_{\text{NonResElec}}$   
ELSE,  $\text{Area}_{\text{FuelSrcExc}} = 0 \text{ ft}^2$   
  
IF, Predominant Occupancy = "NonResidential", Predominant Fuel Source = “Electric”

AND  $Area_{NonResFF} > 20,000 \text{ ft}^2$

THEN,  $Area_{FuelSrcExc} = Area_{NonResFF}$

ELSE,  $Area_{FuelSrcExc} = 0 \text{ ft}^2$

IF, Predominant Occupancy = "Residential", Predominant Fuel Source = "Fossil Fuel"

AND  $Area_{ResElec} > 20,000 \text{ ft}^2$

THEN,  $Area_{FuelSrcExc} = Area_{ResElec}$

ELSE,  $Area_{FuelSrcExc} = 0 \text{ ft}^2$

IF, Predominant Occupancy = "Residential", Predominant Fuel Source = "Electric"

AND  $Area_{ResFF} > 20,000 \text{ ft}^2$

THEN,  $Area_{FuelSrcExc} = Area_{ResFF}$

ELSE,  $Area_{FuelSrcExc} = 0 \text{ ft}^2$

Where,

$Area_{FuelSrcExc}$  = Fuel Source Exception Area

### 3. **Step 3: Determine Other Exception Area**

Spaces qualifying for heating only systems (Section 3.1.1.1, Exception (e)) or any other spaces with other process loads or schedule of operation exception (Section 3.1.1.1, Exception (b)) would be subtracted from the conditioned floor area for the predominant occupancy to determine the baseline system type; which would consequently be determined based on the calculated floor area and heating fuel type.

IF, Predominant Occupancy = "NonResidential"

Then,  $Area_{NonResFinal} = Area_{NONRES} - Area_{OccExc} - Area_{FuelSrcExc} - Area_{HeatOnlyStr}$

Where,

$Area_{NonResFinal}$  = Non-Residential Conditioned Floor Area used to determine Baseline HVAC System

Separate baseline systems are defined for the occupancy exception area, fuel source exception area, heated only storage area, and process loads/schedule of operation exception area.

#### Calculation of number of floors for a building:

- Calculation of number of floors based on occupancy type:
  - If a mixed residential/non-residential building does not have enough area of each (greater than 20,000 ft<sup>2</sup>) to qualify for additional system type, all floors should be counted as the predominant type.
  - If a mixed residential/non-residential building has enough area of each (greater than 20,000 ft<sup>2</sup>) to qualify for both residential and non-residential systems, then a mixed use floor should be counted in both. So, a five-story building with two floors of residential occupancy, two floors of non-residential occupancy, and one floor of both residential and non-residential occupancy (where area of each occupancy type is greater than 20,000 ft<sup>2</sup>) would be defined as three floors of residential occupancy and three floors non-residential occupancy.
- Calculation of number of floors for above-grade and below-grade floors:
  - Both above and below grade floors will be counted for the calculation of number of floors.
- Calculation of number of floors for partially conditioned floors:
  - A floor with any conditioned area should be counted as a floor. For example, an unconditioned below- or above-grade parking garage where only the elevator, lobbies, or stairwells are conditioned at each floor would also be counted as a floor.

#### Other example scenarios:

- If a building qualifies for two baseline HVAC systems in accordance with Section G3.1.1 exception (a) and both systems use hot-water boilers for heating; the same boiler(s) can serve both the residential and non-residential portions of the building.
- 90,000 ft<sup>2</sup> is conditioned by a VAV system with electric reheat, and 25,000 ft<sup>2</sup> is conditioned with packaged direct expansion (DX) systems with fossil fuel furnaces. In this case, the 90,000 ft<sup>2</sup> of area would be modeled with an electric heat source in the baseline case (System Type #6 - Packaged VAV with electric PFP boxes), and the 25,000 ft<sup>2</sup> of area would be modeled with a fossil fuel heat source in the baseline case (System Type #3 - Packaged single zone AC with fossil fuel furnace).
- 50,000 ft<sup>2</sup> is conditioned by water source heat pumps with a fossil fuel boiler, and 25,000 ft<sup>2</sup> is conditioned by electric heat pumps. In this case, the 50,000 ft<sup>2</sup> area would be modeled with a fossil fuel heat source in the baseline case (System Type #5 - Packaged VAV with hot water reheat), and the 25,000 ft<sup>2</sup> area would be modeled with an electric heat source in the Baseline Case (System Type #4 - Packaged single zone heat pump).

#### Purchased Heat:

For systems using purchased hot water or steam, the heating source shall be modeled as purchased hot water or steam in both the proposed and baseline building designs. Hot water or steam costs shall be based on actual utility rates, and on-site boilers, electric heat, and furnaces shall not be modeled in the baseline building design.

Purchased Chilled Water:

For systems using purchased chilled water, the cooling source shall be modeled as purchased chilled water in both the proposed and baseline building designs. Purchased chilled water costs shall be based on actual utility rates, and on-site chillers and DX equipment shall not be modeled in the baseline building design.

Baseline system requirements for proposed designs using purchased heat or chilled water for heating or cooling are mentioned in Table 3.

**Table 3.** Baseline Requirements for Purchased Heat and Purchased Chilled Water Systems

Proposed		Baseline System
Heating	Cooling	
Purchased heat	Chiller or DX	The baseline heating source shall be purchased heat. The baseline cooling source shall be based on the applicable cooling system from Table 1 and Table 2.
Boiler/electric resistance or gas furnace	Purchased chilled water	Table 1 and Table 2 shall be used to select the baseline HVAC system type, with the following modifications: <ul style="list-style-type: none"> <li>• Purchased chilled water shall be substituted for the cooling source in Table 2.</li> <li>• Systems 1 and 2 shall be constant volume fan coil units with fossil fuel boiler(s).</li> <li>• Systems 3 and 4 shall be constant volume single zone air handlers with fossil fuel furnace(s). Refer to Section 3.6.6 of this document for details.</li> <li>• System 7 shall be used in place of System 5. Refer to Section 3.7.1 of this document for details.</li> <li>• System 8 shall be used in place of System 6. Refer to Section 3.7.2 of this document for details.</li> </ul>
Purchased heat	Purchased chilled water	Table 1 and Table 2 shall be used to determine the baseline HVAC system type, with the following modifications: <ul style="list-style-type: none"> <li>• Purchased heat and purchased chilled water shall be substituted for the heating types and cooling types in Table 2.</li> <li>• System 1 will be constant volume fan coil units. Refer to Section 3.6.5.5 of this document for details on this system type.</li> <li>• System 3 will be a constant volume single zone air handler. Refer to Section 3.6.5.2 of this document for details.</li> <li>• System 7 will be used in place of System 5. Refer to Section 3.7.2 of this document for details.</li> </ul>

### 3.1.2 Organization of Information

Building descriptors are grouped under objects or building components. A wall or exterior surface (an object) would have multiple building descriptors dealing with its geometry, thermal performance, etc. Each building descriptor contains the following information.

<i>Building Descriptor Title</i>	
<i>Applicability</i>	Information on when the building descriptor applies to the proposed design

<i>Definition</i>	A definition for the building descriptor
<i>Units</i>	The units that are used to prescribe the building descriptor. A “List” indicates that a fixed set of choices applies and the user shall only be allowed to enter one of the values in the list.
<i>Input Restrictions</i>	Any restrictions on information that may be entered for the proposed design
<i>Baseline Building</i>	This defines the value for the “baseline building.” A value of “Same as proposed” indicates that the value of the building descriptor is the same as that for the proposed building. In many cases, the value may be fixed, or may be determined from a table lookup. In some cases the input may not be applicable.

### 3.1.3 General Information

#### ***Project Name***

<i>Applicability</i>	All projects
<i>Definition</i>	Name used for the project, if one is applicable
<i>Units</i>	No units
<i>Input Restrictions</i>	Input is optional for the proposed design
<i>Baseline Building</i>	Not applicable

#### ***Project Address***

<i>Applicability</i>	All projects
<i>Definition</i>	Street address, city, state, and zip code
<i>Units</i>	No units
<i>Input Restrictions</i>	Input is mandatory for the proposed design
<i>Baseline Building</i>	Not applicable

#### ***Project Owner***

<i>Applicability</i>	All projects
<i>Definition</i>	Owner(s) of the project or individual or organization for whom the building permit is sought. Information should include name, title, organization, email, and phone number.
<i>Units</i>	No units
<i>Input Restrictions</i>	Input is optional for the proposed design
<i>Baseline Building</i>	Not applicable

#### ***Architect***

<i>Applicability</i>	All projects
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<i>Definition</i>	Architect responsible for the building design. Information should include name, title, organization, email, and phone number.
<i>Units</i>	No units
<i>Input Restrictions</i>	Input is optional for the proposed design
<i>Baseline Building</i>	Not applicable

#### ***HVAC Engineer***

<i>Applicability</i>	All projects
<i>Definition</i>	HVAC engineer responsible for the building design. Information should include name, title, organization, email, and phone number.
<i>Units</i>	No units
<i>Input Restrictions</i>	Input is mandatory for the proposed design
<i>Baseline Building</i>	Not applicable

#### ***Lighting Engineer/Designer***

<i>Applicability</i>	All projects
<i>Definition</i>	Lighting engineer/designer responsible for the building design. Information should include name, title, organization, email, and phone number.
<i>Units</i>	Up to 50 alphanumeric characters
<i>Input Restrictions</i>	Input is mandatory for the proposed design
<i>Baseline Building</i>	Not applicable

#### ***Energy Modeler***

<i>Applicability</i>	All projects
<i>Definition</i>	Individual responsible for performing the analysis. Information should include name, title, organization, email, and phone number.
<i>Units</i>	Up to 50 alphanumeric characters
<i>Input Restrictions</i>	Input is mandatory for the proposed design
<i>Baseline Building</i>	Not applicable

#### ***Date***

<i>Applicability</i>	All projects
<i>Definition</i>	Date of completion of the analysis or the date of its most-recent revision
<i>Units</i>	Date format



*Input Restrictions* Input is mandatory for the proposed design

*Baseline Building* Not applicable

### 3.1.4 Building Model Classification

#### ***Building Classification for Lighting***

*Applicability* When the building area method is used instead of the space-by-space method of classifying lighting in the building

*Definition* The building type or principal activity. One of two available classification methods for identifying the function of the building or the functions of spaces within the building, which in turn determine lighting-related requirements for the baseline building. COMNET Appendix B (COMNET, 2011) lists the building classifications that are available under the building area method.

*Units* List: Choose a building activity from COMNET Appendix B (COMNET, 2011)

*Input Restrictions* For multi-use buildings, the building may be divided and a different building classification may be assigned to each part. Either the building area method or the space-by-space method must be used, but the two classification methods may not be mixed for lighting definitions within a single PRM run.

*Baseline Building* Same as proposed

### 3.1.5 Geographic and Climate Data

For the U.S. and U.S. territories, city, state, and county are required to determine climate data from the available data in Normative Appendices B and D of Standard 90.1-2010.

#### ***Zip Code***

*Applicability* All projects

*Definition* Postal designation

*Units* List

*Input Restrictions* None

*Baseline Building* Not applicable

#### ***Latitude***

*Applicability* All projects

*Definition* The latitude of the project site

*Units* Degrees (°)

*Input Restrictions* None

*Baseline Building* Same as proposed

### ***Longitude***

*Applicability* All projects

*Definition* The longitude of the project site

*Units* Degrees (°)

*Input Restrictions* None

*Baseline Building* Same as proposed

### ***Elevation***

*Applicability* All projects

*Definition* The height of the building site above sea level

*Units* Feet (ft)

*Input Restrictions* None

*Baseline Building* Same as proposed

### ***DOE Climate Zone***

*Applicability* All projects

*Definition* One of the 17 U.S. Department of Energy (DOE) climate zones and subzones

*Units* List

*Input Restrictions* None

*Baseline Building* Same as proposed

### ***Daylight Savings Time Observed***

*Applicability* All projects

*Definition* An indication that daylight savings time is observed. The schedules of operation are shifted by an hour twice a year and this affects solar gains, temperature, and other factors.

*Units* Boolean (True/False)

*Input Restrictions* True

*Baseline Building* True

**County**

<i>Applicability</i>	All projects
<i>Definition</i>	The county where the project is located
<i>Units</i>	List
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

**City**

<i>Applicability</i>	All projects
<i>Definition</i>	The city where the project is located
<i>Units</i>	List
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

**State**

<i>Applicability</i>	All projects
<i>Definition</i>	The state where the project is located
<i>Units</i>	List
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

**Design Day Data**

<i>Applicability</i>	All projects
<i>Definition</i>	A data structure indicating design day information used for the sizing of the proposed system. Note that this information may not necessarily match the information used in the annual simulation.
<i>Units</i>	Data structure: contains the following: Cooling Design Dry-Bulb (1%), Cooling Design Wet-Bulb (1%), Heating Design Temperature (99.6%)
<i>Input Restrictions</i>	Must match climate data in Standard 90.1-2010 Normative Appendix D
<i>Baseline Building</i>	Same as proposed

### **Weather File**

<i>Applicability</i>	All projects
<i>Definition</i>	The hourly (i.e., 8,760 hour per year) weather data to be used in performing the building energy simulations. Weather data must include outside dry-bulb temperature, outside wet-bulb temperature, atmospheric pressure, wind speed, wind direction, cloud amount, cloud type (or total horizontal solar and total direct normal solar), clearness number, ground temperature, humidity ratio, density of air, and specific enthalpy.
<i>Units</i>	Data file
<i>Input Restrictions</i>	The weather file selected shall be in the same climate zone as the proposed design. If multiple weather files exist for one climate zone, then the weather file closest in distance to the proposed design and in the same climate zone shall be used.
<i>Baseline Building</i>	Weather data shall be the same for both the proposed design and baseline building

### **Ground Reflectance**

<i>Applicability</i>	All projects
<i>Definition</i>	Ground reflectance affects daylighting calculations and solar gain. The reflectance can be specified as a constant for the entire period of the energy simulation or it may be scheduled, which might be appropriate to account for snow cover in the winter.
<i>Units</i>	Data structure: schedule, fraction
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Ground reflectance shall be the same for both the proposed design and the baseline building when it is specified to capture snow cover

### **Local Terrain**

<i>Applicability</i>	All projects
<i>Definition</i>	An indication of how the local terrain shields the building from the prevailing wind. Estimates of this effect are provided in the ASHRAE Handbook of Fundamentals.
<i>Units</i>	List: the list shall contain only the following choices:

Description	Exponent ( $\alpha$ )	Boundary layer thickness, $\delta$ (m)
Flat, open country	0.14	270
Rough, wooded country, Suburbs	0.22	370
Towns and cities	0.33	460
Ocean	0.10	210
Urban, industrial, forest	0.22	370

<i>Input Restrictions</i>	Weather data should be representative of the long-term conditions at the site
<i>Baseline Building</i>	The baseline building terrain should be equal to the proposed design

### 3.1.6 Site Characteristics

#### *Shading of Building Site*

<i>Applicability</i>	All projects
<i>Definition</i>	Shading of building fenestration, roofs, or walls by other structures, surrounding terrain, vegetation, and the building itself
<i>Units</i>	Data structure
<i>Input Restrictions</i>	The default is for the site to be unshaded. External shading from other buildings or other objects can be modeled for the Standard 90.1-2010 PRM. All elements whose effective height is greater than their distance from the proposed building and width facing the proposed building is greater than one-third of the proposed building are required to be accounted for in the analysis.
<i>Baseline Building</i>	The proposed design and baseline building are modeled with identical assumptions regarding shading of the building site. Refer to building descriptor 3.5.1 regarding requirements for self-shading for the baseline building.

### 3.1.7 Calendar

#### *Year for Analysis*

<i>Applicability</i>	All projects
<i>Definition</i>	The calendar year to be used for the annual energy simulations. This input determines the correspondence between days of the week and the days on which weather events on the weather tape occur and has no other impact.
<i>Units</i>	List: choose a year (other than a leap year)
<i>Input Restrictions</i>	Allow any year other than a leap year
<i>Baseline Building</i>	Same calendar year as the proposed design

### *Schedule of Holidays*

<i>Applicability</i>	All projects
<i>Definition</i>	A list of dates on which holidays are observed and on which holiday schedules are used in the simulations
<i>Units</i>	Data structure
<i>Input Restrictions</i>	The following 10 holidays represent the default set. When a holiday falls on a Saturday, the holiday is observed on the Friday preceding the Saturday. If the holiday falls on a Sunday, the holiday is observed on the following Monday. The default holidays can be modified or additional holidays can be defined.

New Year's Day	January 1
Martin Luther King Day	Third Monday in January
Presidents Day	Third Monday in February
Memorial Day	Last Monday in May
Independence Day	July 4
Labor Day	First Monday in September
Columbus Day	Second Monday in October
Veterans Day	November 11
Thanksgiving Day	Fourth Thursday in November
Christmas Day	December 25

*Baseline Building* The baseline building shall observe the same holidays specified for the proposed design

### **3.1.8 Simulation Control**

#### *Number of Timesteps*

<i>Applicability</i>	All projects
<i>Definition</i>	<p>The timestep object specifies the “basic” timestep for the simulation. The value entered here is the number of timesteps to use within an hour. Longer timesteps have lower values for number of timesteps per hour. For example, a value of 6 entered here directs the program to use a zone timestep of 10 minutes and a value of 60 means a 1-minute timestep. The user’s choice for number of timesteps per hour must be evenly divisible into 60; the allowable choices are 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60.</p> <p>If the model will include calculating the cost of electricity, then the user should be aware that many electric utility tariffs base charges on demand windows of a specified length of time. Demand windows are defined in Section 4.2 of this document. If the choice of number of timesteps per hour is not consistent with the demand window, then unexpected results may be obtained. For reasonable prediction of the maximum rates for electricity use in calculating demand charges, the length of the zone timestep needs to be consistent with the tariff’s demand window. The following table lists the values that are consistent with various demand windows.</p>

**Table 4.** Acceptable Timesteps for Demand Window Values

Demand Window	Applicable Number of Timesteps per Hour
Quarter Hour	4, 12, 20 or 60
Half Hour	2, 4, 6, 10, 12, 20, 30 or 60
Full Hour, Day, Week	Any

<i>Units</i>	None
<i>Input Restrictions</i>	Maximum of 1 hour. If demand window is specified to be less than 1 hour, the length of the zone timestep needs to be consistent with Table 4 to prevent inaccurate results.
<i>Baseline Building</i>	Same as proposed

## 3.2 HVAC Zones

An HVAC zone is a space or collection of spaces having similar space-conditioning requirements, the same heating and cooling setpoint, and is the basic thermal unit (or zone) used in modeling the building. An HVAC zone can include one or more spaces.

A thermal block is a virtual HVAC zone that consists of multiple actual HVAC zones that have similar characteristics. Section 2.2 of this document outlines the rules for defining HVAC zones and thermal blocks. Where HVAC zones have been combined into thermal blocks, the descriptors applicable to HVAC zones below also apply to thermal blocks.

### 3.2.1 General Information

#### *HVAC Zone Name*

<i>Applicability</i>	All projects
<i>Definition</i>	A unique identifier for the thermal zone consisting of 50 or fewer alphanumeric characters
<i>Units</i>	Text
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Not applicable

#### *HVAC Zone Description*

<i>Applicability</i>	All projects
<i>Definition</i>	A brief description of the HVAC zone that identifies the spaces that make up the HVAC zone or other descriptive information. The description should tie the HVAC zone to the building plans.
<i>Units</i>	Text
<i>Input Restrictions</i>	HVAC zones in the proposed building model shall match those in the proposed building

design, with each temperature control device defining a separate thermal zone.

Refer to Section 2.2 of this manual for guidance on how to define thermal blocks, HVAC zones, and spaces.

*Baseline Building* Same as proposed

**Space Conditioning Category**

*Applicability* All projects

*Definition* Designation of the space as a directly conditioned space, semi-heated, unconditioned, or plenum (i.e., unoccupied but partially conditioned as a consequence of its role as a path for returning air).

Conditioned Space: a space that has a heating and/or cooling system of sufficient size to maintain temperatures suitable for human comfort. Cooled space, heated space, and indirectly conditioned space are defined as follows:

- Cooled space: an enclosed space within a building that is cooled by a cooling system whose sensible output capacity exceeds 5 Btu/h·ft<sup>2</sup> of floor area.
- Heated space: an enclosed space within a building that is heated by a heating system whose output capacity relative to the floor area is greater than or equal to the criteria in Table 5.
- Indirectly conditioned space: an enclosed space within a building that is not a heated space or a cooled space, which is heated or cooled indirectly by being connected to adjacent space(s) provided:
  - The product of the U-factor(s) and surface area(s) of the space adjacent to connected space(s) exceeds the combined sum of the product of the U-factor(s) and surface area(s) of the space adjoining the outdoors, unconditioned spaces, and to or from semi-heated spaces (e.g., corridors) or
  - That air from heated or cooled spaces is intentionally transferred (naturally or mechanically) into the space at a rate exceeding 3 air changes per hour (ACH) (e.g., atria).

Semi-Heated Space: an enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h·ft<sup>2</sup> of floor area but is not a conditioned space.

Unconditioned space: an enclosed space within a building that is not a conditioned space or a semi-heated space.

**NOTE** : Crawlspace, attics, and parking garages with natural or mechanical ventilation are not considered enclosed spaces. Rules for unconditioned spaces, not considered enclosed, are documented in Section 2.3.3 of this document.

**Table 5.** Standard 90.1-2010 Heated Space Criteria

Heating Output (Btu/h·ft <sup>2</sup> )	Climate Zone
5	1 and 2
10	3
15	4 and 5
20	6 and 7
25	8



<i>Units</i>	List: Conditioned, Semi-heated, and Unconditioned
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed for all space types except when spaces are designated as semi-heated spaces in the proposed or baseline building. The criteria for a semi-heated space must be verified in both the Baseline Building and the proposed building.

For spaces in the proposed building, the following should be verified:

- The heating temperature setpoint is always < 60°F, and
- The proposed system capacity falls within the limits for a semi-heated space.

If these conditions are met, the spaces are designated as semi-heated for the proposed building, and baseline building sizing runs in accordance with Section 2.6.2 are carried out where the space in the baseline building is simulated with semi-heated envelope requirements to verify heating and cooling system capacity. If the heating system output capacity is greater than or equal to 3.4 Btu/h·ft<sup>2</sup> of floor area but less than the values in Table 5 and the cooling capacity is less than 5 Btu/h·ft<sup>2</sup>, then the space is considered semi-heated in the baseline building and the sizing run is complete. If the heating or cooling capacity falls outside the range of a semi-heated space, the space is considered a conditioned space and the baseline building sizing run is repeated with conditioned space envelope requirements.

#### ***HVAC Zone Type***

<i>Applicability</i>	All projects
<i>Definition</i>	Designation of the thermal zone as directly conditioned, semi-heated, indirectly conditioned (i.e., conditioned only by passive heating or cooling from an adjacent thermal zone), or plenum (i.e., unoccupied but partially conditioned as a consequence of its role as a path for returning air).  A thermal zone may include a single space or more than one space. Each thermal zone shall have a single temperature control device.
<i>Units</i>	List: Directly Conditioned, Indirectly Conditioned, Semi-Heated, Unconditioned or Plenum
<i>Input Restrictions</i>	The default thermal zone type is “directly conditioned”
<i>Baseline Building</i>	The descriptor is identical for the proposed design and baseline building

#### ***Occupancy Type***

<i>Applicability</i>	All projects
<i>Definition</i>	Separate exterior building envelope requirements are specified for each of three categories of conditioned space: (a) nonresidential conditioned space, (b) residential conditioned space, and (c) semi-heated space.  <ul style="list-style-type: none"> <li>• Non-residential space conditioning category: all occupancies other than residential.</li> <li>• Residential space conditioning categories: spaces in buildings used primarily for living</li> </ul>

and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/sorority houses, hostels, prisons, and fire stations.

- Semi-heated: spaces that meet the semi-heated space criteria.

<i>Units</i>	Text, unique
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed for all space types except semi-heated. A sizing run, with semi-heated envelope construction properties, would need to be done to determine heating capacity per unit area for the baseline building.

#### ***System Name***

<i>Applicability</i>	All projects
<i>Definition</i>	The name of the HVAC system that serves this thermal zone. The purpose of this building descriptor is to link the thermal zone to a system.
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	The baseline building may have a different system mapping if the baseline building has a different HVAC type than the proposed design. Baseline system types 5-8 are required to be one system per floor. This could result in different system names as well.

#### ***Floor Area***

<i>Applicability</i>	All projects
<i>Definition</i>	The gross floor area of a thermal zone, including walls and minor spaces for mechanical or electrical services such as chases not assigned to other thermal zones
<i>Units</i>	Square feet (ft <sup>2</sup> )
<i>Input Restrictions</i>	The floor area of the thermal zone is derived from the floor area of the individual spaces that make up the thermal zone
<i>Baseline Building</i>	Same as proposed

### **3.2.2 Interior Lighting**

Inputs for interior lighting are specified at the space level (see specification below). In those instances when thermal zones contain just one space, the inputs here will be identical to the inputs for the single space that is contained within the thermal zone.

For those instances when a thermal zone contains more than one space, the software shall either model the lighting separately for each space and sum energy consumption and heat gain for each timestep of the analysis or it must incorporate a procedure to sum inputs or calculate weighted averages such that

the lighting power used at the thermal zone level is equal to the combination of lighting power for each of the spaces contained in the thermal zone.

In some cases, combining lighting power at the space level into lighting power for the thermal zone may be challenging and would have to be done at the level of each timestep in the simulation. These cases include:

- a. A thermal zone that contains some spaces that have daylighting and others that do not
- b. A thermal zone that contains spaces with different schedules of operation
- c. A thermal zone that contains some spaces that have a schedule adjusted for lighting controls and other spaces that do not
- d. Combinations of the above

### **3.2.3 Receptacle Loads**

Inputs for receptacle and process loads are specified at the space level (see specification below). In those instances when thermal zones contain just one space, the inputs here will be identical to the inputs for the single space that is contained within the thermal zone.

For those instances when a thermal zone contains more than one space, the software shall either (1) model the receptacle and process loads separately for each space and sum energy consumption and heat gain for each timestep of the analysis or (2) incorporate a procedure to sum inputs or calculate weighted averages such that the receptacle and process loads used at the thermal zone level are equal to the combination of receptacle and process loads for each of the spaces contained in the thermal zone.

When the spaces contained in a thermal zone have different schedules, combining receptacle and process loads from the space level may be challenging and would have to be done at the level of each timestep in the simulation. See discussion above on lighting.

### **3.2.4 Occupants**

Inputs for occupant loads are specified at the space level (see specification below). In those instances when thermal zones contain just one space, the inputs here will be identical to the inputs for the single space that is contained within the thermal zone.

For those instances when a thermal zone contains more than one space, the software shall either (1) model the occupant loads separately for each space and the heat gain for each timestep of the analysis or (2) incorporate a procedure to sum inputs or calculate weighted averages such that the occupant loads used at the thermal zone level are equal to the combination of occupant loads for each of the spaces contained in the thermal zone.

When the spaces contained in a thermal zone have different occupant schedules, rolling up occupant loads from the space level may be challenging and would have to be done at the level of each timestep in the simulation.

Additionally, for occupants, outside air ventilation is potentially impacted when the Ventilation Rate Procedure (VRP) is used accordance with ASHRAE Standard 62.1-2010 or the IMC-2012, to determine system level ventilation rates. Demand controlled ventilation (DCV) can also affect the ventilation rates based on occupancy. Section 3.5.5.5 and Section 3.5.5.4 discuss the occupancy-based ventilation requirements for VRP and DCV controls.

### 3.2.5 Infiltration

<b>Infiltration Method</b>	
<i>Applicability</i>	All projects
<i>Definition</i>	Energy simulation programs have a variety of methods for modeling uncontrolled air leakage or infiltration. Some procedures use the effective leakage area, which is generally applicable for small residential-scale buildings. The component leakage method requires the user to specify the average leakage through the building envelope per unit area (ft <sup>2</sup> ). Other methods require the specification of a maximum rate, which is modified by a schedule.
<i>Units</i>	Square feet (ft <sup>2</sup> )
<i>Input Restrictions</i>	For Standard 90.1-2010, a fixed infiltration rate can be specified and calculated. <ul style="list-style-type: none"> <li>• As a leakage per area of exterior envelope, including the gross area of exterior walls, roofs, and exposed floors, but excluding slabs on grade and interior partitions.</li> <li>• A zone ACH input</li> </ul>
<i>Baseline Building</i>	The infiltration method used for the baseline building shall be the same as the proposed design

<b>Infiltration Data</b>	
<i>Applicability</i>	All projects
<i>Definition</i>	Information needed to characterize the infiltration rate in buildings. The required information will depend on the infiltration method selected above. For the effective leakage area method, typical inputs are leakage per exterior wall area in square feet or other suitable units and information to indicate the height of the building and how shielded the site is from wind pressures. Only zones with exterior wall area are assumed to be subject to infiltration.
<i>Units</i>	A <i>data structure</i> is required to define the effective leakage area model
<i>Input Restrictions</i>	Any reasonable inputs may be specified, consistent with the chosen infiltration modeling method. Acceptable ranges for inputs should be defined for each method supported by rating software. The peak infiltration rate of the building envelope (I75Pa) at a fixed building pressure differential of 0.3 in. H <sub>2</sub> O will be defaulted to 0.4 cfm/ft <sup>2</sup> exterior building enclosure area, unless a different value is provided by the user and approved by the rating authority.

$$Infiltration = I_{design} \cdot F_{schedule} \cdot \left( A + B \cdot |t_{zone} - t_{odb}| + C \cdot ws + D \cdot ws^2 \right)$$

Where:

$$Infiltration = \text{Zone infiltration airflow (m}^3\text{/s-m}^2\text{)}$$

$I_{design}$	= Design zone infiltration airflow (m <sup>3</sup> /s-m <sup>2</sup> )
$F_{schedule}$	= Fractional adjustment from a prescribed schedule, based on HVAC availability schedules in COMNET Appendix C (COMNET, 2011) (unit less)
$t_{zone}$	= Zone air temperature (°C)
$t_{odb}$	= Outdoor dry bulb temperature (°C)
$ws$	= Wind speed (m/s)
$A$	= Overall coefficient (unitless)
$B$	= Temperature coefficient (1/°C)
$C$	= Wind speed coefficient (s/m)
$D$	= Wind speed squared coefficient (s <sup>2</sup> /m <sup>2</sup> )

The DOE-2 Infiltration methodology coefficients would be used, where:

$$A = 0$$

$$B = 0$$

$$C = 0.224$$

$$D = 0$$

The air leakage rate of the building envelope ( $I_{75Pa}$ ), at a pressure differential of 0.3 in. H<sub>2</sub>O shall be converted to appropriate units for the simulation program using the following formula describing infiltration as a function of exterior wall area:

$$I_{EW} = 0.112 \times I_{75Pa} \times S/A_{EW}$$

$$I_{75Pa} = Q/S$$

Source: (ANSI/ASHRAE/IES, 2013)

Where:

$I_{75Pa}$  = Air leakage rate of the building envelope expressed in cfm/ft<sup>2</sup> at a fixed building pressure differential of 0.3 in. H<sub>2</sub>O, or 75 Pa

$Q$  = Volume of air in cfm flowing through the whole building envelope when subjected to an indoor/outdoor pressure differential of 0.3 in H<sub>2</sub>O or 1.57 PSF in accordance with ASTM E779

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

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

$A_{EW}$  = Total above-grade exterior wall area, ft<sup>2</sup>

**Baseline Building** Same as proposed. Infiltration modeling approach for the baseline building shall be identical to the proposed. The following aspects are required to be the same for baseline and proposed building models:

- The same methodology as defined in the section above

- Air leakage rate
- Adjustments for weather. The coefficients A, B, C, D will be same as designed. If not provided by user, they would be the same as the default values outlined above.
- Building operation in both the proposed design and the baseline design
- HVAC system operation, including strategies that are intended to positively pressurize the building

**NOTE:** If a value for  $I_{75Pa}$  or Q is provided by the user, the infiltration value would be flagged and reported by the software tool.

### ***Infiltration Schedule***

<i>Applicability</i>	When an infiltration method is used that requires the specification of a schedule
<i>Definition</i>	With the ACH method and other methods (see above), it may be necessary to specify a schedule that modifies the infiltration rate for each hour or time step of the simulation. Typically the schedule is either on or off, but it can also be fractional.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	The schedules for infiltration can be specified by the user or the default schedule can be used. The default infiltration schedule shall be set equal to 1 when the fan system is off, and 0.25 when the fan system is on. This is based on the assumption that when the fan system is on it brings the pressure of the interior space above the pressure of the exterior, and decreases the infiltration of outside air. When the fan system is off, interior pressure drops below exterior pressure and infiltration increases. Schedules other than the default shall be permitted to account for building ingress and egress.
<i>Baseline Building</i>	The infiltration schedule for the baseline building shall be the same as the proposed design

### **3.2.6 Natural Ventilation**

Natural ventilation may be modeled for a thermal zone in the proposed design when the following conditions are met:

- Outside air intake from natural ventilation systems shall not be less than the minimum required outdoor air ventilation rates during occupied times in the proposed building model.
  - Controls for cooling system operation and availability of natural ventilation are automatic.
  - Rating authority approves of the proposed procedure.
- **In the case when the thermal zone does not have a cooling system:** The thermal zone in the proposed design is modeled with no cooling when the natural ventilation system maintains temperature. For periods when the space temperature is greater than the cooling setpoint, a cooling system like the one for the baseline building is assumed to operate to maintain temperature. The fans in this simulated system cycle with loads. The corresponding thermal zone in the baseline building is not modeled with natural ventilation. The baseline building HVAC system, as defined in Standard 90.1-2010, Section G3.1.1 (Table 1 and Table 2 of this document), provides cooling to maintain thermostat setpoint.

- **In the case where the thermal zone has a cooling system:** In the case where the thermal zone has an installed cooling system, the fans are required to operate when natural ventilation is insufficient to meet cooling or outdoor air ventilation loads. The cooling system comes on when natural ventilation is insufficient to maintain the temperature setpoint.

In the baseline building, the fans are required to run constantly during occupied periods, and cycle with loads during unoccupied periods, same as the proposed building. The baseline building HVAC system, as defined in Standard 90.1-2010, Section G3.1.1 (Table 1 and Table 2 of this document), provides cooling to maintain thermostat setpoint.

The infiltration rate for the proposed building will be as designed. If natural ventilation is modeled as an increased infiltration rate, it will be specified through two inputs: “Infiltration through building envelope” and “Infiltration as a result of automatically controlled natural ventilation system”. Infiltration as a result of automatically controlled natural ventilation is not modeled for the baseline building.

Outputs for the proposed building with natural ventilation need to demonstrate that minimum outdoor air requirements are being met during all occupied hours. Refer to Section 5.1.3.3 of this document for requirements pertaining to buildings with natural ventilation.

#### *Natural Ventilation Method*

<i>Applicability</i>	All thermal zones with natural ventilation
<i>Definition</i>	The method used to model natural ventilation. The choices will depend to some extent on the capabilities of the energy simulation program. One procedure that could be used with most energy simulation programs would be to approximate the effect of natural ventilation by scheduling a high rate of infiltration when conditions are right. The schedule would typically be developed through computational fluid dynamic software or with other software that can estimate the cooling benefit of natural ventilation and relate it to climate so that the schedule can be developed.
<i>Units</i>	List: Choices depend on the capabilities of the energy simulation program
<i>Input Restrictions</i>	As designed. If natural ventilation is modeled as an increased infiltration rate, it shall be specified through two inputs: “Infiltration through building envelope” and “Infiltration as a result of Automatically Controlled Natural Ventilation System.”
<i>Baseline Building</i>	The baseline building is not modeled with natural ventilation. If natural ventilation is modeled as an increased infiltration rate in the proposed design, the component “Infiltration as a result of Automatically Controlled Natural Ventilation” is not modeled for the baseline building.  <b>NOTE:</b> If the effect of natural ventilation is approximated by scheduling a high rate of infiltration, additional documentation needs to be provided, supporting the calculation process.

### ***Airflow Rate***

<i>Applicability</i>	All projects with natural ventilation that use a method that requires the specification of an airflow rate
<i>Definition</i>	The rate of airflow through the thermal zone when the natural ventilation system is operating
<i>Units</i>	ACH or cfm
<i>Input Restrictions</i>	The airflow rate for the proposed design shall be determined using sound engineering methods, and supporting documentation shall be provided.  If not modeled directly by the simulation program, the exceptional calculation method shall be used, with proper documentation submitted.
<i>Baseline Building</i>	The baseline building is not modeled with natural ventilation

### ***Natural Ventilation Schedule***

<i>Applicability</i>	All projects with natural ventilation that use a method that requires a schedule
<i>Definition</i>	A schedule that modifies the airflow rate through the thermal zone dictates when natural ventilation is enabled
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	The schedule for the proposed design shall be determined using sound engineering methods and keyed to outdoor temperature and perhaps other conditions on the weather file used for the simulation
<i>Baseline Building</i>	The baseline building is not modeled with natural ventilation

### ***Minimum Indoor Temperature***

<i>Applicability</i>	All projects with natural ventilation or mixed mode ventilation with automatic controls
<i>Definition</i>	The minimum indoor temperature below which natural ventilation is disabled
<i>Units</i>	°F
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Maximum Indoor Temperature***

<i>Applicability</i>	All projects with natural ventilation or mixed mode ventilation with automatic controls
<i>Definition</i>	The maximum indoor temperature above which natural ventilation is disabled
<i>Units</i>	°F
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable



### ***Minimum Outdoor Temperature***

<i>Applicability</i>	All projects with natural ventilation or mixed mode ventilation with automatic controls
<i>Definition</i>	The minimum outdoor temperature below which natural ventilation is disabled
<i>Units</i>	°F
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Maximum Outdoor Temperature***

<i>Applicability</i>	All projects with natural ventilation or mixed mode ventilation with automatic controls
<i>Definition</i>	The maximum outdoor temperature above which natural ventilation is disabled
<i>Units</i>	°F
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

## **3.2.7 Thermal Mass**

This set of building descriptors characterize the thermal mass that is not explicitly captured by the definition of exterior surfaces and interior partitions.

### ***Thermal Response Characteristics***

<i>Applicability</i>	All projects
<i>Definition</i>	<p>This building descriptor only addresses the building's contents. Thermal mass associated with floors, interior walls, and other building envelope components is derived from the thermal properties and materials that make up these components. However, if interior partitions are not explicitly entered (see below) their effect may be captured with this input.</p> <p>The thermal capacitance of the building contents are typically specified in terms of the composite weight of the building contents in lb/ft<sup>2</sup> or absolute lb. In this instance, the software assumes an average specific heat for the contents. This input can also be specified as the mass of the contents multiplied by the specific heat of the contents. The latter method would be a summation, since each item may have a different specific heat.</p>
<i>Units</i>	lb/ft <sup>2</sup> or lb
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The interior thermal mass in the baseline building shall be the same as the proposed design

## ***Furniture and Contents***

<i>Applicability</i>	All projects
<i>Definition</i>	A specification of the mass and heat capacity of furniture and other elements in the interior of the building. This includes information about the coverage and weight of furniture in the space as well as how much of the floor is covered by furniture. The latter affects how much of the solar gain that enters the space is directed to the floor with delayed heat gain and how much becomes a more instantaneous load.
<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The interior thermal mass and modeling assumptions in the baseline building shall be the same as the proposed design.

### **3.3 Space Uses**

Each thermal zone discussed above may be subdivided into space uses. This section presents the building descriptors that relate to the space uses. Space uses and the defaults associated with them are listed in COMNET Appendix B (COMNET, 2011). Every thermal zone shall have at least one space, as defined in this section. Daylit spaces should generally be separately defined.

#### **3.3.1 General Information**

##### ***Space Function***

<i>Applicability</i>	All projects
<i>Definition</i>	<p>For identifying space type, either the building type or space type lighting classifications from Standard 90.1-2010, Section 9.5.1 or 9.6.1, shall be used.</p> <p>Usage shall be specified using the building type or space type lighting classifications in accordance with Standard 90.1-2010, Section 9.5.1 or 9.6.1. The user shall specify the space use classifications using either the building type or space type categories, but shall not combine the two types of categories. More than one building type category may be used in a building if it is a mixed-use facility. If space type categories are used, the user may simplify the placement of the various space types within the building model, provided that building-total areas for each space type are accurate.</p> <p>The allowed building types in building area method or space-by-space method are documented in COMNET Appendix B (COMNET, 2011). The building or space type determines the following baseline inputs:</p> <ul style="list-style-type: none"><li>• Number of Occupants (occupant density)</li><li>• Equipment Power Density</li><li>• Lighting Power Density</li><li>• Hot Water Load</li><li>• Ventilation Rate</li></ul>

- Schedules (Based on user input, else can be defaulted to COMNET Appendix C (COMNET, 2011))

When the space classification for a space is not known, the space is required to be classified as an office space.

<i>Units</i>	List
<i>Input Restrictions</i>	The space-by-space method is restricted to the common space types defined in Section 9 of Standard 90.1 and listed in COMNET Appendix B (COMNET, 2011)
<i>Baseline Building</i>	Same as proposed

### **Floor Area**

<i>Applicability</i>	All projects that use the space-by-space classification method (see above)
<i>Definition</i>	The floor area of the space. The area of the spaces that make up a thermal zone shall sum to the floor area of the thermal zone.
<i>Units</i>	Square feet (ft <sup>2</sup> )
<i>Input Restrictions</i>	Area shall be measured to the outside of exterior walls and to the center line of partitions
<i>Baseline Building</i>	Same as proposed

### **3.3.2 Occupants**

COMNET Appendix B (COMNET, 2011) provides space level information on occupancy, lighting, and plug load schedules, as well as occupant density, allowed LPD, and occupant heat gain.

#### **Number of Occupants**

<i>Applicability</i>	All projects
<i>Definition</i>	The number of persons in a space. The number of persons is modified by an hourly schedule (see below), which approaches but does not exceed 1.0. Therefore, the number of persons specified by the building descriptor is similar to design conditions as opposed to average occupancy.
<i>Units</i>	The number of persons may be specified in an absolute number, ft <sup>2</sup> /person, or persons/1000 ft <sup>2</sup>
<i>Input Restrictions</i>	The design occupancy is to be used when known. For cases where the design occupancy is not known, the number of occupants given by space function in COMNET Appendix B (COMNET, 2011) can be used.
<i>Baseline Building</i>	Same as proposed

### ***Occupant Heat Rate***

<i>Applicability</i>	All projects
<i>Definition</i>	The sensible and latent heat produced by each occupant in an hour. This depends on the activity level of the occupants and other factors. Heat produced by occupants must be removed by the air conditioning system as well as the outside air ventilation rate and can have a significant impact on energy consumption.
<i>Units</i>	Btu/h, specified separately for sensible and latent gains
<i>Input Restrictions</i>	The occupant heat rate is determined by the user and, if unknown, can use the values in COMNET Appendix B (COMNET, 2011)
<i>Baseline Building</i>	Same as proposed

### ***Occupancy Schedule***

<i>Applicability</i>	All projects
<i>Definition</i>	The occupancy schedule modifies the number of occupants to account for expected operational patterns in the building. The schedule adjusts the heat contribution from occupants to the space hourly to reflect time-dependent usage patterns. The occupancy schedule can also affect other factors such as outside air ventilation, depending on the control mechanisms specified.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	The actual occupancy schedule is to be used when known When actual schedules are not known, default values specified in COMNET Appendix C (COMNET, 2011) may be used
<i>Baseline Building</i>	Same as proposed

### **3.3.3 Interior Lighting**

The building descriptors in this section are provided for each lighting system. Typically, a space will have only one lighting system, but in some cases, it could have two or more. Examples include general and task lighting systems in offices or hotel multi-purpose rooms that have lighting systems for different functions. It may also be desirable to define different lighting systems for spaces that are daylit and those that are not. For building descriptors related to exterior lighting, see Section 3.8.3 of this document.

### **Lighting Classification Method**

<i>Applicability</i>	Each space in the building
<i>Definition</i>	<p>Indoor lighting power can be specified using the building area method, or the space-by-space method.</p> <p>Building area method can be used for building types listed in COMNET Appendix B (COMNET, 2011). The parking garage portion of the building shall be considered as a separate space. This method cannot be combined with other lighting classification methods described in this section.</p> <p>The space-by-space method can be used for all areas of the building with space types listed in COMNET Appendix B (COMNET, 2011). The procedure specified in Standard 90.1-2010, Section 9.6.1 should be followed while determining applicable space types.</p>
<i>Units</i>	List
<i>Input Restrictions</i>	<p>Only Building Area or Space-by-Space is allowed.</p> <p>If there is a parking garage in the building, the parking garage must be modeled as a separate building if the Building Area method is used.</p>
<i>Baseline Building</i>	Same as proposed

**Table 6.** Lighting Specification

Options: Lighting Classification Method	Building Area Method	Space-by-Space Method
Allowed combinations with other lighting classification methods	None	None
Allowed regulated lighting power types	Interior lighting power allowance (ILPA)	ILPA Additional lighting power
Allowed trade-offs	Trade-offs amongst building area types are permitted provided the total installed lighting power doesn't exceed the ILPA	Interior lighting power between spaces using space-by-space method

### **Regulated Interior Lighting Power**

<i>Applicability</i>	All projects
<i>Definition</i>	Total connected lighting power for all regulated interior lighting power. This includes the loads for lamps and ballasts. The total regulated interior lighting power is the sum of general lighting power and applicable additional lighting power.
<i>Units</i>	watts
<i>Input Restrictions</i>	Derived – not a user input. The proposed value is the sum of the proposed Interior Lighting Power and the proposed Additional Lighting Power.
<i>Baseline Building</i>	<p>For spaces without special task lighting, wall display lighting, or similar requirements, this input will be the same as the interior lighting power. See the interior lighting power building descriptor for details.</p> <p>With the space-by-space method, regulated interior lighting power for each space will be the</p>

sum of interior lighting power and allowed additional lighting power.

### ***Non-regulated Interior Lighting Power***

*Applicability* All projects

*Definition* This includes power for lighting equipment and applications exempt from LPD requirements. However, these exceptions apply only to lighting systems that are an addition to general lighting and are controlled by an independent control device.

Standard 90.1-2010, Section 9.1.1, exempts the following lighting systems from all requirements:

- a. Emergency lighting that is automatically off during normal building operation.
- b. Lighting within dwelling units.
- c. Lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation.
- d. Decorative gas lighting systems.
- e. Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments.
- f. Lighting that is integral to equipment or instrumentation and is installed by its manufacturer.
- g. Lighting specifically designed for use only during medical or dental procedures and lighting integral to medical equipment.
- h. Lighting integral to both open and glass-enclosed refrigerator and freezer cases.
- i. Lighting integral to food warming and food preparation equipment.
- j. Lighting for plant growth or maintenance.
- k. Lighting in spaces specifically designed for use by occupants with special lighting needs, including visual impairment and other medical and age-related issues.
- l. Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.
- m. Lighting in interior spaces that have been specifically designated as a registered interior historic landmark.
- n. Lighting that is an integral part of advertising or directional signage.
- o. Exit signs.
- p. Lighting that is for sale or lighting educational demonstration systems.
- q. Lighting for theatrical purposes, including performance stage and film and video production.
- r. Lighting for television broadcasting in sporting activity areas.
- s. Casino gaming areas.
- t. Furniture-mounted supplemental task lighting that is controlled by automatic shutoff and complies with the Additional Control requirements, Standard 90.1-2010, Section 9.4.1.6(d).

- u. Mirror lighting in dressing rooms and accent lighting in religious pulpit and choir areas.
- v. Parking garage transition lighting: Lighting for covered vehicle entrances and exits from buildings and parking structures that comply with Standard 90.1-2010, Section 9.4.1.3 – Parking Garage Lighting Control requirements of the code.

*Units* W/ft<sup>2</sup> or watts

*Input Restrictions* As designed. The non-regulated lighting power should be cross-referenced to the type of exception and to the construction documents. The default for non-regulated lighting power is zero.

*Baseline Building* The non-regulated interior lighting in the baseline building shall be the same as the proposed design.

### ***Interior Lighting Power Allowance***

*Applicability* All spaces or projects

*Definition* Interior lighting power allowance is the power used by installed electric lighting that provides a uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect as well as exclusive of daylighting

*Units* watts

*Input Restrictions* As designed. For spaces without special task lighting, wall display lighting, or similar requirements, this input will be the same as the regulated lighting power.

Trade-offs in interior lighting power are allowed between spaces all using the space-by-space method provided that the total installed interior lighting power does not exceed the ILPA.

*Baseline Building* With the building area classification method, ILPA is the product of the LPD for the building classification from COMNET Appendix B (COMNET, 2011) and the floor area of the space.

With the space-by-space method, ILPA is the sum of the product of the LPDs for the space types from COMNET Appendix B (COMNET, 2011) and the floor areas for the corresponding spaces.

### ***Additional Lighting Power: Retail Display Lighting Power***

*Applicability* All projects that have display lighting in retail spaces when using the space-by-space classification

*Definition* Display lighting is special lighting to highlight merchandise. To qualify for display lighting under these standards, the lighting must be separately controlled from the general lighting. ASHRAE Standard 90.1-2010 defines the following types of retail lighting:

- Retail Area Type 1: Includes all retail sales floor area that doesn't qualify for Type 2, 3, or 4. The additional allowance for this type is 0.6 W/ft<sup>2</sup>.
- Retail Area Type 2: Includes the sales floor area for vehicles, sporting goods, and small electronics. The allowance is 0.6 W/ft<sup>2</sup>.

- Retail Area Type 3: Includes sales floor area for the sale of furniture, clothing, cosmetics, and artwork. The allowance is 1.4 W/ft<sup>2</sup>.
- Retail Area Type 4: Includes sales floor area for jewelry, crystal, and china. The allowance is 2.5 W/ft<sup>2</sup>.

<i>Units</i>	W/ft <sup>2</sup>
<i>Input Restrictions</i>	As designed. The default for lighting power for retail display wattage is 0.0 watts. The user is required to specify the purpose for additional interior lighting power allowance through retail display lighting. These are then required to be classified in one of the four categories mentioned above.
<i>Baseline Building</i>	Baseline building lighting power is the lesser of proposed design power or the allowed power. The allowed lighting power is defined as the floor area of the retail display times the applicable allowances.

### ***Decorative Lighting***

<i>Applicability</i>	Projects that have decorative lighting and are rated using the space-by-space method
<i>Definition</i>	Decorative lighting includes wall sconces, chandeliers, and other decorative lighting that is provided for purposes other than illuminating visual tasks. Decorative lighting installed under this exception is required to have separate, automatic controls.
<i>Units</i>	W or W/ft <sup>2</sup>
<i>Input Restrictions</i>	As designed. The default for decorative lighting power is 0.0 watts. When using the space-by-space method, the user may input the power for qualifying decorative lighting using the decorative lighting power descriptor and cross-referencing the construction documents.
<i>Baseline Building</i>	Baseline building lighting power is the lesser of proposed design power or the allowed power. The allowed lighting power is defined as the floor area of the applicable space times the 1 W/ft <sup>2</sup> allowance.

### ***Additional Lighting Controls***

<i>Applicability</i>	All projects
<i>Definition</i>	<p>For automatic controls in addition to those required for minimum code compliance under Standard 90.1-2010, Section 9.4.1 (manual lighting controls, occupancy sensor controls), credit may be taken by reducing the connected lighting power or through modifications in lighting schedules used for the proposed building design. Power adjustment factors (PAFs) represent the percent reduction in lighting power that will approximate the effect of the control. Models account for such controls by multiplying the controlled watts by (1 – PAF).</p> <p>Eligible PAFs are defined in Standard 90.1-2010, Appendix G, Table G3.2 (see Table 7 below). Reduction in lighting power using the PAF method can be done only when the control is not required in Standard 90.1-2010, Section 9.4. Controls for which PAFs are eligible are listed in Table G3.2 of the ASHRAE Standards:</p> <ul style="list-style-type: none"> <li>• Occupancy sensing controls for spaces not listed in Standard 90.1-2010, Section 9.4.1.2, exception b.</li> </ul>



- Programmable timing controls for spaces not addressed by Standard 90.1-2010, Section 9.4.1.1.
- Occupancy sensor and programmable timing controls for spaces not listed in Standard 90.1-2010, Section 9.4.1.1 and Section 9.4.1.2, exception b.

**Table 7.** Power Adjustment Percentages for Automatic Lighting Controls

Automatic Control Device(s)	% Reduction
1. Programmable timing control	0%
2. Occupancy sensor	10%
3. Occupancy sensor and programmable timing control	10%

**NOTE:** Standard 90.1-2010, Appendix G, Table G3.2, specifies a separate set of PAFs for non-24-hour spaces, less than 5,000 ft<sup>2</sup>. Those requirements have not been included in this descriptor. Standard 90.1-2007, Section 9.4.1.1, does not require programmable timing control in spaces less than 5,000 ft<sup>2</sup>, a criterion that was removed in Standard 90.1-2010. However, the corresponding PAFs in Table G3.2 were not updated, hence the reference manual ignores the PAFs for this criterion

*Units* List: eligible control types (see above) linked to PAFs

*Input Restrictions* PAF shall be fixed for a given control and area type.

Standard 90.1-2010, Section 9.6.2.c, allows additional lighting power allowance for controls beyond the mandatory minimums in Section 9.4. These are ignored, and PAFs from Appendix G are used for controls above the mandatory minimum for PRM compliance.

If credit for additional controls is taken through modification in lighting schedules, then credible technical documentation needs to be provided to the rating authority supporting the variance in lighting schedules between the baseline and the proposed building model.

*Baseline Building* PAF is zero

### Room Geometry Adjustment

*Applicability* Projects using the space-by-space method

*Definition* Projects using the space-by-space method for compliance can increase the base LPD allowance based on the room cavity ratio (RCR), calculated as shown below. Base LPD can be increased if the calculated RCR is greater than the RCR threshold for that space type shown in Table 9.6.1. of the standard and COMNET Appendix B (COMNET, 2011).

$$H_{rch} = H_{lmh} - H_w$$

$$RCR = 2.5 \times H_{rch} \times L_{rpl} / A_R$$

Where:

$RCR$  = Room cavity ratio

$H_{rch}$  = Room cavity height (ft)

$L_{rpl}$  = Room perimeter length (ft)

$A_R$  = Room area (ft<sup>2</sup>)

$H_{lmh}$  = Luminaire mounting height (ft)

$H_w$  = Work-plane height (ft)

For corridor/transition spaces, this adjustment is allowed when the corridor is less than 8 ft wide, regardless of the RCR.

The LPD allowance for these spaces may be increased by the following amount:

$$LPD \text{ increase} = \text{Base space LPD} \times 0.20$$

Where:

*Base space LPD* = The applicable LPD from Table 9.6.1 of Standard 90.1-2010 and COMNET Appendix B (COMNET, 2011).

<i>Units</i>	List: space types and corresponding RCR
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	For each space type, if designed RCR is greater than the corresponding threshold specified in COMNET Appendix B (COMNET, 2011), increase the base LPD allowance by 20%.

#### ***Lighting Controls: Parking Garage Lighting Controls***

<i>Applicability</i>	All projects with parking garages
<i>Definition</i>	Lighting for parking garages shall comply with the following requirements: <ol style="list-style-type: none"><li>Comply with Section “Automatic Lighting Shutoff.”</li><li>Lighting shall be controlled by one or more devices that automatically reduce lighting power of each luminaire by a minimum of 30% for unoccupied spaces no larger than 3,600 ft<sup>2</sup>.</li><li>Separate controls for daylight transition zone.</li><li>For luminaires within 20 ft of any perimeter wall structure that has a net opening-to-wall ratio of at least 40% and no exterior obstructions within 20 ft, the power shall be automatically reduced in response to daylight.</li></ol> Exceptions: <ol style="list-style-type: none"><li>Daylight transition zones and ramps without parking are exempt from sections b and d above.</li><li>Applications using high-intensity discharge of 150 watts or less or induction lamps are exempt from section b above.</li></ol>
<i>Units</i>	List: <ul style="list-style-type: none"><li>Automatic lighting shutoff</li><li>30% reduction in lighting power at unoccupied times</li><li>Separate controls for daylight transition zone</li><li>Luminaires close to wall perimeter</li></ul>
<i>Input Restrictions</i>	All requirements in list above need to be met for parking garages
<i>Baseline Building</i>	Same as proposed.

However, with approval of the rating authority variations of the lighting schedules, or control sequences of the interior lighting, for parking garages modeled in the baseline building from those in the proposed design shall be allowed by the rating authority based upon documentation that the interior lighting installed in the proposed design represents a significant verifiable departure from documented conventional practice.

The burden of this documentation is to demonstrate that accepted conventional practice would result in different baseline building interior lighting from that installed in the proposed design. If baseline building interior lighting control loads differ from the proposed building, this input must be flagged and instructions given to provide the proper documentation.

**NOTE:** If parking garage interior lighting controls for the baseline building differ from the proposed design, this input would be flagged and reported in the compliance reports.

### ***Lighting Schedules***

<i>Applicability</i>	All projects
<i>Definition</i>	Schedule of operation for interior lighting power used to adjust the energy use of lighting systems hourly to reflect time-dependent patterns of lighting usage. Different schedules may be defined for different lighting circuits, depending on the capabilities of the software.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	Actual schedules are required to be used when available. For cases where design schedules are not available, an appropriate schedule from COMNET Appendix C (COMNET, 2011) may be used.
<i>Baseline Building</i>	The baseline building shall use the same lighting schedules as the proposed design

### ***Fixture Type***

<i>Applicability</i>	All interior lighting fixtures
<i>Definition</i>	The type of lighting fixture, which is used to determine the light heat gain distribution
<i>Units</i>	List: one of three choices: Recessed with Lens, Recessed/Downlight, Not in Ceiling
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	As designed

### ***Luminaire Type***

<i>Applicability</i>	All interior lighting fixtures
<i>Definition</i>	The type of lighting luminaire, which is used to determine the light heat gain distribution The dominant luminaire type determines the daylight dimming characteristics, when there is more than one type of luminaire in the space.
<i>Units</i>	List: Linear Fluorescent, CFL, Incandescent, LED, Metal Halide, Mercury Vapor, High Pressure Sodium
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	As designed

### ***Light Heat Gain Distribution***

<i>Applicability</i>	All projects
<i>Definition</i>	The distribution of the heat generated by the lighting system that is directed to the space, the plenum, the HVAC return air, or other locations. This input is a function of the luminaire type and location. Luminaires recessed into a return air plenum contribute more of their heat to the plenum or the return air stream if the plenum is used for return air, while pendant mounted fixtures hanging in the space contribute more of their heat to the space. Common luminaire type/space configurations are listed in Table 3, Chapter 18, 2009 ASHRAE Handbook of Fundamentals, summarized in Table 8 below. Typically the data will be linked to a list of common luminaire configurations similar to Table 8 so that the user chooses a luminaire type category and heat gain is automatically distributed to the appropriate locations.
<i>Units</i>	List (of luminaire types) or data structure consisting of a series of decimal fractions that assign heat gain to various locations
<i>Input Restrictions</i>	Default values listed in Table 8 shall be used as a default when the luminaire categories apply. Where lighting fixtures having different heat venting characteristics are used within a single space, the wattage weighted average heat-to-return-air fraction shall be used.  When lighting is entered through the LPD input, this value can be specified by the user for the proposed building.
<i>Baseline Building</i>	Same as proposed

**Table 8.** Light Heat Gain Parameters for Typical Operating Conditions (Based on Table 3, Chapter 18, 2009 ASHRAE Handbook – Fundamentals)

Luminaire	Lamp	Ducted/Direct Return		Plenum Return	
		Space Fraction	Radiative Fraction	Space Fraction	Radiative Fraction
Recessed with Lens	Fluorescent	1.00	0.67	0.45	0.67
Recessed/Downlight	Fluorescent	1.00	0.58	0.69	0.58
	CFL	1.00	0.97	0.20	0.97
	Incandescent	1.00	0.97	0.75	0.97

	LED	1.00	0.97	1.00	0.97
	Metal Halide	1.00	0.97	0.75	0.97
Not Recessed	All	1.00	0.54	1.00	0.54

In this table, the Space Fraction is the fraction of the lighting heat gain that goes to the space; the radiative fraction is the fraction of the heat gain to the space that is due to radiation, with the remaining heat gain to the space due to convection.

Hence:

Return Air Fraction = 1 – Space Fraction

Fraction Radiant = Space Fraction × Radiative Fraction

The ASHRAE Handbook of Fundamentals does not distinguish between the short wave and long wave portions of the radiant fraction. For implementation using EnergyPlus (USDOE 2015), 100% of the radiant fraction is assigned to the long wave property in the tool (Field:Fraction Radiant), and the short wave portion (Field:Fraction Visible) is left as default, which is zero.

In addition, the only difference in implementation for fraction radiant vs. fraction visible is that:

- For the long wave portion, the heat absorbed by room surfaces is calculated as the long wave radiation multiplied by the thermal absorptance of the room materials.
- For the short wave portion, the heat absorbed is the short wave radiation multiplied by the solar absorptance of the room materials. For most materials, these values are close, i.e., for gypsum board thermal absorptance = 0.9 and solar absorptance = 0.7.

### 3.3.4 Daylighting Control

This group of building descriptors is applicable for spaces that have daylighting controls or daylighting control requirements. Spaces that have daylighting should be defined separately from spaces that do not.

#### *Daylight Areas*

*Applicability* All daylighted spaces

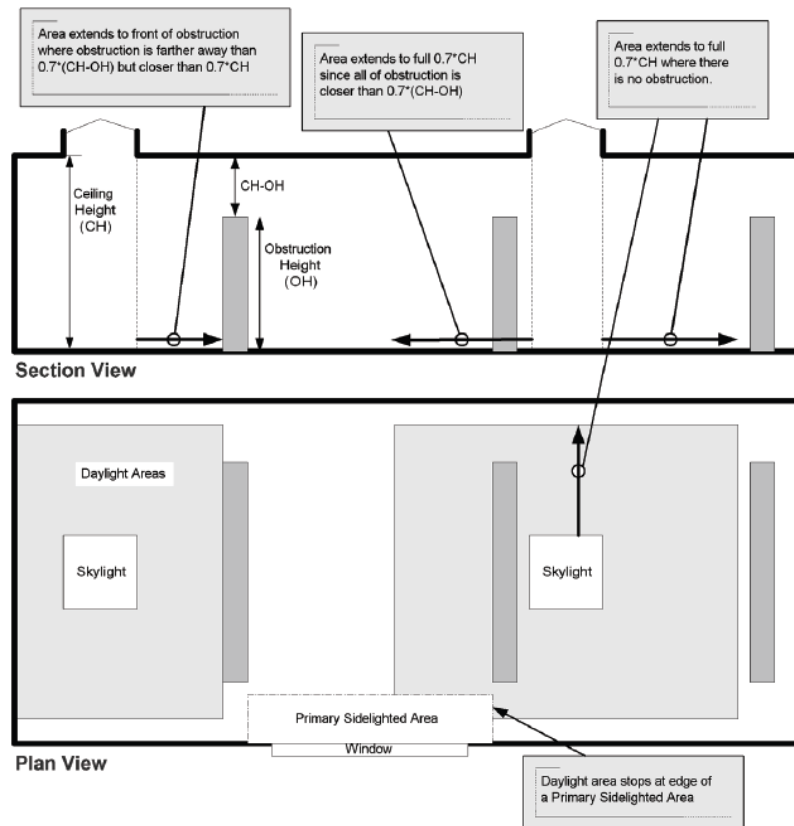
*Definition* The floor area that is daylighted. The skylit area is the portion of the floor area that gets daylighting from a skylight. Two types of sidelit daylighted areas are recognized. The primary daylighted area is the portion that is closest to the daylighting source and receives the most illumination. The secondary daylighted area is an area farther from the daylighting source, but still receives useful daylight.

Sidelighted Areas: The primary daylight area for sidelighting is the area near the window with a depth equal to the distance from the floor to the top of the window and a width equal to window width plus 2 ft on each side of the window opening. The secondary daylight area for sidelighting is the area beyond the primary daylighted area that extends a distance double the distance from the floor to the top of the window and a width equal to window width plus 2 ft on each side of the window opening. Area beyond any obstruction taller than 5 feet should not be included in the primary and secondary daylight area calculation.

**Toplighted Areas under Skylights:** The skylit area is a band around the skylight well that has a depth equal to the 70% of the ceiling height from the edge of the skylight well. The geometry of the skylit daylighted area will be the same as the geometry of the skylight. The process is to follow a path of light that emanates from the edge of the skylight well at an angle of 35° from plumb until it strikes an obstruction. The daylighted area stops at the vertical face of obstruction.

**Toplighted Areas under Roof Monitors:** The daylighted area extends vertically beneath the window and extends a distance equal to the roof monitor sill height, with a width equal to the width of the roof monitor. The size and shape of the roof monitor well is not a factor.

Overlapping daylight areas shall be counted once. If there is an overlap between toplighted, secondary and primary or skylit areas, the toplighted area under roof monitors takes precedence, followed by the toplighted area under skylights, followed by the primary sidelighted areas.



**Figure 4.** Toplighting and Sidelighting Areas

*Units*                      ft<sup>2</sup>

*Input Restrictions*      The daylight areas in a space are derived using other modeling inputs like dimensions of the fenestration and ceiling height of the space.

*Baseline Building*        The daylight areas in the Baseline Building are derived from other modeling inputs like dimensions of the fenestration and ceiling height of the space. Daylit area calculation in the

baseline building is done after the window-to-wall ratio (WWR) and skylight-to-roof ratio rules in Section 3.4.8 of this manual are applied.

### **Daylight Control Requirements**

*Applicability* All spaces with daylighting controls

*Definition* The conditions that determine if daylighting has to be modeled in a space.

Standard 90.1-2010 identifies several types of daylighted areas: primary sidelighted area, toplighted areas under roof monitors, toplighted areas under skylights, and secondary sidelighted areas. Automatic daylighting controls are mandatory for primary sidelighted and toplighted areas. Automatic daylighting controls are not mandatory for secondary sidelighted areas; however, they qualify for power allowance when qualifying automatic controls are installed.

**Primary Sidelighted Area Control Requirements:** An automatic daylighting control is required when the sum of primary sidelighted areas exceeds 250 ft<sup>2</sup>. The multilevel photocontrol shall reduce electric lighting in response to available daylight with at least one control step that is between 50% and 70% of design lighting power and another control step that is no greater than 35% (including off) of design power. Continuous dimming systems qualify as long as power is less than 35% at maximum dimming.

**Toplighted Area Control Requirements:** Automatic daylighting controls are required in daylighted areas under skylights or roof monitors exceeding 900 ft<sup>2</sup>. Interior general lighting is required to be controlled by at least one multilevel photocontrol. The multilevel photocontrol shall reduce electric lighting in response to available daylight with at least one control step that is between 50% and 70% of design lighting power and another control step that is no greater than 35% (including off) of design power.

*Units* List:

- When the combined primary sidelighted area in an enclosed space equals or exceeds 250 ft<sup>2</sup>: Primary Sidelighted, Secondary Sidelighted.
- When the total daylight area under rooftop monitors under enclosed space exceeds 900 ft<sup>2</sup>: Toplighted

*Input Restrictions* As designed. The proposed design needs to qualify for any one of the exceptions listed below if these mandatory controls are not present in the building.

Exceptions to Primary Sidelighted Area Requirements:

- a. Primary sidelighted areas where the tops of the existing adjacent structures are twice as high above the windows as their distance from the windows
- b. Primary sidelighted areas where the sidelighting effective aperture (EA) is less than 0.1 (10%)

Sidelight EA is defined as the relationship of daylight transmitted through windows to the primary sidelighted areas. The sidelighting EA is calculated according to the following formula:

$$\text{Sidelighting Effective Aperture} = \frac{\sum \text{Window Area} \times \text{Window VT}}{\text{Area of Primary Sidelit Area}}$$

- c. Retail spaces

Exceptions to Toplight Area Control Requirements:

- a. Daylighted areas under skylights where it is documented that existing adjacent structures or natural objects block direct beam sunlight for more than 1500 daytime hours per year between 8 a.m. and 4 p.m.
- b. Daylighted areas where the skylight EA is less than 0.006 (0.6%).

$$\text{Skylight Effective Aperture} = \frac{0.85 \times \text{Skylight Area} \times \text{Skylight VT} \times \text{WF}}{\text{Daylit Area under Skylight}}$$

Where:

*Skylight Area* = Total fenestration area of skylights

*Skylight VT* = Area weighted average visible transmittance of skylights as determined in accordance with Standard 90.1-2010, Section 5.8.2.6

*WF* = Area weighted average well factor, where well factor is 0.9 if light well depth is less than 2 ft, or 0.7 if light well depth is 2 ft or greater. Light well depth is measured vertically from the underside of the lowest point on the skylight glazing to the ceiling plane under the skylight.

- c. Buildings in climate zone 8 with daylight areas totaling less than 1,500 ft<sup>2</sup> in an enclosed space.

*Baseline Building* Daylighting controls are required in the baseline building for primary sidelighted and toplighted areas. Anything beyond the mandatory requirements is not added for the baseline building.

If proposed building qualifies for any one of the exceptions, then daylighting controls are not modeled for baseline building either.

***Installed General Lighting Power in the Primary and Toplight Daylit Zone***

<i>Applicability</i>	Daylighted spaces
<i>Definition</i>	The installed lighting power of general lighting in the primary and toplight daylit zone. The primary and toplight daylit zone shall be defined on the plans and be consistent with the definition of the primary and toplight daylit zone in the Standards. Note that a separate building descriptor, Fraction of Controlled Lighting, defines the fraction of the lighting power in the space that is controlled by daylighting.
<i>Units</i>	watts
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The Installed lighting power for the baseline building is the product of the primary daylit area and the LPD for general lighting in the space



### **Installed General Lighting Power in the Secondary Daylit Zone**

<i>Applicability</i>	Daylighted spaces
<i>Definition</i>	The installed lighting power of general lighting in the secondary daylit zone. The secondary daylit zone shall be defined on the plans and be consistent with the definition of the secondary daylit zone in the Standards. Note that a separate building descriptor, Fraction of Controlled Lighting, defines the fraction of the lighting power in the space that is controlled by daylighting.
<i>Units</i>	watts
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The installed lighting power for the baseline building is the product of the secondary daylit area and the LPD for general lighting in the space

### **Reference Position for Illuminance Calculations**

<i>Applicability</i>	All spaces or thermal zones, depending on which object is the primary container for daylighting controls
<i>Definition</i>	<p>The position of the two daylight reference points within the daylit space. Lighting maintained at or above the illuminance setpoint. Thus, for step switching controls, the combined daylight illuminance plus uncontrolled electric light illuminance at the reference position must be greater than the setpoint illuminance before the controlled lighting can be dimmed or tuned off for stepped controls. Similarly, dimming controls will be dimmed so that the combination of the daylight illuminance plus the controlled lighting illuminance is equal to the setpoint illuminance.</p> <p>Preliminary reference points for primary and secondary daylit areas are located at the farthest end of the daylit area aligned with the center of each window. For skylit area, the preliminary reference point is located at the center of the edge of the skylit area closest to the centroid of the space. In each case, the Z-coordinate of the reference position (elevation) shall be located 2.5 feet above the floor.</p> <p>Up to two final reference positions can be selected from among the preliminary reference positions identified in each space.</p>
<i>Units</i>	Data structure
<i>Input Restrictions</i>	<p>The user does not specify the reference position locations; reference positions are automatically calculated by the software based on the procedure outlined below. Preliminary reference positions are each assigned a relative daylight potential (RDP), which estimates the available illuminance at each position, and the final reference position selection is made based on the RDP.</p> <p><b>(RDP:</b> an estimate of daylight potential at a specific reference position. This is NOT used directly in the energy simulation, but is used to determine precedence for selecting the final reference points. The RDP is calculated as a function of EA, azimuth, illuminance setpoint, and the type (skylit, primary sidelit, or secondary sidelit) of the associated daylit zone. RDP is defined as:</p>

$$RDP = C_1 * EA_{dz} + C_2 * SO + C_3$$

Where:

C1, C2, and C2 are selected from the following table.

**Table 9.** Coefficients for Toplight, Sidelight Zones

Illuminance Setpoint	Skylit Daylit Zones			Primary Sidelit Daylit Zones			Secondary Sidelit Daylit Zones		
	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>
< 200 lux	3,927	0	3,051	1,805	-0.40	3,506	7,044	-3.32	1,167
≤ 1000 lux	12,046	0	-421	6,897	-7.22	475	1,512	-2.88	-22
> 1000 lux	5,900	0	-516	884	-5.85	823	212	-0.93	57

**Illuminance Setpoint:** this is defined by the user, and is entered by the user, subject to the limits specified in COMNET Appendix B (COMNET, 2011), determined from the space type.

**Source Orientation (SO):** the angle of the outward facing normal of the daylight source's parent surface projected onto a horizontal plane, expressed as degrees from south. This is not a user input but is calculated from the geometry of the parent surface. For skylights, the source orientation is not applicable. For vertical fenestration SO is defined:

$$SO = \text{AbsoluteValue}(180 - \text{Azimuth})$$

Where

Azimuth is defined as the azimuth of the parent object containing the fenestration associated with the preliminary reference point.

**Effective Aperture (EA):** for the purpose of this calculation, EA represents the effectiveness of all sources that illuminate a specific reference position in contributing to the daylight available to the associated daylit zone. In cases where daylit zones from multiple fenestration objects intersect, the EA of an individual daylit zone is adjusted to account for those intersections according to the following rules:

- For skylit and primary sidelit daylit zones, intersections with other skylit or primary sidelit daylit zones are considered.
- For secondary sidelit daylit zones, intersections with any toplit or sidelit (primary or secondary) daylit zones are considered.

Effective aperture is defined as follows:

$$EA_{dz} = ( VT_{fdz} * A_{fdz} + \sum(F_i * VT_i * A_i) ) / A_{dz}$$

Where: primary

$EA_{dz}$  is the combined EA of all daylight sources illuminating a specific daylit zone.

$VT_{fdz}$  is the user specified visible transmittance of the fenestration object directly associated with the daylit zone

$A_{fdz}$  is the area of the fenestration object directly associated with the daylit zone

$VT_i$  is the user specified visible transmittance of the fenestration object associated with each intersecting daylit zone

$A_i$  is the area of the fenestration object directly associated with each intersecting daylit zone

$F_i$  is the fraction of intersecting area between the daylit zone in question and each

intersecting daylight zone:

$$F_i = A_{intersection}/A_{dzi}$$

$A_{dzi}$  is the area of each intersecting daylight zone (including area that might fall outside a space or exterior boundary)

$A_{dz}$  is the area of the daylight zone (including area that might fall outside a space or exterior boundary).

**1. First Reference Position:**

Select the preliminary reference point with the highest RDP from amongst all preliminary reference points located within either top or primary sidelight daylight zones. If multiple reference points have identical RDPs, select the reference point geometrically closest to the centroid of the space.

**2. Second Reference Position:**

Select the preliminary reference point with the highest RDP from amongst all remaining preliminary reference points located within either top or primary sidelight daylight zones. If multiple reference points have identical RDPs, select the reference point geometrically closest to the centroid of the space.

*Baseline Building* Reference positions for the baseline design shall be selected using the same procedure as those selected for the proposed design.

### ***Daylight Illuminance Setpoint***

*Applicability* Daylit spaces

*Definition* The design illuminance for the daylit space for purposes of daylighting control

*Units* Footcandles

*Input Restrictions* As designed, but should be consistent with the visual tasks in the space and the recommendations of Illuminating Engineering Society of North America (IES)

*Baseline Building* The baseline illuminance setpoint is the same as the proposed setpoint.

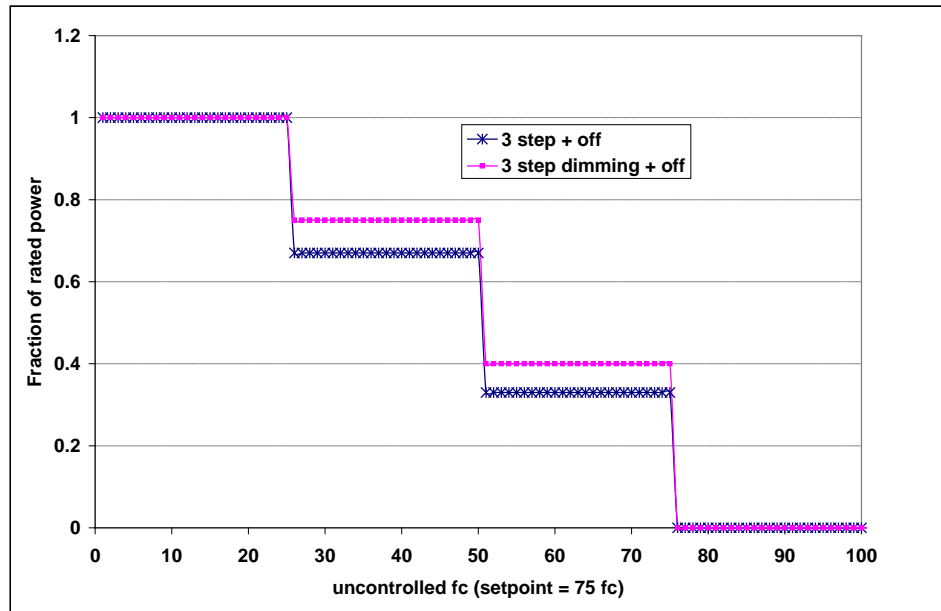
**NOTE:** If the user input for illumination setpoint is above or below the IESNA specification, the input should be flagged and reported in the compliance reports. The user needs to provide documentation in support of the illumination setpoint specified for the proposed design.

### ***Fraction of Zone Controlled Lighting***

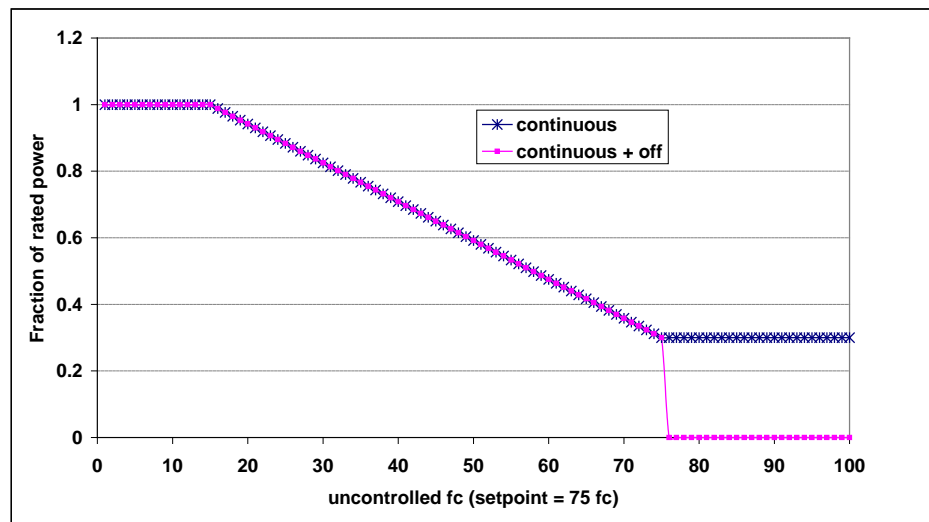
<i>Applicability</i>	Daylighted spaces
<i>Definition</i>	The fraction of the zone's floor area whose electric lighting is controlled by the daylight illuminance through all the first and second reference points
<i>Units</i>	Numeric: fraction
<i>Input Restrictions</i>	<p>If there is only one reference point, then a fraction equal to:</p> <p><math>1.0 - (\text{Fraction of Zone Controlled by First Reference Point})</math> is assumed to have no lighting control.</p> <p>If there are 2 reference points:</p> <p><math>1.0 - ([\text{Fraction of Zone Controlled by First Reference Point}] + [\text{Fraction of Zone Controlled by Second Reference Point}])</math> is assumed to have no lighting control.</p>
<i>Baseline Building</i>	<p>If there is only one reference point, then a fraction equal to:</p> <p><math>1.0 - (\text{Fraction of Zone Controlled by First Reference Point})</math> is assumed to have no lighting control.</p> <p>If there are 2 reference points:</p> <p><math>1.0 - ([\text{Fraction of Zone Controlled by First Reference Point}] + [\text{Fraction of Zone Controlled by Second Reference Point}])</math> is assumed to have no lighting control.</p>

### ***Daylighting Control Type***

<i>Applicability</i>	Daylighted spaces
<i>Definition</i>	<p>The type of control that is used to control the electric lighting in response to daylight available at the reference point. The options are as follows:</p> <ul style="list-style-type: none"><li>• Stepped dimming controls have discrete steps of light output, but typically the intermediate steps of light output are associated with higher levels of fraction of rated power. When the lights are fully off or fully on, the fraction of rated power matches the fraction of light output. Stepped controls vary the electric input power and lighting output power in discrete, equally spaced steps. See Figure 5.</li><li>• Continuous dimming controls have a fraction to rated power to fraction of rated output that is a linear interpolation of the minimum power fraction at the minimum dimming light fraction to rated power (power fraction = 1.0) at full light output. See Figure 6.</li><li>• Continuous dimming + off controls are the same as continuous dimming controls except that these controls can turn all the way off when none of the controlled light output is needed. See Figure 6.</li></ul>



**Figure 5.** Example Stepped Daylight Control



**Figure 6.** Example Dimming Daylight Control

*Units*

List (see above)

*Input Restrictions*

As designed. The minimum required daylighting controls must reduce lighting power to between 50% and 70% in the first step and to between 0% (off) and 35% in the second step. Continuous dimming systems qualify as long as power is less than 35% at maximum dimming.

*Baseline Building*

Stepped dimming as described above when daylighting controls are required in primary sidelighted and toplight daylight zones.

### ***Minimum Dimming Power Fraction***

<i>Applicability</i>	Daylighted spaces
<i>Definition</i>	The minimum power fraction when controlled lighting is fully dimmed. Minimum power fraction = (Minimum power) / (Full rated power).
<i>Units</i>	Numeric: fraction
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	35% of the maximum lighting power at minimum control step when daylighting controls are required in sidelighted and toplighted zones

### ***Minimum Dimming Light Fraction***

<i>Applicability</i>	Daylighted and dimming controls
<i>Definition</i>	Minimum light output of controlled lighting when fully dimmed. Minimum light fraction = (Minimum light output) / (Rated light output)
<i>Units</i>	Numeric: fraction
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable when the baseline building is required to have daylighting since stepped controls are used

### ***Number of Control Steps***

<i>Applicability</i>	Daylighted spaces that use stepped controls
<i>Definition</i>	Number of control steps. For step dimming, identifies number of steps that require fraction of rated light output and rated power fraction.
<i>Units</i>	Numeric: integer
<i>Input Restrictions</i>	As designed if stepped controls are provided in proposed building
<i>Baseline Building</i>	When daylighting controls are required in primary sidelighted and toplight daylight zones, three control steps shall be used: 100%, 67%, and 33% of maximum lighting power

## **3.3.5 Receptacle and Process Loads**

Receptacle loads contribute to heat gains in spaces and directly use energy.

### ***Receptacle Power***

<i>Applicability</i>	All building projects
<i>Definition</i>	Receptacle power is power for typical general service loads in the building. Receptacle power includes equipment loads normally served through electrical receptacles, such as office equipment and printers, but does not include either task lighting or equipment used for HVAC purposes. Receptacle power values are slightly higher than the largest hourly

receptacle load that is actually modeled because the receptacle power values are modified by the receptacle schedule, which approaches but does not exceed 1.0.

Receptacle power is considered an unregulated load; no credit has been offered in the past for savings; identical conditions have been required for both the baseline building and the proposed design. Offering credit for receptacle loads is very difficult due to their temporal nature and because information is not always available on what equipment would go in the building. Tenants also have the ability to plug and unplug devices at their leisure or switch them out for different equipment, adding to the difficulty of assigning credit for promised energy efficiency.

*Units*

Total power (W) for the space or power density (W/ft<sup>2</sup>)

Software shall also use the prescribed values below to specify the latent heat gain fraction and the radiative/convective heat gain split.

For software that specifies the fraction of the heat gain that is lost from the space, this fraction shall be prescribed at 0 unless the equipment is located under an exhaust hood.

*Input Restrictions*

Receptacle and process loads, such as those for office and other equipment, shall be estimated based on the building type or space type category. These loads shall be included in simulations of the building and shall be included when calculating the baseline building performance and proposed building performance.

For Standard 90.1-2010, receptacle loads in the proposed design may be calculated in one of two ways:

- a. As designed or assumed by the design team for loads calculation. Great care must be used in the application of space design receptacle loads from HVAC or electrical designers as these may not include appropriate diversity to represent annual operation.
- b. Standard 90.1-2010 recommended defaults may be used, in which case the same values must be used for the baseline building and there is no credit for reductions.

*Baseline Building*

The receptacle power in the baseline building shall be the same as the proposed design.

However, with approval of the rating authority, variations of the power requirements, schedules, or control sequences of the equipment modeled in the baseline building from those in the proposed design shall be allowed by the rating authority based upon documentation that the equipment installed in the proposed design represents a significant verifiable departure from documented conventional practice. The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building equipment different from that installed in the proposed design. If baseline building plug loads differ from the proposed building, this input must be flagged and instructions given to provide the proper documentation.

### ***Receptacle Heat Gain Fraction***

<i>Applicability</i>	All projects
<i>Definition</i>	<p>The electrical input to the equipment ultimately appears as heat that contributes to zone loads. This heat can be divided into four different fractions. These are given by the input fields:</p> <ul style="list-style-type: none"><li>• <b>Fraction Latent:</b> This field is a decimal number between 0.0 and 1.0 and is used to characterize the amount of latent heat given off by electric equipment in a zone. The number specified in this field will be multiplied by the total energy consumed by electric equipment to give the amount of latent energy produced by the electric equipment. This energy affects the moisture balance within the zone.</li><li>• <b>Fraction Radiant:</b> This field is a decimal number between 0.0 and 1.0 and is used to characterize the amount of long-wave radiant heat being given off by electric equipment in a zone. The number specified in this field will be multiplied by the total energy consumed by electric equipment to give the amount of long wavelength radiation gain from electric equipment in a zone.</li><li>• <b>Fraction Lost:</b> This field is a decimal number between 0.0 and 1.0 and is used to characterize the amount of “lost” heat being given off by electric equipment in a zone. The number specified in this field will be multiplied by the total energy consumed by electric equipment to give the amount of heat that is “lost” and does not impact the zone energy balances. This might correspond to electrical energy converted to mechanical work or heat that is vented to the atmosphere.</li><li>• <b>Fraction Convected:</b> This field is a decimal number between 0.0 and 1.0 and is used to characterize the fraction of the heat from electric equipment convected to the zone air.</li></ul> <p>The sum of all 4 of these fractions should be 1.</p>
<i>Units</i>	Data structure: fraction
<i>Input Restrictions</i>	<p>As designed. If not specified by the user, default values for receptacle power heat gain fractions will be used.</p> <p>Radiative = 0.20, Latent = 0.00, Convective = 0.80</p>
<i>Baseline Building</i>	Same as proposed

### ***Receptacle Schedule***

<i>Applicability</i>	All projects
<i>Definition</i>	Schedule for receptacle power loads used to adjust the intensity hourly to reflect time-dependent patterns of usage. These schedules are assumed to reflect the mandatory automatic receptacle control requirements.
<i>Units</i>	Data structure: schedule, fraction
<i>Input Restrictions</i>	Actual schedules shall be used when known. Standard 90.1-2010 default schedules (documented in COMNET Appendix B (COMNET, 2011)) can be used when design schedules are not available.
<i>Baseline Building</i>	Schedules for the baseline building shall be identical to those for the proposed design.



However, with approval of the rating authority variations of the power requirements, schedules, or control sequences of the equipment modeled in the baseline building from those in the proposed design shall be allowed based upon documentation that the equipment installed in the proposed design represents a significant verifiable departure from documented conventional practice.

The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building equipment different from that installed in the proposed design. If baseline building plug loads differ from the proposed building, this input must be flagged and instructions given to provide the proper documentation.

### ***Automatic Receptacle Control***

<i>Applicability</i>	All projects
<i>Definition</i>	Standard 90.1-2010 requires that 50% of all 125-volt 15- and 20-Ampere receptacle outlets in private offices, open offices, and computer classrooms be automatically switched off when the space is not occupied.  The switched outlets may be controlled by a programmable time clock (see Standard 90.1-2010, Section 9.4.1.1) or by occupancy sensors that indicate whether the space is occupied.
<i>Units</i>	No units
<i>Input Restrictions</i>	As designed, with a minimum of 50% of applicable receptacles conforming to this requirement. For proposed designs with more than 50% of receptacles controlled when space is not occupied, credit can be taken through the following process:  $RPC = (RC - 50\%) \times 10\%$ <p>Hence, the equipment power density for the proposed building =</p> $EPD_n = EPD_{ex} - (EPD_{ex} * RPC)$ <p>Where:</p> <p><i>RPC</i> = Receptacle power credit  <i>RC</i> = Percentage of receptacles controlled  <i>EPD<sub>n</sub></i> = New equipment power density (W/ft<sup>2</sup>)  <i>EPD<sub>ex</sub></i> = Existing equipment power density (W/ft<sup>2</sup>)</p>
<i>Baseline Building</i>	Same as proposed unless the proposed building controls more than 50% of the receptacles, in which case the baseline equipment schedule assumes that a minimum of 50% of receptacles are controlled. No additional reduction is taken.

### **3.3.6 Commercial Refrigeration Equipment**

Commercial refrigeration equipment includes the following:

- Walk-in refrigerators
- Walk-in freezers
- Refrigerated casework

Walk-in refrigerators and freezers typically have remote condensers. Some refrigerated casework has remote condensers, while some has a self-contained condenser built into the unit. Refrigerated casework with built-in condensers rejects heat directly to the space while remote condensers reject heat in the remote location, typically on the roof or behind the building.

Refrigerated casework can be further classified by the purpose, the type of doors and, when there are no doors, the configuration: horizontal, vertical, or semi-vertical. DOE has developed standards for refrigerated casework. Table 10 shows these classifications along with the standard level of performance, expressed in kWh/d, which depends on the class of equipment, the total display area, and the volume of the casework.

**Table 10.** DOE Requirements for Refrigerated Casework (kWh/d)

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

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

<sup>\*\*</sup> V is the volume of the case, as measured in ARI Standard 1200–2006, Appendix C.

<sup>\*\*\*</sup> Kilowatt hours per day.

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

DOE does not publish standard levels of performance for walk-in refrigerators and freezers. COMNET (COMNET, 2011) default values for these are given in Table 11. These values are expressed in W/ft<sup>2</sup> of refrigerator or freezer area. This power is assumed to occur continuously. Some walk-ins have glass display doors on one side so that products can be loaded from the back. Glass display doors increase the power requirements of walk-ins. Additional power is added when glass display doors are present. The total power for walk-in refrigerators and freezers is given in Equation (1).

$$P_{Walk-in} = (A_{Ref} \cdot PD_{Ref} + N_{Ref} \cdot D_{Ref}) + (A_{Frz} \cdot PD_{Frz} + N_{Frz} \cdot D_{Frz}) \quad (1)$$

Where:

- $P_{Walk-in}$  = The estimated power density for the walk-in refrigerator or freezer in (W)
- $A_{xxx}$  = The area of the walk-in refrigerator or freezer (ft<sup>2</sup>)
- $N_{xxx}$  = The number of glass display doors (unitless)
- $PD_{xxx}$  = The power density of the walk-in refrigerator or freezer taken from Table 11 (W/ft<sup>2</sup>)

$D_{xxx}$  = 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 11.** Default Power for Walk-In Refrigerators and Freezers (W/ft<sup>2</sup>)

Floor Area	Refrigerator	Freezer
100 ft <sup>2</sup> or less	8.0	16.0
101 ft <sup>2</sup> to 250 ft <sup>2</sup>	6.0	12.0
251 ft <sup>2</sup> to 450 ft <sup>2</sup>	5.0	9.5
451 ft <sup>2</sup> to 650 ft <sup>2</sup>	4.5	8.0
651 ft <sup>2</sup> to 800 ft <sup>2</sup>	4.0	7.0
801 ft <sup>2</sup> to 1,000 ft <sup>2</sup>	3.5	6.5
More than 1,000 ft <sup>2</sup>	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.

### **Refrigeration Modeling Method**

<i>Applicability</i>	All buildings that have commercial refrigeration for cold storage or display
<i>Definition</i>	<p>The method used to estimate refrigeration energy and to model the thermal interaction with the space where casework is located. Two methods are included in this manual:</p> <ul style="list-style-type: none"> <li>• COMNET defaults. With this method, the power density values provided in COMNET Appendix B (COMNET, 2011) are used; schedules are assumed to be continuous operation.</li> <li>• DOE performance ratings. With this method, the energy modeler takes inventory of the refrigerated casework in the rated building and sums the rated energy use (typically in kWh/day). Walk-in refrigerators and freezers shall use the defaults from Equation (1) and the values from Table 11. All refrigeration equipment is then assumed to operate continuously.</li> </ul> <p>Explicit refrigeration model. With this method, all components of the refrigeration system are explicitly modeled in DOE-2.2R or another hourly simulation program with this capability. This method is not covered by this manual.</p>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed, using one of the three methods described above
<i>Baseline Building</i>	Same as for new construction

## Refrigeration Power

<i>Applicability</i>	All buildings or spaces that have commercial refrigeration for cold storage or display and do not use the explicit refrigeration model
<i>Definition</i>	Commercial refrigeration power is the average power for all commercial refrigeration equipment, assuming constant year-round operation. Equipment includes walk-in refrigerators and freezers, open refrigerated casework, and closed refrigerated casework. It does not include residential type refrigerators used in kitchenettes or refrigerated vending machines. These are covered under <i>receptacle power</i> .
<i>Units</i>	Kilowatts (kW) or W/ft <sup>2</sup>
<i>Input Restrictions</i>	<p>With the COMNET defaults method, the values in COMNET Appendix B (COMNET, 2011) are prescribed. These values are multiplied by the floor area of the rated building to estimate the refrigeration power.</p> <p>With the DOE performance ratings method, refrigeration power is estimated by summing the kWh/day for all the refrigeration equipment in the space and dividing by 24 hours. The refrigeration power for walk-in refrigerators and freezers is added to this value.</p>
<i>Baseline Building</i>	<p>Refrigeration power is the same as the proposed design when the COMNET defaults are used. When the DOE performance ratings method is used, refrigeration power for casework shall be determined from Table 10; the power for walk-in refrigerators and freezers shall be the same as the proposed design.</p> <p>However, variations of the power requirements, schedules, or control sequences of the refrigeration equipment modeled in the baseline building from those in the proposed design shall be allowed by the rating authority based upon documentation that the refrigeration equipment installed in the proposed design represents a significant verifiable departure from documented conventional practice.</p> <p>The burden of this documentation is to demonstrate that accepted conventional practice would result in Baseline Building refrigeration equipment different from that installed in the proposed design. Occupancy and occupancy schedules shall not be changed.</p> <p><b>NOTE:</b> Any variation between proposed and baseline refrigeration power should be reported for rating authority approval and inspection.</p>

## Remote Condenser Fraction

<i>Applicability</i>	All buildings that have commercial refrigeration for cold storage or display and use the COMNET defaults or DOE performance ratings methods
<i>Definition</i>	<p>The fraction of condenser heat that is rejected to the outdoors. For self-contained refrigeration casework, this value will be zero. For remote condenser systems, this value is 1.0. For combination systems, the value should be weighted according to refrigeration capacity.</p> <p>For refrigeration with self-contained condensers and compressors, the heat that is removed from the space is equal to the heat that is rejected to the space, since the evaporator and condenser are both located in the same space. There may be some latent cooling associated with operation of the equipment, but this may be ignored with the COMNET defaults or DOE performance ratings methods. The operation of self-contained refrigeration units may be approximated by adding a continuously operating electric load to the space that is equal</p>

to the energy consumption of the refrigeration units. Self-contained refrigeration units add heat to the space that must be removed by the HVAC system.

When the condenser is remotely located, heat is removed from the space but rejected outdoors. In this case, the refrigeration equipment functions in a manner similar to a continuously running split system air conditioner. Some heat is added to the space for the evaporator fan, the anti-fog heaters, and other auxiliary energy uses, but refrigeration systems with remote condensers remove more heat from the space where they are located than they add. The HVAC system must compensate for this imbalance.

For remotely located condensers using the COMNET defaults or DOE performance ratings method, the heat that is removed from the space is determined as follows:

$$Q = [(1 - F) \times kW - (F \times kW \times COP)] \times 3.413 \quad (2)$$

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.

$kW$  = The power of the refrigeration system determined by using the COMNET defaults or the DOE performance ratings method (kW)

$F$  = The remote condenser fraction (see building descriptor below) (unitless)

$COP$  = The coefficient of performance of the refrigeration system (unitless)

The simple approach outlined above assumes that there is no latent cooling associated with the refrigeration system. The heat addition or removal resulting from the above equation can be modeled in a number of ways to accommodate the variety of calculation engines available. It can be scheduled if the engine can accommodate a heat removal schedule. It can be modeled as a separate, constantly running air conditioner if the engine can accommodate two cooling systems serving the same thermal zone. Other modeling techniques are acceptable as long as they are thermodynamically equivalent.

<i>Units</i>	Fraction
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as the proposed design

### **Refrigeration COP**

<i>Applicability</i>	All buildings that have commercial refrigeration for cold storage or display and use the COMNET defaults or DOE performance ratings methods
<i>Definition</i>	The coefficient of performance (COP) of the refrigeration system. This is used only to determine the heat removed or added to the space, not to determine the refrigeration power or energy.
<i>Units</i>	Fraction

<i>Input Restrictions</i>	This value is prescribed to be 3.6 for refrigerators and 1.8 for freezers <sup>1</sup>
<i>Baseline Building</i>	Same as the proposed design

### **Refrigeration Schedule**

<i>Applicability</i>	All buildings that have commercial refrigeration for cold storage or display
<i>Definition</i>	The schedule of operation for commercial refrigeration equipment. This is used to convert refrigeration power to energy use.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	Continuous operation is prescribed
<i>Baseline Building</i>	Same as the proposed design

### **3.3.7 Elevators, Escalators, and Moving Walkways**

Elevators, escalators, and moving walkways account for 3% to 5% of electric energy use in buildings.<sup>2</sup> Buildings up to about five to seven stories typically use hydraulic elevators because of their lower initial cost. Mid-rise buildings commonly use traction elevators with geared motors, while high-rise buildings typically use gearless systems where the motor directly drives the sheave. The energy using components include the motors and controls as well as the lighting and ventilation systems for the cabs.

Elevators are custom designed for each building. In this respect they are less like products than they are engineered systems, e.g., they are more akin to chilled water plants where the engineer chooses a chiller, a tower, pumping, and other components, which are field engineered into a system. The main design criteria are safety and service. Some manufacturers have focused on energy efficiency of late and introduced technologies such as advanced controls that optimize the position of cars for minimum travel and regeneration motors that become generators when a loaded car descends or an empty car rises. These technologies can result in 35% to 40% savings.<sup>4</sup>

The motors and energy using equipment is typically located within the building envelope so it produces heat that must be removed by ventilation or by air conditioning systems. In energy models, a dedicated thermal zone (elevator shaft) will typically be created and this space can be indirectly cooled (from adjacent spaces) or positively cooled. Motors, drives, and braking equipment are usually located in a separate space that is often cooled by independent cooling equipment. The elevator energy use should be divided equally between the shaft and the equipment room. In the scenario, where geometrically modeling a separate elevator shaft is complicated, it is acceptable to model separate “virtual” shaft space/zones on each floor. These spaces need to be identified so that they’re not included in the gross floor area calculation.

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<sup>1</sup> These values are consistent with the assumptions for the default values for walk-ins, which assume an EER of 12.39 for refrigerators and 6.33 for freezers.

<sup>2</sup> Sachs, Harvey M., Opportunities for Elevator Energy Efficiency Improvements, American Council for an Energy Efficient Economy, April 2005.

Little is known on how to model elevators. As engineered systems, the model would need information on the number of starts per day, the number of floors, motor and drive characteristics, and other factors. Some work has been done to develop and categorize energy models for elevators;<sup>3</sup> however, a simple procedure is recommended based on a count of the number of elevators, escalators, and moving walkways in the building. This data is shown in Table 12.<sup>4</sup>

**Table 12.** Unit Energy Consumption Data for Elevators, Escalators, and Moving Walkways<sup>5</sup>

Mode	Elevators		Escalators and Moving Walkways	
	Power (W)	Annual Hours	Power (W)	Annual Hours
Active	10,000	300	4,671	4,380
Ready	500	7,365	n.a.	0
Standby	250	1,095	n.a.	0
Off	0	0	0	4,380
Typical Annual Energy Use	7,000 kWh/y		20,500 kWh/y	

***Elevator/Escalator Power***

<i>Applicability</i>	All buildings that have commercial elevators, escalators, or moving walkways
<i>Definition</i>	The power for elevators, escalators, and moving walkways for different modes of operation. Elevators typically operate in three modes: active (when the car is moving passengers), ready (when the lighting and ventilation systems are active but the car is not moving), and standby (when the lights and ventilation systems are off). Escalators and moving walkways are either active or turned off.
<i>Units</i>	W/unit
<i>Input Restrictions</i>	The power values for different modes of operation for elevators, escalators, and moving walkways can either be defined by the user or can be defaulted to the values specified in Table 12 for the proposed design.
<i>Baseline Building</i>	<p>The power values for elevators, escalators and moving walkways will be the same as the proposed design.</p> <p>However, with approval of the rating authority, variations of the power requirements, schedules, or control sequences of elevators, escalators and moving walkways modeled in the baseline building from those in the proposed design shall be allowed based upon documentation that the elevators, escalators, and moving walkways installed in the proposed design represent a significant verifiable departure from documented conventional practice.</p> <p>The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building equipment different from that installed in the proposed design. If baseline building elevators, escalators, and moving walkways loads differ from</p>

<sup>3</sup> Al-Sharif, Lutfi, Richard Peters and Rory Smith, Elevator Energy Simulation Model, Elevator World, November 2005, Volume LII, No. 11.

<sup>4</sup> TIAX, Commercial and Residential Sector Miscellaneous Electricity Consumption: Y2005 and Projections to 2030, Final Report to the U.S. Department of Energy's Energy Information Administration (EIA) and Decision Analysis Corporation (DAC), September 22, 2006, Reference Number D0366.

<sup>5</sup> The TIAX report does not give energy consumption data for moving walkways. For the purposes of this manual, it is assumed to be equal to escalators.

the proposed building, this input must be flagged and instructions given to provide the proper documentation.

**NOTE:** If elevators, escalators, and moving walkways loads/schedule for the baseline building differ from the proposed design, this needs to be flagged and reported in the compliance reports.

### ***Elevator/Escalator Schedule***

<i>Applicability</i>	All buildings that have commercial elevators, escalators, or moving walkways
<i>Definition</i>	The schedule of operation for elevators, escalators, and moving walkways. This is used to convert elevator/escalator power to energy use.
<i>Units</i>	Data structure: schedule, state
<i>Input Restrictions</i>	The schedule specified for the building should match the operation patterns of the building. If no schedules are present, defaults based on the building area type or space type may be used.
<i>Baseline Building</i>	<p>Same as the proposed design</p> <p>However, with approval of the rating authority variations of the power requirements, schedules, or control sequences of elevators, escalators, and moving walkways modeled in the baseline building from those in the proposed design shall be allowed based upon documentation that the elevators, escalators, and moving walkways installed in the proposed design represent a significant verifiable departure from documented conventional practice.</p> <p>The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building equipment different from that installed in the proposed design. If baseline building elevators, escalators, and moving walkways loads differ from the proposed building, this input must be flagged and instructions given to provide the proper documentation.</p> <p><b>NOTE:</b> If elevators, escalators, and moving walkways loads/schedule for the baseline building differ from the proposed design, this needs to be flagged and reported in the compliance reports.</p>

### **3.3.8 Gas Process Equipment**

Commercial gas equipment includes the following:

- Ovens
- Fryers
- Grills
- Other equipment

The majority of gas equipment is located in the space, but is often placed under an exhaust hood, and may contribute both sensible and latent heat. Gas equipment is typically modeled by specifying the rate of peak gas consumption and modifying this with a fractional schedule. Energy consumption data for gas equipment is only beginning to emerge.



Because of these limits, the procedure for commercial gas is limited. The procedure consists of default values for power density for both the proposed design and the baseline building. These defaults can be overridden if actual values are known. No credit for commercial gas energy efficiency features is offered.

COMNET Appendix B (COMNET, 2011) specifies default values that can be used for process and gas loads. Schedules are specified in COMNET Appendix C (COMNET, 2011) that reflect diversity in equipment operation. Process and gas loads can also be specified through an input for peak equipment power and associated diversity schedule.

### ***Gas Equipment Power and Power Density***

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	Commercial gas power density is the peak power for commercial gas equipment, with operation schedules defined through a separate descriptor.  The gas equipment energy use can also be defined through an input of peak gas equipment power with operation schedules defined through a separate descriptor.
<i>Units</i>	Btu/h or Btu/h-ft <sup>2</sup>
<i>Input Restrictions</i>	As designed. For cases where design values are not available, defaults specified in COMNET Appendix B (COMNET, 2011) may be used.
<i>Baseline Building</i>	Same as the proposed design. However, variations of the power requirements, schedules, or control sequences of the gas equipment modeled in the baseline building from those in the proposed design shall be allowed by the rating authority based upon documentation that the gas equipment installed in the proposed design represents a significant verifiable departure from documented conventional practice.  The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building gas equipment different from that installed in the proposed design. Occupancy and occupancy schedules shall not be changed.  <b>NOTE:</b> Any variation between proposed and baseline gas equipment power should be flagged for rating authority approval and inspection.

### ***Gas Equipment Heat Gain Fractions***

<i>Applicability</i>	All projects
<i>Definition</i>	The fuel input to the gas equipment ultimately appears as heat that contributes to zone loads. This heat can be divided into four different fractions. These are given by the input fields. <ul style="list-style-type: none"> <li>• Fraction Latent: This field is a decimal number between 0.0 and 1.0 and is used to characterize the amount of latent heat given off by the gas equipment in a zone. The number specified in this field will be multiplied by the total energy consumed by gas equipment to give the amount of latent energy produced by the gas equipment. This energy affects the moisture balance within the zone.</li> <li>• Fraction Radiant: This field is a decimal number between 0.0 and 1.0 and is used to characterize the amount of long-wave radiant heat being given off by gas equipment in</li> </ul>

a zone. The number specified in this field will be multiplied by the total energy consumed by gas equipment to give the amount of long wavelength radiation gain from electric equipment in a zone.

- **Fraction Lost:** This field is a decimal number between 0.0 and 1.0 and is used to characterize the amount of “lost” heat being given off by gas equipment in a zone. The number specified in this field will be multiplied by the total energy consumed by gas equipment to give the amount of heat that is “lost” and does not impact the zone energy balances. This might correspond to gas energy converted to mechanical work or heat that is vented to the atmosphere.
- **Fraction Convected:** This field is a decimal number between 0.0 and 1.0 and is used to characterize the fraction of the heat from gas equipment convected to the zone air.

The sum of all 4 of these fractions should be 1.

<i>Units</i>	Data structure: fraction
<i>Input Restrictions</i>	As designed. If not specified by the user, default values for gas equipment heat gain fractions will be used.  For software that specifies the fraction of the heat gain that is lost from the space, this fraction shall be defaulted to 0.70.  The default values for fraction radiant, fraction latent, and fraction convected will be specified as 0.15, 0.05, and 0.10 respectively.
<i>Baseline Building</i>	Same as proposed

#### ***Gas Equipment Schedule***

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	The schedule of operation for commercial gas equipment. This is used to convert gas power to energy use.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	As determined by building owner or design professional
<i>Baseline Building</i>	Same as the proposed design

#### ***Gas Equipment Location***

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	The assumed location of the gas equipment for modeling purposes. Choices are in the space or external.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as the proposed design

## 3.4 Building Envelope Data

Spaces types can be conditioned, unconditioned, and semi-heated. Section 3.3 of this document defines each of these space types as well as the space conditioning categories.

### 3.4.1 Building Orientation

<i>Orientation</i>	
<i>Applicability</i>	All projects
<i>Definition</i>	The building orientation
<i>Units</i>	Degrees (°)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	<p>The baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90, 180, and 270 degrees, then averaging the results. The building shall be modeled so that it does not shade itself.</p> <p>Exceptions:</p> <ol style="list-style-type: none"><li>If it can be demonstrated to the satisfaction of the Program Evaluator that the building orientation is dictated by site considerations.</li><li>Buildings where the vertical fenestration area on each orientation varies by less than 5%.</li></ol> <p><b>NOTE:</b> Exception 'a' would need a flag on the software tool user interface, and if checked, it would need to be supported through documentation.</p>

### 3.4.2 Materials

Energy simulation programs commonly define construction assemblies by listing a sequence of material layers that make up the construction assembly. Typical construction assemblies and their respective material layers are defined in Normative Appendix A of Standard 90.1-2010. COMNET Appendix D (COMNET, 2011) includes typical construction materials used for baseline construction assemblies as well as applicable for proposed construction assemblies.

<i>Material Name</i>	
<i>Applicability</i>	When construction assemblies reference materials that are not standard
<i>Definition</i>	The name of a construction material used in the exterior envelope of the building
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	Material name is a required input for materials not available from the standard list. The user may not modify entries for predefined materials.
<i>Baseline Building</i>	Not applicable

### **Density**

<i>Applicability</i>	All non-standard materials
<i>Definition</i>	The density (or mass per unit of volume) of the construction material as documented in an ASHRAE handbook, a comparably reliable reference, or manufacturers' literature
<i>Units</i>	lb/ft <sup>3</sup>
<i>Input Restrictions</i>	Density is a required input when non-standard materials are specified
<i>Baseline Building</i>	Not applicable

### **Specific Heat**

<i>Applicability</i>	All non-standard materials
<i>Definition</i>	The specific heat capacity of a material is numerically equal to the quantity of heat that must be supplied to a unit mass of the material to increase its temperature by 1°F
<i>Units</i>	Btu/lb·°F
<i>Input Restrictions</i>	Specific heat is a required input when non-standard materials are specified. The specific heat capacity of the construction material as documented in an ASHRAE handbook, a comparably reliable reference, or manufacturers' literature.
<i>Baseline Building</i>	Not applicable

### **Thermal Conductivity**

<i>Applicability</i>	All non-standard materials
<i>Definition</i>	The thermal conductivity of a material of unit thickness is numerically equal to the quantity of heat that will flow through a unit area of the material when the temperature difference through the material is 1 °F
<i>Units</i>	Btu/h·ft·°F
<i>Input Restrictions</i>	Thermal conductivity is a required input for non-standard materials
<i>Baseline Building</i>	Not applicable

### **Thickness**

<i>Applicability</i>	All non-standard materials
<i>Definition</i>	The thickness of a material
<i>Units</i>	ft or in.
<i>Input Restrictions</i>	Thickness is a required input for non-standard materials. The user shall document the data source for thermal conductivity used for additional materials under the material name descriptor.
<i>Baseline Building</i>	Not applicable

### 3.4.3 Construction Assemblies

For use with Standard 90.1-2010, construction assemblies for the proposed design shall be created by selecting from a library of building construction layers in Standard 90.1-2010, Appendix A. The software shall specify all composite layers that consist of both framing and insulation and shall use established methods defined in the ASHRAE Handbook of Fundamentals for calculating effective R-values of composite layers.

#### **Assembly Name**

<i>Applicability</i>	All projects
<i>Definition</i>	The name of a construction assembly that describes a roof, wall, or floor assembly. The name generally needs to be unique so it can be referenced precisely by surfaces.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	Construction name is a required input
<i>Baseline Building</i>	Not applicable

#### **Specification Method**

<i>Applicability</i>	All projects
<i>Definition</i>	The method of describing a construction assembly. The simpler method is to describe the U-factor of the construction assembly, which can account for thermal bridging and other factors. However, this method does not account for the time delay of heat transfer through the construction assembly. Generally, with the U-factor method, heat transfer is assumed to occur instantly. The more complex method is to describe the construction assembly as a series of layers, each layer representing a material. With this method, heat transfer is delayed in accord with the thermal mass and other properties of the assembly. For below-grade constructions, a C-factor can be specified; for slab-on-grade constructions, an F-factor is specified.
<i>Units</i>	List: layers, U-factor, C-factor, F-factor, R-value
<i>Input Restrictions</i>	The layers method shall be used for all constructions except for metal building or similar constructions with negligible thermal mass
<i>Baseline Building</i>	Not applicable

#### **Layers**

<i>Applicability</i>	All construction assemblies that use the layers method of specification
<i>Definition</i>	A structured list of material names that describe a construction assembly, beginning with the exterior finish and progressing through the assembly to the interior finish. Material names must be from COMNET Appendix D (COMNET, 2011).
<i>Units</i>	List: layers of construction assembly

<i>Input Restrictions</i>	The user is required to describe all layers in the actual assembly and model the proposed design based on the layer descriptions
<i>Baseline Building</i>	See building descriptors for roofs, exterior walls, exterior floors, doors, fenestration, and below-grade walls.

### 3.4.4 Roofs

#### Geometry

The geometry of roofs, walls, floors, doors, and fenestration should match the construction documents or as-built drawings as accurately as possible. Curved surfaces such as a dome or semi-circular wall may be approximated by a series of constructions.

<b>Roof Name</b>	
<i>Applicability</i>	All roof surfaces
<i>Definition</i>	A unique name or code that identifies the roof and ties it to the construction documents submitted for energy code review. It is not mandatory to name roofs.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	None
<b>Roof Type</b>	
<i>Applicability</i>	All roof surfaces
<i>Definition</i>	One of three classifications of roofs defined in Standard 90.1-2010, i.e., insulation entirely above deck, metal building, and attic and other. The prescriptive U-factor requirements for roofs depend on the type. The PRM fixes the type for the baseline building to “insulation entirely above deck.”
<i>Units</i>	List: Attic and Other Roofs; Metal Building Roofs; and Roofs with Insulation Entirely Above Deck
<i>Input Restrictions</i>	Not applicable for new construction; as designed for existing buildings
<i>Baseline Building</i>	For existing buildings, the baseline building roof type is the same as that for the proposed design

## **Roof Geometry**

<i>Applicability</i>	All roofs, required input
<i>Definition</i>	Roof geometry defines the position, orientation, azimuth, tilt, and dimensions of the roof surface. The geometry of roofs should match the construction documents or as-built drawings as accurately as possible. Unusual curved surfaces such as a dome or semi-circular wall may be approximated by a series of constructions. The details of how the coordinate system is implemented may vary among software programs. The data structure for surfaces is described in Section 3.10.3 of this manual.
<i>Units</i>	Data structure: surface
<i>Input Restrictions</i>	The only restriction is that the surfaces defined must agree with the building being modeled, as represented on the construction drawings or as-built drawings
<i>Baseline Building</i>	Roof geometry will be identical in the proposed and baseline building designs

## **Roof Construction**

<i>Applicability</i>	All roofs, required input
<i>Definition</i>	A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior) layer and the last layer represents the inside (or interior) layer. See the building descriptors above for roof construction type.
<i>Units</i>	List: layers
<i>Input Restrictions</i>	<p>The construction assembly, as designed, defined by a series of layers. Each layer specified must be listed in the materials database in COMNET Appendix D (COMNET, 2011).</p> <p><b>NOTE:</b> Table A9.2A in Standard 90.1-2010 Appendix A specifies the effective insulation/framing layer R-values for roof and floor insulation installed between metal framing 4' OC. These values are intended to be used for all other framing, 16", 2' and 3'.</p>
<i>Baseline Building</i>	<p>Roofs in the baseline building are of the type "insulation entirely above deck." The insulation requirement is determined by climate zone and baseline standard. The baseline building roof construction shall be modeled as layers are defined.</p> <p>For new construction, the baseline building roof type is insulation above deck. The U-factor required for roof construction is defined in Tables 5.5-1 to 8 of the Standard. Programs that model a U-factor shall use an outside air film resistance and an inside air film resistance of R-0.17 and R-0.61, respectively.</p>

**Table 13.** Standard 90.1-2010 Baseline Roof Construction

Layer	R-Value
Outside Air Film	0.17
Built-up Roofing	0
Insulation	Ri as defined below
Inside Air Film	0.61
Total Resistance	1/U-criteria
U-Factor	U-criteria*

\*U-criteria in accordance with climate zone and applicable Table 5.5 1-8 for roofs with insulation entirely above deck.

$$R_i = 1/U\text{-criteria} - 0.78$$

**Table 14.** Standard 90.1-2010 Requirements for Roof Insulation for each Space Conditioning Category

	Non-Residential		Residential		Semiheated	
	Insulation R-Value	U-Criteria	Insulation R-Value	U-Criteria	Insulation R-Value	U-Criteria
Climate Zone 1	R-15 c.i.	0.063	R-20 c.i.	0.048	R-3.8 c.i.	0.218
Climate Zone 2	R-20 c.i.	0.048	R-20 c.i.	0.048	R-3.8 c.i.	0.218
Climate Zone 3	R-20 c.i.	0.048	R-20 c.i.	0.048	R-5 c.i.	0.173
Climate Zone 4	R-20 c.i.	0.048	R-20 c.i.	0.048	R-5 c.i.	0.173
Climate Zone 5	R-20 c.i.	0.048	R-20 c.i.	0.048	R-7.6 c.i.	0.119
Climate Zone 6	R-20 c.i.	0.048	R-20 c.i.	0.048	R-10 c.i.	0.093
Climate Zone 7	R-20 c.i.	0.048	R-20 c.i.	0.048	R-10 c.i.	0.093
Climate Zone 8	R-20 c.i.	0.048	R-20 c.i.	0.048	R-15 c.i.	0.063

**Table 15.** Standard 90.1-2010 Baseline Building Roof Construction Assemblies

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft F)	Density (lb/ft <sup>3</sup> )	Specific Heat (Btu/lb F)	R-value (ft <sup>2</sup> · °F · h/ Btu)
Roof R-20 c.i.	Exterior air film					0.17
	Roofing membrane					0.00
	R-20 continuous insulation	4.8	0.02	1.8	0.29	20.00
	Steel deck	0.06	26	480	0.10	0.00
	Interior air film					0.61
	Total for assembly					20.78
Roof R-15 c.i.	Exterior air film					0.17
	Roofing membrane					0.00
	R-15 continuous insulation	3.6	0.02	1.8	0.29	15.00
	Steel deck	0.06	26	480	0.10	0.00
	Interior air film					0.61
	Total for assembly					15.78
Roof R-10 c.i.	Exterior air film					0.17
	Roofing membrane					0.00
	R-10 continuous insulation	2.4	0.02	1.8	0.29	10.00
	Steel deck	0.06	26	480	0.10	0.00



Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft F)	Density (lb/ft <sup>3</sup> )	Specific Heat (Btu/lb F)	R-value (ft <sup>2</sup> °F·h/ Btu)
	Interior air film					0.61
	Total for assembly					10.78
Roof R-7.6 c.i.	Exterior air film					0.17
	Roofing membrane					0.00
	R-7.6 continuous insulation	1.8	0.02	1.8	0.29	7.6
	Steel deck	0.06	26	480	0.10	0.00
	Interior air film					0.61
	Total for assembly					8.38
Roof R-5 c.i.	Exterior air film					0.17
	Roofing membrane					0.00
	R-5 continuous insulation	1.2	0.02	1.8	0.29	5.00
	Steel deck	0.06	26	480	0.10	0.00
	Interior air film					0.61
	Total for assembly					5.78
Roof R-3.8 c.i.	Exterior air film					0.17
	Roofing membrane					0.00
	R-3.8 continuous insulation	0.9	0.02	1.8	0.29	3.80
	Steel deck	0.06	26	480	0.10	0.00
	Interior air film					0.61
	Total for assembly					4.58

For existing buildings, if the roof component is not altered or if roof insulation or decking is not exposed during alteration, the baseline building roof construction shall match the proposed design roof construction of the existing building. If the roof is altered, and the roof sheathing or insulation is exposed, the baseline roof shall meet the U-factor requirements for the roof type of the proposed building.

#### ***Roof Solar Reflectance and Thermal Emittance***

<i>Applicability</i>	All opaque exterior roof surfaces exposed to ambient conditions
<i>Definition</i>	The solar reflectance of a material. For roofing materials, the 3-year-aged reflectance value from a laboratory accredited by a nationally recognized accreditation organization such as the Cool Roof Rating Council (CRRC) testing should be used.
<i>Units</i>	Unitless fraction between 0 and 1
<i>Input Restrictions</i>	For roof surfaces: The default value is prescribed to be 0.3 for solar reflectance and 0.9 for emittance.  For roofs these defaults may be overridden when 3-year-aged data for reflectance and emittance is determined according to ASTM C1549 or ASTM E1918 for reflectance and ASTM C1371 or ASTM E408 for emittance.
<i>Baseline Building</i>	All roofs in climate zones 1 through 3 are required to have a minimum 3-year-aged solar reflectance of 0.55 and in addition, a minimum 3-year-aged thermal emittance of 0.75.

Exceptions:

- a. Ballasted roofs with a minimum stone ballast of 17 lb/ft<sup>2</sup> or 23 lb/ft<sup>2</sup> pavers.
- b. Vegetated roof systems that contain a minimum thickness of 2.5 in. of growing medium and covering a minimum of 75% of the roof area with durable plantings.
- c. Roofs, where a minimum of 75% of the roof area:
  - a. Is shaded during the peak sun angle on June 21 by permanent components or features of the building, or
  - b. Is covered by off-set photovoltaic arrays, building integrated photovoltaic arrays, or solar air or water collectors, or
  - c. Is permitted to be interpolated using a combination of parts a. and b. above.
- d. Steep sloped roofs.
- e. Low sloped metal building roofs in climate zones 2 and 3.
- f. Roofs over ventilated attics or roofs over semi-heated spaces or roofs over conditioned spaces that are not cooled spaces.
- g. Asphaltic membranes in climate zones 2 and 3.

All other roofs, including roofs exempt from the requirements mentioned above, shall be modeled with 0.3 for solar reflectance and 0.9 for emittance. Roofs in other climate zones or those meeting exceptions to Standard 90.1-2010 Section 5.5.3.1.1 shall be the same as proposed.

### 3.4.5 Exterior Wall

<i>Exterior Wall Name</i>	
<i>Applicability</i>	All walls, optional input
<i>Definition</i>	A unique name or code that relates the exterior wall to the design documents. This is an optional input since there are other acceptable ways to key surfaces to the construction documents.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	None

<i>Wall Type</i>	
<i>Applicability</i>	All wall surfaces, optional
<i>Definition</i>	One of four categories of above-grade wall assemblies used to determine minimum insulation requirements for walls. The four wall type categories are as follows: <ul style="list-style-type: none"><li>a. Mass walls</li></ul>

- b. Metal building walls
- c. Steel framed walls
- d. Wood framed and other

A mass wall is defined as a wall with total heat capacity greater than (1) 7 Btu/ft<sup>2</sup>·°F or (2) 5 Btu/ft<sup>2</sup>·°F, provided that the wall has a material unit weight not greater than 120 lb/ft<sup>3</sup>. (Heat capacity is defined as the product of the specific heat in Btu/lb -F, the thickness in ft, and the density in lb/ft<sup>3</sup>.)

<i>Units</i>	List: Mass Walls, Metal Building Walls, Metal Framing Walls, and Wood Framing and Other Walls
<i>Input Restrictions</i>	This input is required for existing buildings when any wall is altered. This input is not required for new construction.
<i>Baseline Building</i>	All walls in the baseline building are modeled as “steel framed”

### **Wall Geometry**

<i>Applicability</i>	All walls, required input
<i>Definition</i>	Wall geometry defines the position, orientation, azimuth, and tilt of the wall surface. The geometry of roofs should match the construction documents or as-built drawings as accurately as possible. Curved surfaces such as a dome or semi-circular wall may be approximated by a series of constructions. The details of how the coordinate system is implemented may vary between simulation engines. The data structure for surfaces is described in Section 3.10.3 of this manual.
<i>Units</i>	Data structure: surface
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Wall geometry in the baseline building is identical to the proposed design

### **Wall Solar Reflectance**

<i>Applicability</i>	All opaque exterior surfaces exposed to ambient conditions
<i>Definition</i>	The solar reflectance of a material
<i>Units</i>	Unitless fraction between 0 and 1
<i>Input Restrictions</i>	For walls and other non-roof surfaces, the default reflectance is 0.3. The default values may be overridden only when the lower reflectance can be documented by manufacturers’ literature or tests.
<i>Baseline Building</i>	Same as proposed

### Wall Thermal Emittance

<i>Applicability</i>	All opaque exterior surfaces exposed to ambient conditions; this is prescribed for exterior walls at 0.9
<i>Definition</i>	The thermal emittance of a material. For roofing materials, the 3-year-aged emittance value from CRRC testing should be used if available.
<i>Units</i>	Unitless fraction between 0 and 1
<i>Input Restrictions</i>	For walls and other non-roof surfaces: The value is prescribed to be 0.9. The default values may be overridden only in cases when the lower emittance can be documented by manufacturers' literature or tests.
<i>Baseline Building</i>	Same as proposed

### Wall Construction

<i>Applicability</i>	All walls that use the layers method
<i>Definition</i>	A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior) layer and the last layer represents the inside (or interior) layer. See the building descriptors above for wall construction type.
<i>Units</i>	List: layers
<i>Input Restrictions</i>	As designed, with the construction assembly defined by a series of layers. Each layer specified, with the exception of composite layers, must be listed in the materials database in Standard 90.1-2010, Appendix A.
<i>Baseline Building</i>	For new construction, the baseline building wall type is steel framed where the insulation is installed within the cavity of the steel stud framing. The U-factor required for wall construction of the baseline building is defined in Tables 5.5-1 to 8 of the Standard. Programs that model a U-factor shall use an outside air film resistance and an inside air film resistance of R-0.17 and R-0.62, respectively.

For metal framed walls, the baseline building construction shall include the following layers:

Layer	R-Value
Outside air film	R - 0.17
Stucco (0.375 in.)	R - 0.08
Insulation – continuous insulation	R c.i.
Gypsum board (0.625 in.)	R - 0.56
Insulation – cavity insulation	R <sub>framing ins</sub>
Gypsum board (0.625 in.)	R - 0.56
Inside air film	R - 0.68
Total resistance	1/U-criteria
U-factor	U-criteria*

\*U-criteria in accordance with climate zone and applicable Table 5.5 1-8 for steel frame walls

$$R_{\text{framing ins}} = 1/U\text{-criteria} - R_{\text{c.i.}} - 2.05$$

**Table 16.** Standard 90.1-2010 Requirements for Steel Framed Wall Construction for Non-Residential Space Conditioning Categories

	Non Residential Space Conditioning Categories		
	U-criteria	Minimum Insulation	R <sub>framing ins</sub> (Eff R Value)
Climate Zone 1	0.124	R-13	R-6.01
Climate Zone 2	0.124	R-13	R-6.01
Climate Zone 3	0.084	R-13 + R-3.8 ci	R-6.01
Climate Zone 4	0.064	R-13 + R-7.5 c.i.	R-6.01
Climate Zone 5	0.064	R-13 + R-7.5 c.i.	R-6.01
Climate Zone 6	0.064	R-13 + R-7.5 c.i.	R-6.01
Climate Zone 7	0.064	R-13 + R-7.5 c.i.	R-6.01
Climate Zone 8	0.064	R-13 + R-7.5 c.i.	R-6.01

**Table 17.** Standard 90.1-2010 Requirements for Steel Framed Wall Construction for Residential Space Conditioning Categories

	Residential Space Conditioning Categories		
	U-criteria	Minimum Insulation	R <sub>framing ins</sub> (Eff R Value)
Climate Zone 1	0.124	R-13	R-6.01
Climate Zone 2	0.084	R-13 + R-7.5 c.i.	R-6.01
Climate Zone 3	0.084	R-13 + R-7.5 c.i.	R-6.01
Climate Zone 4	0.084	R-13 + R-7.5 c.i.	R-6.01
Climate Zone 5	0.084	R-13 + R-7.5 c.i.	R-6.01
Climate Zone 6	0.084	R-13 + R-7.5 c.i.	R-6.01
Climate Zone 7	0.042	R-13 + R-15.6 c.i.	R-6.01
Climate Zone 8	0.037	R-13 + R-18.8 c.i.	R-6.01

**Table 18.** Standard 90.1-2010 Requirements for Steel Framed Wall Construction for Semi-Heated Conditioning Categories

	Semi-Heated Space Conditioning Categories		
	U-criteria	Minimum Insulation	R <sub>framing ins</sub> (Eff R Value)
Climate Zone 1	0.352	NR	NR
Climate Zone 2	0.124	R-13	R-6.01
Climate Zone 3	0.124	R-13	R-6.01
Climate Zone 4	0.124	R-13	R-6.01
Climate Zone 5	0.124	R-13	R-6.01
Climate Zone 6	0.124	R-13	R-6.01
Climate Zone 7	0.124	R-13	R-6.01
Climate Zone 8	0.084	R-13 + R-3.8 c.i.	R-6.01

**Table 19.** Baseline Building Wall Construction Assemblies

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft °F)	Density (lb/ft <sup>3</sup> )	Specific Heat (Btu/lb °F)	R-value (ft <sup>2</sup> ·°F·h/Btu)
Wall R-13 + R-18.8	Air film					0.17
	Stucco	0.400	0.4167	116	0.2	0.08
	R-18.8 continuous insulation	1.800	0.0200	1.8	0.29	18.8

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft °F)	Density (lb/ft <sup>2</sup> )	Specific Heat (Btu/lb °F)	R-value (ft <sup>2</sup> ·°F·h/ Btu)
	Gypsum board	0.625	0.0930	50	0.2	0.56
	R-13 insulation/steel framing					6.00
	Gypsum board	0.625	0.0930	50	0.2	0.56
	Interior air film					0.68
	Total for assembly					26.85
Wall R-13 + R-15.6	Air film					0.17
	Stucco	0.400	0.4167	116	0.2	0.08
	R-15.6 continuous insulation	1.800	0.0200	1.8	0.29	15.6
	Gypsum board	0.625	0.0930	50	0.2	0.56
	R-13 insulation/steel framing					6.00
	Gypsum board	0.625	0.0930	50	0.2	0.56
	Interior air film					0.68
	Total for assembly					23.65
Wall R-13 + R-7.5	Air film					0.17
	Stucco	0.400	0.4167	116	0.2	0.08
	R-7.5 continuous insulation	1.800	0.0200	1.8	0.29	7.50
	Gypsum board	0.625	0.0930	50	0.2	0.56
	R-13 insulation/steel framing					6.00
	Gypsum board	0.625	0.0930	50	0.2	0.56
	Interior air film					0.68
	Total for assembly					15.55
Wall R-13 + R-3.8	Air film					0.17
	Stucco	0.400	0.4167	116	0.2	0.08
	R-3.8 continuous insulation	0.912	0.0200	1.8	0.29	3.80
	Gypsum board	0.625	0.0930	50	0.2	0.56
	R-13 insulation/steel framing					6.00
	Gypsum board	0.625	0.0930	50	0.2	0.56
	Interior air film					0.68
	Total for assembly					11.85
Wall R-13	Air film					0.17
	Stucco	0.400	0.4167	116	0.2	0.08
	Gypsum board	0.625	0.0930	50	0.2	0.56
	R-13 insulation/steel framing					6.00
	Gypsum board	0.625	0.0930	50	0.2	0.56
	Interior air film					0.68
	Total for assembly					8.05

For existing walls, same as proposed, except any newly created or exposed existing wall cavities shall be modeled with insulation filling the cavity with a minimum R-3 per inch.

### 3.4.6 Exterior Floors

<b>Floor Name</b>	
<i>Applicability</i>	All floor surfaces
<i>Definition</i>	A unique name or code that relates the exposed floor to the design documents. Exposed floors include floors exposed to the outdoors and floors over unconditioned spaces, but do not include slab-on-grade floors, below-grade floors, or interior floors.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	None

<b>Floor Type</b>	
<i>Applicability</i>	All exterior floor surfaces, optional
<i>Definition</i>	The category that defines the baseline building prescriptive floor requirements
<i>Units</i>	List: Mass, Steel-Joist, Wood-Framed and Other
<i>Input Restrictions</i>	Not applicable for new construction; any of the options
<i>Baseline Building</i>	The baseline building floors shall be of type “steel-joist”

<b>Floor Geometry</b>	
<i>Applicability</i>	All exterior floors, required input
<i>Definition</i>	Floor geometry defines the position, orientation, azimuth, and tilt of the floor surface. The details of how the coordinate system is implemented may vary among software programs. The data structure for surfaces is described in the reference section of this chapter.
<i>Units</i>	Data structure: surface
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Baseline building floor geometry is identical to the proposed design.

<b>Floor Construction</b>	
<i>Applicability</i>	All floors, required input
<i>Definition</i>	A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior) layer and the last layer represents the inside (or interior) layer. See the building descriptors above for floor construction type.
<i>Units</i>	List: layers
<i>Input Restrictions</i>	The construction assembly, defined by a series of layers. Each layer specified must be listed in the materials database in Standard 90.1-2010, Appendix A.

**NOTE:** Standard 90.1-2010, Table A9.2A in Appendix A specifies the effective insulation/framing layer R-values for roof and floor insulation installed between metal framing 4' OC. These values are intended to be used for all other framing, 16", 2', and 3'.

*Baseline Building* For new construction, the floor type for the baseline building is steel joist. The U-factor required for floor construction is defined in Tables 5.5-1 to 5.5-8 of the Standard. Programs that model a U-factor shall use a semi-exterior air film resistance and an inside air film resistance of R-0.46 and R-0.92, respectively.

For steel joist floors, the baseline building construction shall include the following layers:

Layer	Resistance
Interior air film	R-0.92
Carpet and pad	R-1.23
4" concrete	R-0.25
Metal deck/insulation	R <sub>framing ins</sub>
Semi-exterior air film	R-0.46
Total resistance	1/U-criteria
U-factor	U-criteria*

\*U-criteria in accordance with climate zone and applicable Tables 5.5 1-8 for steel joist floors.  
 $R_i = 1/U\text{-criteria} - 2.86$

**Table 20.** Standard 90.1-2010 Requirements for Steel Joist Floors for Non-Residential Space Conditioning Categories

	Non Residential Spaces		
	U-Criteria	Min Insulation R- Value	Ri
Climate Zone 1	U-0.35	NR	NR
Climate Zone 2	U-0.052	R-19	R-16.37
Climate Zone 3	U-0.052	R-19	R-16.37
Climate Zone 4	U-0.038	R-30	R-23.45
Climate Zone 5	U-0.038	R-30	R-23.45
Climate Zone 6	U-0.038	R-30	R-23.45
Climate Zone 7	U-0.038	R-30	R-23.45
Climate Zone 8	U-0.032	R-38	R-28.39

**Table 21.** Standard 90.1-2010 Requirements for Steel Joist Floors for Residential Space Conditioning Categories

	Residential Spaces		
	U-Criteria	Min Insulation R- Value	Ri
Climate Zone 1	U-0.35	NR	NR
Climate Zone 2	U-0.052	R-19	R-16.37
Climate Zone 3	U-0.052	R-19	R-16.37
Climate Zone 4	U-0.038	R-30	R-23.45
Climate Zone 5	U-0.038	R-30	R-23.45
Climate Zone 6	U-0.032	R-38	R-28.39
Climate Zone 7	U-0.032	R-38	R-28.39
Climate Zone 8	U-0.032	R-38	R-28.39



**Table 22.** Standard 90.1-2010 Requirements for Steel Joist Floors for Semi-Heated Space Conditioning Categories

	Semi-Heated Spaces		
	U-Criteria	Min Insulation R-Value	Ri
Climate Zone 1	U-0.35	NR	NR
Climate Zone 2	U-0.069	R-13	R-11.63
Climate Zone 3	U-0.069	R-13	R-11.63
Climate Zone 4	U-0.069	R-13	R-11.63
Climate Zone 5	U-0.052	R-19	R-16.37
Climate Zone 6	U-0.052	R-19	R-16.37
Climate Zone 7	U-0.052	R-19	R-16.37
Climate Zone 8	U-0.052	R-19	R-16.37

**Table 23.** Baseline Building Exterior Floor Construction Assemblies

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft °F)	Density (lb/ft <sup>3</sup> )	Specific Heat (Btu/lb °F)	R-value (ft <sup>2</sup> ·°F·h/Btu)
Floor R-38	Interior air film (flow down)					0.92
	Carpet and pad					1.23
	4" concrete	4	1.3333	140	0.2	0.25
	R-38 insulation between joists					28
	Metal deck	0.06	26	480	0.1	0.00
	Semi-exterior air film					0.46
	Total for assembly					30.86
	Floor R-30	Interior air film (flow down)				
Carpet and pad						1.23
4" concrete		4	1.3333	140	0.2	0.25
R-30 insulation between joists						23.5
Metal deck		0.06	26	480	0.1	0.00
Semi-exterior air film						0.46
Total for assembly						26.36
Floor R-19		Interior air film (flow down)				
	Carpet and pad					1.23
	4" concrete	4	1.3333	140	0.2	0.25
	R-19 insulation between joists					16.37
	Metal deck	0.06	26	480	0.1	0.00
	Semi-exterior air film					0.46
	Total for Assembly					19.23
	Floor R-13	Interior air film (flow down)				
Carpet and pad						1.23
4" concrete		4	1.3333	140	0.2	0.25
R-13 insulation between joists						11.63
Metal deck		0.06	26	480	0.1	0.00
Semi-exterior air film						0.46
Total for assembly						14.49

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft °F)	Density (lb/ft <sup>3</sup> )	Specific Heat (Btu/lb °F)	R-value (ft <sup>2</sup> · °F · h/Btu)
Floor- no insulation	Interior air film (flow down)					0.92
	Carpet and pad					1.23
	4" concrete	4	1.3333	140	0.2	0.25
	Metal deck	0.06	26	480	0.1	0.00
	Semi-exterior air film					0.46
	Total for assembly					2.86

### 3.4.7 Doors

#### **Door Name**

<i>Applicability</i>	All exterior doors, optional input
<i>Definition</i>	A unique name or code that relates the door to the design documents submitted. Doors that are more than 50% glass are treated as windows and must be determined and entered by using the fenestration building descriptors.
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	None

#### **Door Type**

<i>Applicability</i>	All exterior doors, required input
<i>Definition</i>	For the purposes of determining building envelope requirements, the classifications are defined as follows: <ol style="list-style-type: none"> <li>1. Non-swinging: roll-up, metal coiling, sliding, and all other doors that are not swinging doors.</li> <li>2. Swinging: all operable opaque panels with hinges on one side and opaque revolving doors. The prescriptive U-factor requirements depend on door type and climate. This building descriptor may be derived from other building descriptors, in which case a specific input is not necessary.</li> </ol>
<i>Units</i>	List: Swinging or Non-swinging
<i>Input Restrictions</i>	The door type shall be consistent with the type of door represented on the construction documents or as-built drawings
<i>Baseline Building</i>	The baseline building door type shall be the same as the proposed design

### Door Geometry

<i>Applicability</i>	All exterior doors
<i>Definition</i>	Door geometry defines the position and dimensions of the door surface relative to its parent wall surface. The azimuth and tilt (if any) of the door are inherited from the parent surface. The position of the door within the parent surface is specified through X,Y coordinates. The size is specified as a height and width (all doors are generally assumed to be rectangular). The details of how the geometry of doors is specified may vary for each energy simulation program.
<i>Units</i>	Data structure: opening
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Door geometry in the baseline building is identical to the proposed design

### Door U-factor

<i>Applicability</i>	All exterior doors
<i>Definition</i>	The thermal transmittance of the door, including the frame
<i>Units</i>	Btu/h·ft <sup>2</sup> ·°F
<i>Input Restrictions</i>	Door U-factors shall be taken from the default values in Appendix A of Standard 90.1-2010 or shall be obtained from National Fenestration Rating Council (NFRC) test procedures.
<i>Baseline Building</i>	For new construction, the U-factor required for door construction is defined in Tables 5.5-1 to 5.5-8 of the Standard

**Table 24.** Standard 90.1-2010 Requirements for Doors

Swinging or Non-swinging	Climate Zone	Space Conditioning Category		
		Nonresidential U-Value	Residential U-Value	Semi-Heated U-Value
Swinging	Climate Zone 1	0.7	0.7	0.7
	Climate Zone 2	0.7	0.7	0.7
	Climate Zone 3	0.7	0.7	0.7
	Climate Zone 4	0.7	0.7	0.7
	Climate Zone 5	0.7	0.5	0.7
	Climate Zone 6	0.7	0.5	0.7
	Climate Zone 7	0.5	0.5	0.7
	Climate Zone 8	0.5	0.5	0.7
Non-swinging	Climate Zone 1	1.45	1.45	1.45
	Climate Zone 2	1.45	0.5	1.45
	Climate Zone 3	1.45	0.5	1.45
	Climate Zone 4	1.5	0.5	1.45
	Climate Zone 5	0.5	0.5	1.45
	Climate Zone 6	0.5	0.5	1.45
	Climate Zone 7	0.5	0.5	1.45
	Climate Zone 8	0.5	0.5	0.5

### 3.4.8 Fenestration

Note that fenestration includes windows, doors that have more than 50% glazed area, and skylights. A skylight is a fenestration that has a tilt of less than 60° from horizontal.

#### ***Fenestration Name***

<i>Applicability</i>	All fenestration, optional input
<i>Definition</i>	A unique name or code that relates the fenestration to the design documents and a parent surface
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	Not restrictions
<i>Baseline Building</i>	Not applicable

#### ***Fenestration Type (Vertical Fenestration)***

<i>Applicability</i>	All vertical fenestration
<i>Definition</i>	This is a classification of vertical fenestration that determines the thermal performance and solar performance requirement for vertical fenestration
<i>Units</i>	List: Nonmetal Framing, Metal Framing (Curtain Wall/Storefront), Metal Framing (Entrance Door), Metal Framing (All Other)
<i>Input Restrictions</i>	No restrictions, other than that the vertical fenestration type must agree with the type specified on the construction documents or the as-built drawings
<i>Baseline Building</i>	Same as the proposed design

#### ***Fenestration Type (Skylights)***

<i>Applicability</i>	All skylights
<i>Definition</i>	This is a classification of skylights that determines the thermal performance and solar performance requirement for vertical fenestration
<i>Units</i>	List: Glass Skylight with Curb, Plastic Skylight with Curb, Skylight without Curb
<i>Input Restrictions</i>	No restrictions, other than the skylight types specified must agree with the construction documents or the as-built drawings
<i>Baseline Building</i>	Same as the proposed design

## Fenestration Geometry and Area

<i>Applicability</i>	All fenestration
<i>Definition</i>	Fenestration geometry defines the position and dimensions of the fenestration surface within its parent surface and the identification of the parent surface. The orientation and tilt are inherited from the parent surface. The details of how the coordinate system is implemented may vary between software programs.
<i>Units</i>	Data structure: opening
<i>Input Restrictions</i>	<p>As designed. The defined fenestration should match with the construction drawings or as-built drawings.</p> <p>Specification of the fenestration position within its parent surface is required for the following conditions:</p> <ul style="list-style-type: none"><li>• Exterior shading is modeled from buildings, vegetation, other objects. All elements whose effective height is greater than their distance from a proposed building and whose width facing the proposed building is greater than one-third that of the proposed building shall be accounted for in the analysis</li><li>• If daylighting is modeled within the adjacent space.</li></ul>
<i>Baseline Building</i>	<p>The geometry of the fenestration in the baseline building shall be identical to the proposed design with the following exceptions:</p> <ul style="list-style-type: none"><li>• Calculated separately for each space conditioning category: If the gross area of all windows (including framing) in each space conditioning category in the building exceeds 40% of the gross above-grade exterior wall area for that space conditioning category, the dimensions of each window shall be reduced such that the window area is equal to 40% of the above-grade exterior wall area. This reduction needs to be done by increasing the sill height until the 40% limit is reached for each space conditioning category.</li><li>• Fenestration on demising walls separating conditioned space from unconditioned space would be included in the fenestration area calculations for conditioned space.</li><li>• Calculated separately for each space conditioning category: If the gross area of skylights (including framing) in each space conditioning category in the building exceeds 5% of the gross roof area for that space conditioning category, the dimensions of each skylight shall be reduced such that the skylight area in the proposed design is equal to 5% of the gross roof area.</li></ul>

The rules for calculating WWR for the baseline building for each space conditioning category are defined as follows:

$$WWR_{NR} = A_{NREWin} / A_{NREWa}$$

$$WWR_R = A_{REWin} / A_{REWa}$$

$$WWR_{SH} = A_{SHEWin} / A_{SHEWa}$$

The same rules apply for the calculation of gross roof area and skylight area.

Where:

- $WWR_{NR}$  = Window-to-wall ratio for non-residential conditioned spaces
- $WWR_R$  = Window-to-wall ratio for residential conditioned spaces
- $WWR_{SH}$  = Window-to-wall ratio for semi-heated spaces
- $A_{NREWa}$  = Nonresidential above-grade exterior wall area
- $A_{REWa}$  = Residential above-grade exterior wall area
- $A_{SHEWa}$  = Semi-exterior above-grade wall area
- $A_{NREWin}$  = Nonresidential above grade exterior window area
- $A_{REWin}$  = Residential above-grade exterior window area
- $A_{SHEWin}$  = Area of windows in semi-exterior walls

*Nonresidential above-grade exterior wall area* is defined as the gross above-grade wall area for nonresidential conditioned space, which only includes those walls that separate nonresidential conditioned spaces from the exterior.

*Residential above grade exterior wall area* is defined as the gross wall area for residential conditioned space, which only includes those walls that separate residential conditioned spaces from the exterior.

*Semi-exterior above grade wall area* is defined as the gross above-grade wall area for semi-heated space which includes:

- Those above-grade walls that enclose semi-heated space (regardless of whether those walls are adjacent to the exterior, or adjacent to an unconditioned space, or adjacent to a conditioned space)
- Above-grade demising walls that separate nonresidential conditioned space from unconditioned space
- Above-grade demising walls that separate residential conditioned space from unconditioned space

Hence

Semi-exterior wall area = Area of above grade exterior walls surrounding semi-heated spaces + Area of above grade demising walls between semi-heated and conditioned space + Area of above grade demising walls between semi-heated and unconditioned + Area of above grade demising walls between conditioned and unconditioned spaces

There is no exception for street-level, street-side vertical fenestration in the PRM (mentioned in the prescriptive requirements of Standard 90.1-2010 Section 5.5.4).

### ***Fenestration Construction***

<i>Applicability</i>	All fenestration
<i>Definition</i>	A collection of values that together describe the performance of a fenestration system. The values that are used to specify the criteria are U-factor, solar heat gain coefficient (SHGC), and visible light transmittance (VT). U-factor and SHGC inputs are whole-window values.
<i>Units</i>	Data structure: shall include at a minimum the following properties as specified by NFRC ratings:

- U-factor: whole window U-factor
- SHGC: whole window solar heat gain coefficient
- VT: visible transmittance

*Input Restrictions* The U-factor, SHGC, and VT for fenestration shall be modeled as certified and labeled in accordance with NFRC 100, 200, and 300, respectively. Unlabeled skylights shall be assigned the U-factors in Standard 90.1-2010, Normative Appendix A, Table A8.1A for the SHGCs and Table A8.1B for VTs.

Unlabeled vertical fenestration, both operable and fixed, shall be assigned the U-factors, SHGCs, and VTs in Normative Appendix A, Table A8.2.

*Baseline Building* The baseline building design is assumed to have glazing flush with the outside surface of the exterior wall surface.

For new construction, the requirements for vertical fenestration U factor, SHGC, and VT by window type and framing type are specified in Table 5.5-1 through Table 5.5-8 of Standard 90.1-2010. In cases where there are no requirements for SHGC or VT, the baseline building shall be equal to the proposed design.

### **External Shading Devices**

*Applicability* All fenestration

*Definition* Devices or building features that are documented in the construction documents and shade the glazing, such as overhangs, fins, shading screens, and setbacks of windows from the exterior face of the wall. Objects that shade the building but are not part of the building and parts of the building that cause the building to shade itself are also modeled, but are not a part of this building descriptor. See Shading of the Building Site. The software shall be capable of modeling vertical fins and overhangs. Recessed windows may also be modeled with side fins and overhangs.

*Units* Data structure: opening shade

*Input Restrictions* No restrictions other than the inputs must match the construction documents

*Baseline Building* The baseline building is modeled without external shading devices and as flush with the exterior wall

### **Internal Shading Devices**

*Applicability* All fenestration

*Definition* Curtains, blinds, louvers, or other devices that are applied on the room side of the glazing material. Glazing systems that use blinds between the glazing layers are also considered internal shading devices. Glass coatings, components, or treatments of the glazing materials are addressed through the fenestration construction building descriptor.

*Units* Data structure: indicates the type of control, or blind schedule if applicable

*Input Restrictions* Manual fenestration shading devices such as blinds or shades may be modeled or not, but if they are, they are required to be modeled the same in the baseline building, so that there is

no credit.

Automatically controlled fenestration shades or blinds may be modeled in the proposed design.

*Baseline Building* Manual shades or blinds shall be modeled the same as in the proposed building.  
Automatically controlled fenestration shades or blinds will not be modeled in the baseline building.

### ***Dynamic Glazing***

*Applicability* Fenestration with dynamic glazing

*Definition* Dynamic glazing can vary the SHGC and VT of the glazing in response to a signal from an energy management system, direct sunlight on the glazing, or other inputs

*Units* Unitless

*Input Restrictions* Between 0 and 1. Dynamic glazing can be modeled for the proposed design and controlled according to sequences specified in the construction documents. If controlled manually, then the proposed model is required to use the average SHGC and VT.

*Baseline Building* Not applicable

### ***SHGC Dim Fraction***

*Applicability* Fenestration with dynamic glazing

*Definition* For dynamic glazing, this is the fraction of the SHGC when darkened to the SHGC during normal operation. This can be applied when the solar heat gain exceeds a specified threshold, or controlled by an electrical signal.

*Units* Unitless

*Input Restrictions* Between 0 and 1

*Baseline Building* Not applicable

### ***VT Dim Fraction***

*Applicability* Fenestration with dynamic glazing

*Definition* For dynamic glazing, this is the fraction of the visible transmittance when darkened to the visible transmittance during normal operation. This can be applied when the solar heat gain exceeds a specified threshold, or controlled by an electrical signal.

*Units* Unitless

*Input Restrictions* Between 0 and 1

*Baseline Building* Not applicable



### ***Dynamic Solar Heat Gain Threshold***

<i>Applicability</i>	Fenestration with automatically controlled dynamic glazing
<i>Definition</i>	For dynamic glazing, this is the solar heat gain threshold above which the dynamic glazing is active (darkened). When the solar heat gain drops below this threshold, the glazing is switched back to being inactive (clearest setting). Indoor and outdoor air temperatures (OATs) are the setpoints required for controlling the switchable solar heat gain threshold. This may be used in combination with the solar heat gain and illuminance thresholds for control. A flag may be used to indicate that this control is not used.
<i>Units</i>	Incident solar threshold (Btu/h-ft <sup>2</sup> )
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Switchable Space Temperature Threshold***

<i>Applicability</i>	Fenestration with automatically controlled dynamic glazing
<i>Definition</i>	For dynamic glazing, this is the space temperature above which the dynamic glazing is active (darkened). When the space temperature drops below this threshold, the glazing is switched back to being inactive (clearest setting). Indoor and outdoor air temperatures are the setpoints required for controlling the dynamic solar heat gain threshold. This may be used in combination with the solar heat gain and illuminance thresholds for control. A flag may be used to indicate that this control is not used.
<i>Units</i>	°F
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Dynamic Illuminance Threshold***

<i>Applicability</i>	Fenestration with automatically controlled dynamic glazing
<i>Definition</i>	For dynamic glazing, this is the illuminance threshold above which the dynamic glazing is regulated between active (darkened) and inactive (clearest setting). With a single illuminance setpoint, the dynamic glazing will adjust between the clearest and darkest setting to allow the desired illuminance level. A flag may be used to indicate that this control is not used.
<i>Units</i>	lux
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Dynamic Glazing Schedule***

<i>Applicability</i>	Fenestration with dynamic glazing controlled by an electrical signal
<i>Definition</i>	For dynamic glazing, this is an hourly schedule for when the dynamic glazing is darkened, when controlled by an electrical signal
<i>Units</i>	Boolean: 1 if dynamic glazing is active (darkened); 0 if not active
<i>Input Restrictions</i>	0 or 1 for schedule values. As designed.
<i>Baseline Building</i>	Not applicable

### **3.4.9 Below-Grade Walls**

#### ***Below-Grade Wall Name***

<i>Applicability</i>	All projects, optional input
<i>Definition</i>	A unique name that keys the below-grade wall to the construction documents
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Not applicable

#### ***Below-Grade Wall Geometry***

<i>Applicability</i>	All projects
<i>Definition</i>	A geometric construct that describes the dimensions and placement of walls located below grade. Below-grade walls have soil or crushed rock on one side and interior space on the other side. Some simulation models account for the depth below grade when estimating heat transfer, so the geometry may include height and width.
<i>Units</i>	Data structure: below-grade wall geometry
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed

### Below-Grade Wall Construction

<i>Applicability</i>	All projects, required input
<i>Definition</i>	A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior) layer and the last layer represents the inside (or interior) layer. See the building descriptors above for below-grade wall construction type.
<i>Units</i>	Data structure: construction assembly  The construction can be described as a C-factor, which is similar to a U-factor, except that the outside air film is excluded, or the construction can be represented as a series of layers, like exterior constructions.
<i>Input Restrictions</i>	As designed. Values for the C-factor can be taken from Standard 90.1-2010, Normative Appendix A, Section A4, Table A4.2.
<i>Baseline Building</i>	For new construction, see Table 25. The baseline building shall use default values for C-factor. The height shall be the same as specified in the proposed design.  For below-grade walls, the baseline building construction shall include the following layers:
	Insulation continuous $R_{insulation}$
	Mass wall $R -$ (see Standard 90.1-2010, Appendix A4.2)
	Gypsum board (1/2 in.) $R - 0.45$
	Inside air film $R - 0.62$

**Table 25.** Baseline Building Below-Grade Wall Construction Assemblies

Insulation R-Value	Layer	Thickness (inch)	Conductivity (Btu/h ft °F)	Density (lb/ft <sup>3</sup> )	Specific Heat (Btu/lb °F)	R-value (ft <sup>2</sup> ·°F·h/Btu)	C-factor (Btu/ft <sup>2</sup> ·°F·h)
NR	115 lb/ft <sup>3</sup> CMU, solid grout	8	0.45	115	0.20	0.87	1.140
R-7.5 c.i.	115 lb/ft <sup>3</sup> CMU, solid grout	8	0.45	115	0.20	0.87	
	R-7.5 continuous insulation	1.8	0.02	1.8	0.29	7.50	
	Total assembly					8.37	0.119
R-10 c.i.	115 lb/ft <sup>3</sup> CMU, solid grout	8	0.45	115	0.20	0.87	
	R-10 continuous insulation	2.4	0.02	1.8	0.29	10.00	
	Total assembly					10.87	0.092
R-12.5 c.i.	115 lb/ft <sup>3</sup> CMU, solid grout	8	0.45	115	0.20	0.87	
	R-10 continuous insulation	3.0	0.02	1.8	0.29	12.50	
	Total assembly					13.37	0.075

**Table 26.** Baseline Building Requirements for Below-Grade Walls

Climate Zone	Non-Residential C-factor (Minimum Insulation)	Residential C-factors (Minimum Insulation)	Semi Heated C-factors (Minimum Insulation)
Climate Zone 1	C-1.140 (NR)	C-1.140 (NR)	C-1.140 (NR)
Climate Zone 2	C-1.140 (NR)	C-1.140 (NR)	C-1.140 (NR)
Climate Zone 3	C-1.140 (NR)	C-1.140 (NR)	C-1.140 (NR)
Climate Zone 4	C-1.140 (NR)	C-0.119 (R-7.5 c.i.)	C-1.140 (NR)
Climate Zone 5	C-0.119 (R-7.5 c.i.)	C-0.119 (R-7.5 c.i.)	C-1.140 (NR)
Climate Zone 6	C-0.119 (R-7.5 c.i.)	C-0.119 (R-7.5 c.i.)	C-1.140 (NR)
Climate Zone 7	C-0.119 (R-7.5 c.i.)	C-0.092 (R-10 c.i.)	C-1.140 (NR)
Climate Zone 8	C-0.119 (R-7.5 c.i.)	C-0.075 (R-12.5 c.i.)	C-1.140 (NR)

### 3.4.10 Slab Floors in Contact with Ground

These building descriptors apply to slab-on-grade floors that are in direct contact with the ground.

#### *Slab Floor Name*

<i>Applicability</i>	All slab floors, optional
<i>Definition</i>	A unique name or code that relates the exposed floor to the construction documents
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Not applicable

#### *Slab Floor Type*

<i>Applicability</i>	All slab floors, required
<i>Definition</i>	One of two classes for floors in contact with ground. The classes are: <ol style="list-style-type: none"> <li>1. Heated slab-on-grade floors</li> <li>2. Unheated slab-on-grade floors</li> </ol> <p>Heated slab-on-grade floors include all floors that are heated directly to provide heating to the space. Unheated slab-on-grade floors are all other floors in contact with the ground.</p>
<i>Units</i>	List: Heated or Unheated
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	The baseline building slab floor type is unheated

### **Slab Floor Geometry**

<i>Applicability</i>	All slab floors, required
<i>Definition</i>	A geometric construct representing a slab floor in contact with the earth. The geometric representation can vary depending on how the energy simulation software models slabs-on-grade. Some models require that only the perimeter of the slab be entered. Other models divide the slab into a perimeter band within 2 ft of the edge and the interior portion or core area, such that the perimeter area and the core area sum to the total area of the slab.
<i>Units</i>	Data structure: as appropriate for the simulation tool This may include: area, perimeter exposed
<i>Input Restrictions</i>	No restrictions
<i>Baseline Building</i>	The geometry of the slab floor in the baseline building is identical to the slab floor in the proposed design

### **Slab Floor Construction**

<i>Applicability</i>	All slab floors, required input
<i>Definition</i>	<p>A specification containing a series of layers that result in a construction assembly for the proposed design. The first layer in the series represents the outside (or exterior) layer and the last layer represents the inside (or interior) layer. See the building descriptors above for slab floor type.</p> <p>A description of how the slab is insulated (or not). How the construction is described will depend on the energy simulation model. The construction can be represented by an F-factor that represents the entire construction (floor and insulation).</p> <p>Simple models may include just an F-factor, representing an instantaneous heat loss/gain to outside air. The F-factor could be related to the configuration of insulation in the proposed design. Other slab loss models may require that the surface area of the slab floor be divided between the perimeter and the interior. The insulation conditions then define heat transfer between both outside air and ground temperature.</p> <p>The insulation condition for slabs includes the R-value of the insulation and the distance it extends into the earth at the slab edge and how far it extends underneath the slab.</p>
<i>Units</i>	<p>List (depends on the model that is used)</p> <p>For F-factor method: F-factor from Normative Appendix A, Table A6.3; this is one selection from list 1 and one selection from list 2. Note that some combinations from list 1 and list 2 are not allowed – see Normative Appendix A, Table A6.3.</p> <p>List 1: None, 12 in horizontal, 24 in horizontal, 36 in horizontal, 48 in horizontal, 12 in vertical, 24 in vertical, 36 in vertical, 48 in vertical, Fully insulated slab</p> <p>List 2: R-0, R-5, R-7.5, R-10, R-15, R-20, R-25, R-30, R-35, R-40, R-45, R-50, R-55</p>
<i>Input Restrictions</i>	For new construction, F-factors shall be taken from Table A6.3 of Standard 90.1-2010, Normative Appendix A for both heated slab floors and unheated slab floors. For all methods, inputs shall be consistent with the construction documents. For alterations the same requirements apply.

*Baseline Building* Slab loss shall be modeled in the same manner in the baseline building as in the proposed design.

- a. Slab loss can be modeled with the simple method (F-factor) for unheated slabs. A layer-by-layer input can be used. The base assembly is a slab floor of 6-inch concrete poured directly onto the earth (Concrete 140lb/ft<sup>3</sup> – 6 in.), the bottom of the slab is at grade line and soil conductivity is 0.75 Btu/h-ft °F.

For new construction, the configuration of insulation and the F-factors for the baseline building unheated slab floors are shown in Table A6.3 in Normative Appendix A. The F-factors for the baseline building have been listed in the table below.

**Table 27.** Baseline Building Slab on Grade Envelope Requirements

Climate Zone	Non Residential		Residential		Semi-Heated	
	Insulation	F-Factor	Insulation	F-Factor	Insulation	F-Factor
Climate Zone 1	NR	0.73	NR	0.73	NR	0.73
Climate Zone 2	NR	0.73	NR	0.73	NR	0.73
Climate Zone 3	NR	0.73	NR	0.73	NR	0.73
Climate Zone 4	NR	0.73	R-10 for 24 in. vertical	0.54	NR	0.73
Climate Zone 5	NR	0.73	R-10 for 24 in. vertical	0.54	NR	0.73
Climate Zone 6	R-10 for 24 in. vertical	0.54	R-15 for 24 in. vertical	0.52	NR	0.73
Climate Zone 7	R-15 for 24 in. vertical	0.52	R-15 for 24 in. vertical	0.52	NR	0.73
Climate Zone 8	R-15 for 24 in. vertical	0.52	R-20 for 24 in. vertical	0.51	NR	0.73

For existing buildings, if the slab-on-grade floor component is not altered, the baseline building construction shall match the proposed design construction of the existing building. If the slab-on-grade component is altered, the component shall reflect the existing conditions prior to any revisions to the assembly.

### 3.4.11 Heat Transfer between Thermal Zones

<i>Partition Name</i>	
<i>Applicability</i>	All partitions, optional
<i>Definition</i>	A unique name or code that relates the partition to the construction documents
<i>Units</i>	Text: unique
<i>Input Restrictions</i>	The text should provide a key to the construction documents
<i>Baseline Building</i>	Not applicable

### ***Partition Geometry***

<i>Applicability</i>	All partitions
<i>Definition</i>	A geometric construct that defines the position and size of partitions that separate one thermal zone from another. The construct shall identify the thermal zones on each side of the partition. Since solar gains are not generally significant for interior partitions, the geometry of partitions is sometimes specified as just an area along with identification of the thermal zones on each side.
<i>Units</i>	Data structure: surface with additional information identifying the two thermal zones that the partition separates
<i>Input Restrictions</i>	No restrictions other than agreement with the construction documents
<i>Baseline Building</i>	The geometry of partitions in the baseline building shall be identical to the proposed design

### ***Partition Construction***

<i>Applicability</i>	All partitions
<i>Definition</i>	A description of the construction assembly for the partition
<i>Units</i>	Data structure: construction assembly
<i>Input Restrictions</i>	No restrictions other than the need for agreement with the construction documents. However, “virtual” air walls may be used to separate zones, where real perimeter zones and interior zones are defined within an open space.
<i>Baseline Building</i>	Interior walls for baseline should be same as proposed. Interior floors/ceilings shall be same as proposed.

## **3.5 HVAC Zone Level Systems**

This group of building descriptors relates to HVAC systems at the zone level. There is not a one-to-one relationship between HVAC components in the proposed design and the baseline building since the baseline building system is determined from building type, size, and heating source. Additions and alterations should follow the same requirements stated for new construction proposed designs and new construction baseline buildings; unless otherwise noted in the descriptor.

### 3.5.1 Space Temperature Control

#### *Baseline Building Space Thermostat Throttling Range*

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The number of degrees that the room temperature must change to cause the HVAC system to go from no heating or cooling (i.e., space temperatures floating) to full heating or cooling
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed with a default of 2°F
<i>Baseline Building</i>	Same as the proposed design  For simulation using EnergyPlus, the reporting tolerances would be set as 1°F to simulate a throttling range of 2°F

#### *Space Temperature Schedule*

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	An hourly space thermostat schedule
<i>Units</i>	Data structure: temperature schedule
<i>Input Restrictions</i>	Design temperature schedules are required to be used when available. When design temperature schedules are not available, the schedules specified in COMNET Appendix C (COMNET, 2011) can be used as a default.
<i>Baseline Building</i>	Schedules in the baseline building shall be identical to the proposed design

### 3.5.2 Terminal Device Data

#### *Terminal Type*

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	A terminal unit includes any device serving a zone (or group of zones collected in a thermal zone) that has the ability to reheat or re-cool in response to the zone thermostat. This includes: <ul style="list-style-type: none"><li>• None (the case for single zone units)</li><li>• VAV box</li><li>• Series fan-powered VAV box</li><li>• Parallel fan-powered VAV box</li><li>• Induction-type VAV box</li><li>• Dual-duct mixing box (constant volume and VAV)</li><li>• Two- and three-duct mixing dampers (multi-zone systems)</li></ul>



- Reheat coil (constant volume systems)
- Perimeter induction units
- Chilled beams
- Radiant heating and cooling

*Units* List (see above)

*Input Restrictions* As designed

*Baseline Building* Table 28 specifies the HVAC terminal device for each of the baseline building systems. See Table 1 for a summary of the HVAC mapping.

**Table 28.** Baseline Building HVAC Terminal Devices

Baseline System HVAC Terminal Type		
	Baseline Building System	Terminal Type
System 1	PTAC	None
System 2	PTHP	None
System 3	PSZ AC	None
System 4	PSZ HP	None
System 5	PVAV reheat	VAV with hot water reheat
System 6	Packaged VAV with PFP boxes	Parallel fan-powered boxes with electric reheat
System 7	VAV with Reheat	VAV with hot water reheat
System 8	VAV with PFP boxes	Parallel fan-powered boxes with electric reheat
System 9	Heating and ventilation	None
System 10	Heating and ventilation	None

### 3.5.3 Terminal Heating

This group of building descriptors applies to proposed design systems that have reheat coils at the zone level. The building descriptors are applicable for baseline building systems 5, 6, 7, and 8.

#### *Terminal Heat Type*

*Applicability* Systems that have reheat coils at the zone level

*Definition* The heating source for the terminal unit. This includes:

- Electric resistance
- Gas furnace
- Oil furnace
- Hot water
- Steam

*Units* List (see above)

*Input Restrictions* As designed

*Baseline Building* The table below shows the terminal heat type for each baseline building system

**Table 29.** Baseline Building Terminal Heat Type

Baseline Building System		Terminal Heat Type
System 1	PTAC	None
System 2	PTHP	None
System 3	PSZ AC	None
System 4	PSZ HP	None
System 5	PVAV reheat	Hot water
System 6	Packaged VAV with PFP boxes	Electric resistance
System 7	VAV with reheat	Hot water
System 8	VAV with PFP boxes	Electric resistance
System 9	Heating and ventilation	None
System 10	Heating and ventilation	None

### **Terminal Heat Capacity**

<i>Applicability</i>	Systems that have reheat coils at the zone level
<i>Definition</i>	The heating capacity of the terminal heating source
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed. However, if the UMLH exceed 300, the energy analyst and design team may have to increase the size of the equipment so that the UMLH are less than 300. See Figure 3 and Section 2.6.1.
<i>Baseline Building</i>	Oversizing would be carried out at zone level where the oversizing parameters would be applied to the zone design cooling airflow rates and zone loads. The software shall automatically size the terminal heating capacity to be 25% greater than the design loads. Refer to Section 2.6.2 of this document for more details.

### **Reheat Delta T**

<i>Applicability</i>	Systems that have reheat coils at the zone level
<i>Definition</i>	This is an alternate method to enter the terminal heat capacity. It can be calculated as follows:

$$\begin{aligned} \Delta T_{reheat} &= T_{reheat} - T_{cool\_supply} \\ \Delta T_{reheat} &= Q_{coil} / (CFM * Cp) \end{aligned} \quad (3)$$

Where:

$\Delta T_{reheat}$  = Heat rise across the terminal unit heating coil (°F)

$T_{reheat}$  = Heating air temperature at design (°F)

$T_{cool\_supply}$  = Supply air temperature at the heating coil (°F)

$Q_{coil}$  = Heating coil load (Btu/h)

$CFM$  = Standard airflow rate (cfm)

	$C_p$ = Specific heat of air (Btu/lb-°F)
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed, but may need to be increased if UMLH are greater than 300
<i>Baseline Building</i>	Same as proposed. If the proposed building doesn't have a reheat system, then the reheat delta T shall be based on a supply-air-to-room-air temperature difference of 20°F and shall be no more than 40°F.

### 3.5.4 Baseboard Heat

#### **Baseboard Capacity**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The total heating capacity of the baseboard unit(s)
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable to the Baseline Building

#### **Baseboard Heat Control**

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	Defines the control scheme of base board heating as either: <ul style="list-style-type: none"> <li>• Controlled by a space thermostat</li> <li>• Controlled based on OA T</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable for the baseline building

### 3.5.5 Zone Level Airflow

#### 3.5.5.1 VAV Airflow

This group of building descriptors applies to proposed design systems that vary the volume of air at the zone level. The building descriptors are applicable for baseline building systems 5 through 8.

### ***Design Airflow***

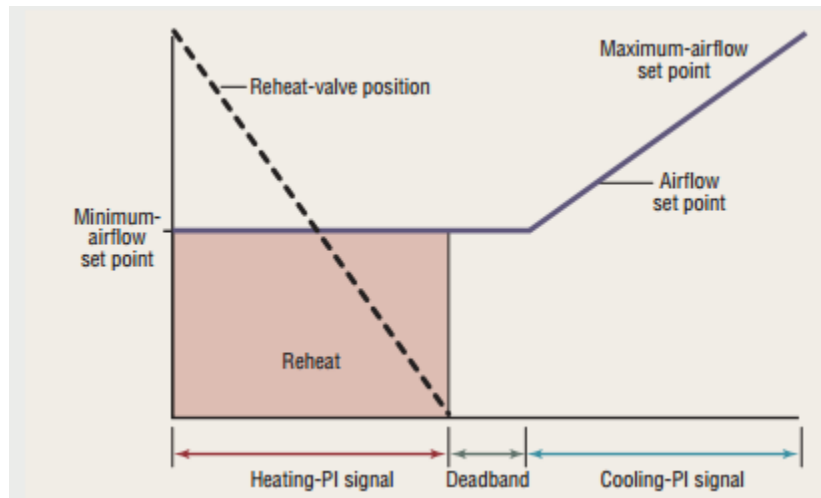
<i>Applicability</i>	Systems that vary the volume of air at the zone level
<i>Definition</i>	The air delivery rate at design conditions
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed. If the UMLH in the proposed design are greater than 300, the simulation should not proceed and the user may have to modify the design airflow value manually.
<i>Baseline Building</i>	<p>For systems 5 through 8, the software shall automatically size the system airflow to meet the baseline building loads based on</p> <ul style="list-style-type: none"><li>• a supply-air-to-room-air temperature difference of 20°F,</li><li>• or the minimum outdoor airflow rate,</li><li>• or the airflow rate required to comply with the applicable codes or accreditation standards, whichever is greater.</li></ul> <p>However, airflows for systems serving laboratory spaces shall be sized based on a supply air to room air temperature difference of 17°F or the required ventilation air or make-up air, whichever is greater.</p>

### ***Terminal Minimum Stop***

<i>Applicability</i>	Systems that vary the volume of air at the zone level
<i>Definition</i>	The minimum airflow that will be delivered by a terminal unit before reheating occurs
<i>Units</i>	Unitless fraction of airflow (cfm) or specific airflow (cfm/ft <sup>2</sup> )
<i>Input Restrictions</i>	This input must be greater than or equal to the outside air ventilation rate
<i>Baseline Building</i>	For systems 5 to 8 the minimum airflow for the VAV reheat boxes should be set to 30% of the zone peak supply air volume or the outside air ventilation rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is larger. Refer to the section Zone Exhaust for requirements related to systems serving laboratory spaces.

### ***Terminal Heating Control Type***

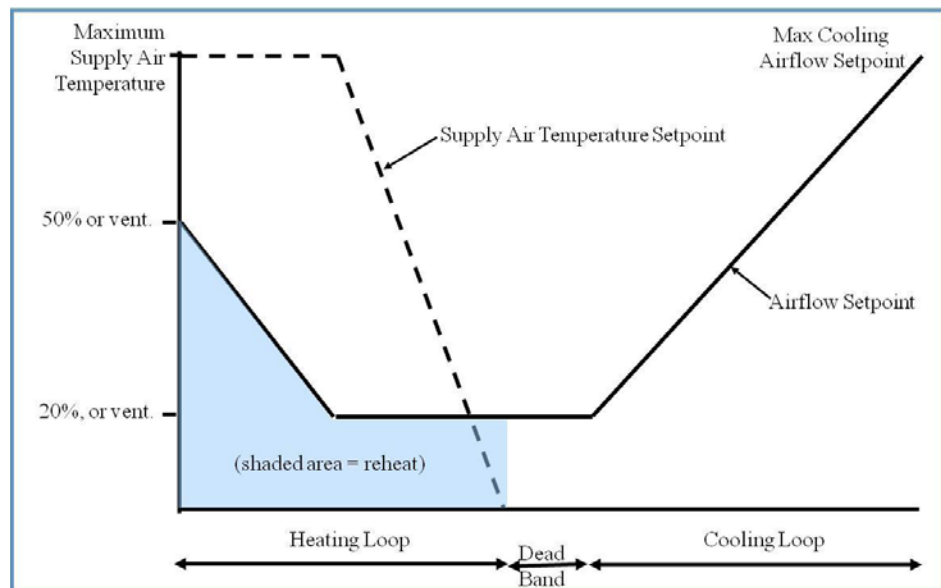
<i>Applicability</i>	VAV boxes with reheat
<i>Definition</i>	<p>The control strategy for the heating mode. The nomenclature in simulation programs to simulate this may differ from that provided below.</p> <p>Single Maximum</p> <p>In the single maximum control mode, the airflow is set to a minimum constant value in both the deadband and heating mode. This airflow can vary but is typically 30% to 50% of maximum. This control mode typically has a higher minimum airflow than the minimum used in the dual maximum below, resulting in more frequent reheat.</p>



**Figure 7.** Single Maximum VAV Box Control (Courtesy: Taylor Engineering)

Dual Maximum: raises the SAT as the first stage of heating, and increases the airflow to the zone as the second stage of heating.

1. The first stage of heating consists of modulating the zone SAT setpoint up to a maximum setpoint no larger than 95°F while the airflow is maintained at the dead band flow rate.
2. The second stage of heating consists of modulating the airflow rate from the dead band flow rate up to the heating maximum flow rate (50% of design flow rate) while maintaining the maximum setpoint temperature.



**Figure 8.** Dual Maximum Control Sequence

*Units*

List: Single Maximum, Dual Maximum

*Input Restrictions* As designed

*Baseline Building* Single maximum at 30% of zone peak airflow or the outside air ventilation rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is larger. The ventilation outdoor air and exhaust/relief dampers should be shut-off during preoccupancy building warm-up, cool down and setback except for economizer operation.

Refer to the section Zone Exhaust for requirements related to laboratory spaces.

### 3.5.5.2 Overhead Fan-Powered Boxes

This group of building descriptors applies to terminal equipment that includes zone fans for overhead VAV systems. The building descriptors are applicable for baseline building systems 6 and 8. Significant changes have occurred in this equipment type in the past few years, with EC motors allowing variable airflow of the box fans and greatly reduced energy use for series box fans. Simulation program representation of variable fan airflow fan-powered boxes is under development, and use of variable fan series boxes is widespread. The airflow control is often integrated with zone CO<sub>2</sub> measurement and control.

#### ***Fan-Powered Box Type***

*Applicability* HVAC zones that have fan-powered boxes

*Definition* Defines the type of fan-powered induction box. This is either:

- Series, constant volume box fan; or
- Parallel, constant volume box fan

*Units* List (see above)

*Input Restrictions* As designed

*Baseline Building* Applicable to baseline systems 6 and 8 and the fan-powered box type is parallel, with a constant volume fan

#### ***Fan Power***

*Applicability* HVAC zones that have fan-powered boxes

*Definition* The rated power input of the fan in a fan-powered box

*Units* W or W/cfm

*Input Restrictions* As designed

*Baseline Building* For baseline building systems 6 and 8, power is prescribed at 0.35 W/cfm

### ***Parallel Fan-Powered Box-Induced Air Zone***

<i>Applicability</i>	HVAC zones that have fan-powered boxes
<i>Definition</i>	Zone from which a series or parallel fan-powered box draws its air
<i>Units</i>	List (of zones)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	If the proposed design has a plenum, then induced air will be drawn from that plenum. If the proposed design does not have a plenum, then induced air will be drawn from the space.

### ***Parallel Fan-Powered Box- Induction Ratio***

<i>Applicability</i>	HVAC zones that have fan-powered boxes
<i>Definition</i>	The ratio of induction-side airflow of a fan-powered box at design heating conditions to the design primary airflow
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	50%

### ***Parallel Fan Box Thermostat Setpoint***

<i>Applicability</i>	HVAC zones that have parallel fan-powered boxes
<i>Definition</i>	The temperature difference above the heating setpoint at which the parallel fan is turned on
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	2°F above the heating setpoint schedule
<i>Baseline Building</i>	2°F above the heating setpoint schedule

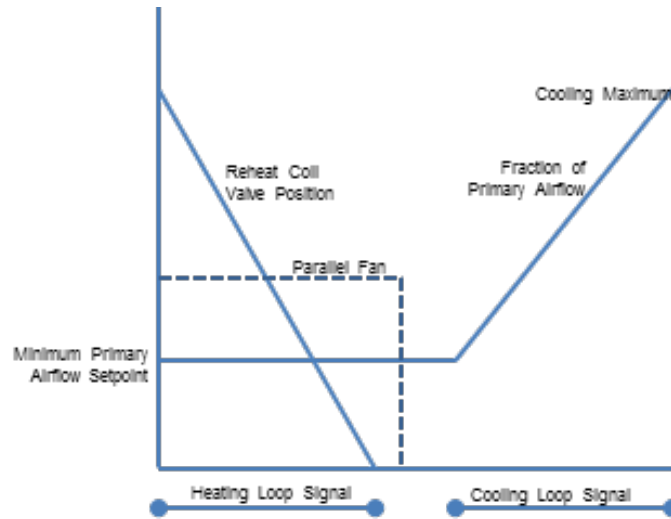
### ***Fan-Powered Boxes: Terminal Heating Control Type***

<i>Applicability</i>	HVAC zones that have parallel fan-powered boxes
<i>Definition</i>	<p>Fan Control: With parallel style fan-powered VAV boxes, the constant volume terminal unit fan is only on when the primary airflow is at design minimum and the zone temperature is less than 2°F above the heating setpoint schedule. When the system is scheduled to operate and the zone terminal fan is running, the box mixes plenum air with primary air.</p> <p>Heating Operation: During heating mode, the terminal unit discharge air temperature is increased from minimum to the design heating temperature. Throughout occupied heating the cooling, primary airflow is kept at design minimum and the terminal unit fan is running.</p> <p>Deadband Operation: The cooling primary airflow is kept at minimum airflow and the heating valve is closed. The terminal unit fan will energize as the first stage of heating when the zone temperature drops to 2°F. above heating setpoint.</p> <p>Cooling Operation: As the space temperature increases, the cooling supply airflow is</p>

increased from minimum to design cooling maximum. Throughout cooling the box fan is off. To comply with Section 6.5.2.1, Exception a, the minimum primary airflow for this control logic must be no larger than 30% of the zone design cooling airflow or the minimum airflow for ventilation.

Night Cycle Heating Control: A call for heating during night cycle control shall be met by running the terminal fan and increasing the terminal unit discharge air temperature from minimum to the design heating temperature without the use of primary air.

Single Maximum Parallel Fan Powered VAV Box Control



**Figure 9.** Single Maximum Control Sequence for Parallel Fan Powered VAV with Reheat Boxes

- Units* List: Single Maximum
- Input Restrictions* As designed
- Baseline Building* Single maximum with minimum airflow rate set to 30% of peak design primary airflow rate or the outside air ventilation rate, whichever is larger

**3.5.5.3 Zone Exhaust**

This group of building descriptors describes the rate of exhaust and the schedule or control for this exhaust. An exhaust system can serve one thermal zone or multiple thermal zones. Energy is summed for the exhaust system level, not the thermal zone level.

***Kitchen: Exhaust Hood Length***

- Applicability* Exhaust fans in spaces of type kitchen
- Definition* The exhaust hood length
- Units* ft



*Input Restrictions* As designed  
*Baseline Building* Same as the proposed design

***Kitchen: Exhaust Hood Style***

*Applicability* Exhaust fans in spaces of type kitchen  
*Definition* This input defines the style of the kitchen hood  
*Units* List: Wall-Mounted Canopy, Single Island, Double Island, Eyebrow, Backshelf/Passover  
*Input Restrictions* As designed  
*Baseline Building* Same as the proposed design

***Kitchen: Exhaust Hood Cooking Duty***

*Applicability* Exhaust fans in spaces of type kitchen  
*Definition* The hood cooking duty as defined in Table 6.5.7.1.3 of Standard 90.1-2010  
*Units* List: Light Duty, Medium Duty, Heavy Duty, Extra Heavy Duty  
*Input Restrictions* As designed  
*Baseline Building* Same as the proposed design

***Kitchen: Exhaust Airflow Rate***

*Applicability* Exhaust fans in spaces of type kitchen  
*Definition* Rate of exhaust from a thermal zone. Standard 90.1-2010, Section 6.5.7.1.3, requires each hood in a kitchen/dining facility with a total kitchen hood exhaust airflow rate greater than 5,000 cfm to have an exhaust rate that complies with Table 31. If a single hood, or hood section, is installed over appliances with different duty ratings, then the maximum allowable flow rate for the hood or hood section shall not exceed the Table 31 values for the highest appliance duty rating under the hood or hood section.

**Table 30.** Maximum Net Exhaust Flow Rate, cfm per Linear Foot of Hood Length

Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra Heavy Duty Equipment
Wall-mounted canopy	140	210	280	385
Single island	280	350	420	490
Double island (per side)	175	210	280	385
Eyebrow	175	175	Not allowed	Not allowed
Backshelf/passover	210	210	280	Not Allowed

<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	If the exhaust airflow rate of the proposed design is less than or equal to the exhaust flow rate prescribed in Table 30 above, then the baseline exhaust flow rate will be the same as proposed. However, if the kitchen hood exhaust airflow rate for the proposed design is greater than the airflow rate prescribed, then the baseline building uses airflow rates equal to that in the table.

#### ***Kitchen: Demand Ventilation***

<i>Applicability</i>	All kitchen HVAC zones
<i>Definition</i>	A demand ventilation system uses a light beam and a photo detector to detect the presence of smoke. It also has a temperature sensor to detect heat. The exhaust fan slows down below design levels and both exhaust and replacement airflow rates are reduced when the system detects no smoke or heat.
<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	For proposed designs with exhaust airflow rate greater than 5000 cfm, baseline models are required to use demand ventilation system on 75% of the exhaust air and makeup air. Airflow will be reduced by 50% during 50% of kitchen occupied hours.

#### ***Laboratory: Exhaust Minimum Airflow Rate***

<i>Applicability</i>	All laboratory zones
<i>Definition</i>	Rate of exhaust from a zone
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed except for the unoccupied periods, where systems serving laboratory spaces shall reduce the exhaust and makeup air volume during unoccupied periods to the largest of 50% of zone peak airflow, the minimum outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards.

#### ***Exhaust Fan Name***

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	A reference to an exhaust fan system that serves the thermal zone
<i>Units</i>	Text or other unique reference to an exhaust fan system defined in the secondary systems section
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as the proposed design

### ***Exhaust Fan Operation Schedule***

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	Schedule indicating the pattern of use for exhaust air from the thermal zone. This input should consider the position of fume hood sash opening. For toilets and other exhaust applications, the schedule may coincide with the operation of the exhaust fan system.
<i>Units</i>	Data structure: schedule, fraction
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed except for the unoccupied periods, where systems serving laboratory spaces shall reduce the exhaust and makeup air volume during unoccupied periods to the largest of 50% of zone peak airflow, the minimum outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards.

### **3.5.5.4 Outdoor Air Ventilation**

#### ***Ventilation Source***

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The source of ventilation for an HVAC system. The choices are: <ul style="list-style-type: none"><li>• Natural (by operable openings)</li><li>• Mechanical (by fan)</li></ul>
<i>Units</i>	List: Natural or Forced
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	For residential units, set to same as proposed, for all other occupancies, set to mechanical

#### ***Minimum Ventilation Rate***

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The minimum quantity of ventilation air that must be provided to the space when it is occupied
<i>Units</i>	cfm or cfm/ft <sup>2</sup>
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Minimum ventilation system outdoor air intake flow shall be the same for the proposed and baseline building designs. However, if the minimum outdoor air intake flow in the proposed design is provided in excess of the amount required by the rating authority or building official, then the baseline building design shall be modeled to reflect the greater of that required by the rating authority or building official and will be less than the proposed design. Exceptions: kitchens and laboratory spaces.  For systems serving kitchens, the minimum outside air ventilation rate is the exhaust air

ventilation rate minus available transfer air. Refer to building descriptor Kitchen Exhaust.  
For systems serving laboratories, refer to building descriptor Laboratory Exhaust.

### ***Design Ventilation Rate and Schedule***

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The quantity of ventilation air that is provided to the space for the specified thermal zone at maximum occupancy
<i>Units</i>	cfm or cfm/occupant
<i>Input Restrictions</i>	The outdoor air ventilation rate would be as designed. Outdoor air ventilation schedule for proposed building can be either of the two: <ol style="list-style-type: none"><li>As designed</li><li>The outdoor air ventilation schedule follows the HVAC availability schedule. In this case outdoor air isn't supplied during unoccupied times or during night cycling operation.</li></ol>

Some proposed building designs might bring in ventilation air during unoccupied hours for night flush or economizer operation. Due to these reasons, an option for user input of schedule for outdoor air availability is provided.

<i>Baseline Building</i>	Same as proposed, except: <ol style="list-style-type: none"><li>When designing systems in accordance with ASHRAE Standard 62.1, Section 6.2, Ventilation Rate Procedure, where the proposed design has a zone air distribution effectiveness greater than 1.0, the baseline ventilation shall be calculated using the proposed design ventilation rate procedure calculation with the zone air distribution effectiveness changed to 1.0. Refer to Section 3.5.5.5 for details on the ventilation rate procedure.</li><li>If the proposed design ventilation rate exceeds that required by the rating authority or building official, then the baseline design ventilation rate shall be only what is required by the rating authority or building official, whichever is greater.</li></ol>
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### ***Ventilation Control Method***

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The method used to determine outside air ventilation needed for each hour in the simulation. This information is reported to the system serving the zone. The method of controlling outside air at the system level in response to this information is discussed under secondary systems. Options at the zone level are: <ul style="list-style-type: none"><li>Occupant sensors: When the space is occupied, the outside air requirement is equal to the <i>design ventilation rate</i>; otherwise, the outside air requirement is the <i>minimum ventilation rate</i>.</li><li>CO<sub>2</sub> sensors in the space: The outside air is varied to maintain a maximum CO<sub>2</sub> concentration in the space. This shall be approximated by multiplying the ventilation</li></ul>

rate per occupant by the number of occupants for that hour. (When turnstile counts are used to automatically adjust ventilation levels based on occupancy, this method may also be used.)

- Fixed ventilation rate: Outside air is delivered to the zone at a constant rate and is equal to the design ventilation rate (see above).

*Units* List (see above)

*Input Restrictions* As designed

*Baseline Building* If the design occupancy is greater than 40 persons per 1,000 ft<sup>2</sup>, for spaces larger than 500 ft<sup>2</sup>, set control method to *CO<sub>2</sub> sensors in the space*, if

- the floor area is served by systems with either an air-side economizer,
- automatic modulating control of the outdoor air damper, or
- the design OA flow is greater than 3000 cfm.

For all other spaces, the ventilation rate is fixed. These criteria are with respect to the baseline systems that serve the zone.

Exceptions to this requirement are mentioned in the building descriptor Demand Control Ventilation.

In accordance with Standard 90.1-2010, Section 6.4.3.4.5, enclosed parking garages greater than 30,000 ft<sup>2</sup> must automatically detect contaminant levels (typically CO) and stage or modulate fan airflow rates to 50% or less provided acceptable contaminant levels are maintained. This requirement does not apply to garages where

- the ventilation system motor nameplate horsepower ratio exceeds 1500 ft<sup>2</sup>/hp, or
- there is no mechanical heating or cooling.

In addition, this requirement does not apply if it is not permitted by the authority having jurisdiction.

### ***Design Ventilation Rate: Demand Control Ventilation***

*Applicability* All HVAC zones

*Definition* Demand control ventilation is required for spaces larger than 500 ft<sup>2</sup> and with a design occupancy for ventilation of greater than 40 people per 1000 ft<sup>2</sup> of floor area and served by systems with one or more of the following:

- a. An air-side economizer
- b. Automatic modulating control of the outdoor air damper
- c. A design outdoor airflow greater than 3000 cfm

#### **Exceptions:**

- a. Systems with the exhaust air energy recovery complying with Standard 90.1-2010, Section 6.5.6.1
- b. Multiple-zone systems without dynamic demand control (DDC) of individual zones communicating with a central control panel

- c. Systems with a design outdoor airflow less than 1200 cfm
- d. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 1200 cfm

*Units* cfm or cfm/occupant

*Input Restrictions* As designed. DCV is a mandatory requirement for spaces larger than 500 ft<sup>2</sup>, with design occupancy of more than 40 people per 1000 ft<sup>2</sup> unless any of the exceptions specified above apply.

*Baseline Building* Same as proposed for spaces or systems where DCV is required as described above. For other spaces and systems, DCV is not modeled.

### ***Design Ventilation Rate: Demand Control Ventilation***

*Applicability* All HVAC zones

*Definition* DCV is required for spaces larger than 500 ft<sup>2</sup> and with a design occupancy for ventilation of greater than 40 people per 1000 ft<sup>2</sup> of floor area and served by systems with one or more of the following:

- a. An air-side economizer
- b. Automatic modulating control of the outdoor air damper
- c. A design outdoor airflow greater than 3000 cfm

Exceptions:

- a. Systems with the exhaust air energy recovery complying with Standard 90.1-2010, Section 6.5.6.1
- b. Multiple-zone systems without DDC of individual zones communicating with a central control panel
- c. Systems with a design outdoor airflow less than 1200 cfm
- d. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 1200 cfm

*Units* cfm or cfm/occupant

*Input Restrictions* As designed. DCV is a mandatory requirement for spaces larger than 500 ft<sup>2</sup>, with design occupancy of more than 40 people per 1000 ft<sup>2</sup> unless any of the exceptions specified above apply.

*Baseline Building* Same as proposed for spaces or systems where DCV is required as described above. For other spaces and systems DCV is not modeled.

### 3.5.5.5 Ventilation Rate Procedure

#### ***Ventilation Standard***

<i>Applicability</i>	All projects
<i>Definition</i>	The ventilation standard used for the calculation of minimum ventilation rate required. The ventilation rates are defined based on the ventilation standard selected. This should be specified at the project level.
<i>Units</i>	List. ASHRAE Standard 62.1, IMC-2012, Title-24-2013, Other
<i>Input Restrictions</i>	No restrictions. Any of the defined standards can be selected.
<i>Baseline Building</i>	Same as proposed  The baseline rules for determining the use of DCV are defined according to Standard 90.1-2010, even if the user specifies the ventilation standard as ‘Other’

#### ***Ventilation Specification Method***

<i>Applicability</i>	All HVAC zones
<i>Definition</i>	The method used to calculate total ventilation rates to a zone. The input must be either “Sum,” “Maximum,” or “No Ventilation.” <ul style="list-style-type: none"><li>• Sum means that the flows calculated from the fields Outdoor Airflow per Person and Outdoor Airflow per Area will be added to obtain the zone outdoor airflow rate.</li><li>• Maximum means that the maximum flow derived from Outdoor Airflow per Person, Outdoor Airflow per Area, and Air Changes per Hour (using the associated conversions to cfm for each field) will be used as the zone outdoor airflow rate.</li><li>• No ventilation indicates that the zone doesn’t receive any outdoor air.</li></ul>
<i>Units</i>	List: Sum, Maximum, No Ventilation
<i>Input Restrictions</i>	As designed.  For ventilation standard specified as = “62.1” and “IMC-2012,” the only available specification method would be “Sum.” For “T24-2013,” the only available specification method is “Maximum.” For ventilation standard specified as “Other,” the specification method can be specified as either Sum or Maximum, and includes all components.
<i>Baseline Building</i>	Same as proposed

#### ***Zone Air Distribution Effectiveness***

<i>Applicability</i>	All HVAC zones and spaces
<i>Definition</i>	The zone air distribution effectiveness ( $E_z$ ) shall be no greater than the default value determined using Table 31.

**Table 31.** Air Distribution Effectiveness (ASHRAE Standard 62.1-2010)

Air Distribution Configuration	Ez
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level. Note: For lower velocity supply air.	1.0
Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply jet reaches 4.5 ft (1.4 m) or more above the floor. Note: Most underfloor air distribution systems (UFADs) comply with this provision.	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation (DV) achieves unidirectional flow and thermal stratification	1.2
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust and/or return	0.8
Makeup supply drawn in near to the exhaust and/or return location	0.5

*Units* None

*Input Restrictions* As designed

*Baseline Building* Same as proposed

### ***Ventilation Multiplier***

*Applicability* All projects

*Definition* The ventilation multiplier is defined at the project level. This multiplier is applied to the user's design component ventilation rates (Ra and Rp) to uniformly increase the component ventilation rates entered. The principal purpose of the multiplier is to facilitate simulating a uniform increase in proposed design ventilation rates, such as for buildings pursuing the LEED credit for 30% increased ventilation.

*Units* No units

*Input Restrictions* As designed. The default value is 1.

*Baseline Building* The ventilation multiplier is always 1 for the baseline building.



## Ventilation Rates

**Applicability** All HVAC zones

**Definition** The method used to calculate total ventilation rates to a zone. The input must be either flow/person, flow/area, flow/zone, air changes/hour, sum, or maximum.

- Flow/Person (Rp) means the program will use the input from the field Outdoor Airflow per Person and the actual zone occupancy to calculate a zone outdoor airflow rate.
- Flow/Area (Ra) means that the program will use the input from the field Outdoor Airflow per Zone Floor Area and the actual zone floor area as the zone outdoor airflow rate. Flow/Zone means that the program will use the input of the field Outdoor Airflow per Zone as the zone outdoor airflow rate.
- Air changes per hour (ACH) means that the program will use the input from the field Air Changes per Hour and the actual zone volume (divided by 3600 seconds per hour) as the zone outdoor airflow rate.

For non-occupied spaces, the values for Ra, Rp and ACH can be zero for the proposed and baseline building. Software tools can allow a check-box for indicating spaces that would be non-occupied and hence are permitted to have a value for zero for Ra and Rp.

**Units** List: Flow/Person, Flow/Area, Air Changes per Hour

**Input Restrictions** As designed.  
If the user specifies ventilation standard as 'Other' and DCV is used, a non-zero value for Rp must be specified for the ventilation air flow to vary with occupancy.

**Baseline Building** The ventilation rates for the baseline building are determined by the ventilation standard and the space function. The code minimum ventilation rates cannot be overridden by the user.

For zones/spaces with ventilation standard specified as 'Other'

- The code minimum ventilation rates are required to be specified by the user.
- If DCV controls are not specified for the proposed but are required for the baseline, the ventilation rate for the area component is determined based on Standard 62.1 and the balance of the user's total design air flow is allocated to the Rp component for the baseline.

## Total Design Zone Ventilation Airflow

**Applicability** All HVAC zones

**Definition** The total design outdoor air supplied to a zone ( $V_{z\text{-design}}$ ).

Minimum outdoor air supplied to a zone ( $V_{bz\text{-min}}$ ) is calculated based on the user input values of the ventilation multiplier ( $V_m$ ),  $E_z$ , Ra and Rp. The method used to calculate total minimum ventilation airflow to a zone is specified below-

$$V_{bz\text{-min}} = V_m \times [(R_p \times P_z + R_a \times A_z)/E_z]$$

Where,

$V_{bz\text{-min}}$  = Total Breathing Zone Outdoor Airflow (CFM)

$V_m$  = Ventilation Multiplier

$R_p$  = Outdoor Airflow Rate per Person (CFM/person)

$R_a$  = Outdoor Airflow Rate per unit Area (CFM/ft<sup>2</sup>)

$P_z$  = Zone Population: The number of people in the zone during typical occupancy

$A_z$  = Zone Floor Area (ft<sup>2</sup>): the net occupiable floor area of the zone.

*Units*

List: CFM

*Input Restrictions*

As designed. The total design ventilation airflows should also include the impact of  $E_z$  and the ventilation multiplier. The user entered value for space/zone design ventilation airflow is required to be within 3% of the value calculated from the user entered  $R_a$ ,  $R_p$ ,  $E_z$  and  $V_m$  values, else the compliance analysis shouldn't be allowed to proceed. The user is required to modify the values for  $R_a$ ,  $R_p$  or  $E_z$  such that the total airflow calculated from the components and the user defined airflow is within the tolerance limit. Similarly, if DCV controls are used in the proposed building design, the user entered value for  $V_{z\text{-design}}$  should be within 3% tolerance of the value calculated by the design area rate component ( $R_a$ ) and  $E_z$ .

Exhaust airflows are checked at the building story level. If the sum of proposed total design ventilation airflows for all spaces on a building story level (excluding spaces with ventilation standard specified as 'Other') is not within 10% of the calculated total code minimum ventilation airflow, compliance analysis should not be allowed to proceed. To proceed, either the ventilation airflows for spaces that are under-ventilated, need to be increased or alternatively, the ventilation standard should be specified as 'Other' for spaces that are under-ventilated. For zones/spaces with DCV controls, the minimum ventilation airflow is the airflow when the space is unoccupied, calculated using the area component and  $E_z$ .

*Baseline Building*

The baseline *design* ventilation airflow rates for all spaces/thermal zones equal the proposed with the exception of the following:

- a. The zone distribution effectiveness for the proposed building ( $E_z$ ) > 1. In this case,  $E_z$  = 1 for the baseline building.
- b. The proposed design ventilation airflow, on a building story basis, exceeds the code minimum ventilation airflow for the building story. In this case, the baseline ventilation rates will be calculated by uniformly reducing the proposed rates such that the total ventilation airflow to spaces on the building story equals the code minimum flow. This maintains a proportional distribution of ventilation air to spaces/zones on the building story between the proposed and baseline designs. Spaces with ventilation standard specified as "Other" are excluded from adjustments, and the baseline design ventilation rate equals the proposed.
- c. The proposed design ventilation multiplier is greater than 1. In this case, the baseline design ventilation airflow is not increased by the multiplier. Instead, the total baseline design ventilation airflow is adjusted, as described in exception 2, to be equal to the code minimum ventilation airflow.
- d. The total proposed design ventilation airflow (excluding spaces with ventilation standard specified as "Other"), on a building story basis, is greater than 110% of the total building story exhaust airflow. In this case, the baseline design ventilation airflows will be calculated by uniformly reducing the proposed inputs (excluding spaces with ventilation standard specified as "Other") such that the total ventilation

airflow on the building story equals 110% of the total building story exhaust airflow. This maintains a proportional distribution of ventilation air (at design conditions) to spaces on the building story, while allowing sufficient additional ventilation air for pressurization.

### **Total System Design Ventilation Airflow**

<i>Applicability</i>	All HVAC systems.
<i>Definition</i>	The design outdoor air intake at the system level ( $V_{s\text{-design}}$ )
<i>Units</i>	CFM
<i>Input Restrictions</i>	As designed.  Software tools are required to verify the input value for $V_{s\text{-design}}$ . For all the zones served by the system, software tools are required to sum the zone level ventilation ( $V_{bz\text{-min}}$ ) to calculate the minimum ventilation at the system level ( $V_{s\text{-min}}$ ). If the design outdoor air intake ( $V_{s\text{-design}}$ ) is less than the minimum ventilation airflow ( $V_{s\text{-min}}$ ), the input should be flagged and the user should be required to increase the value for $V_{s\text{-design}}$ until it is equal to or greater than $V_{s\text{-min}}$ .
<i>Baseline Building</i>	The total system ventilation airflow for the baseline building is a sum of the zone level ventilation for the baseline building

### **System Ventilation Efficiency**

<i>Applicability</i>	All HVAC systems
<i>Definition</i>	The efficiency of the ventilation system ( $E_v$ ). This is the ratio of the design ventilation airflow to the minimum system ventilation airflow. $E_v = V_{s\text{-min}} / V_{s\text{-design}}$
<i>Units</i>	Ratio (unitless)
<i>Input Restrictions</i>	Calculated by software tool.  Software tools are required to calculate and verify the input value for $E_v$ . The maximum value of $E_v=1$ (for single zone systems). If $E_v$ is greater than 1, an error should be displayed to the user and the user is required to increase the value of $V_{s\text{-design}}$ until the value of $E_v$ is less than or equal to 1.
<i>Baseline Building</i>	Same as proposed for all zones served by the proposed system. In the scenario where the building has a multizone system in the proposed case, but single zone system in the baseline case, all the zones served by the Multizone system in the proposed case have $E_v$ same as the proposed system.  Similarly, if the proposed system is single zone and the baseline building has multizone systems, then the corresponding zones would have $E_v$ specified as 1, same as the proposed building.  This approach ensures that the ventilation rates are the same between the baseline and the proposed building.

### 3.6 HVAC Secondary Systems

This group of building descriptors relate to the secondary HVAC systems. There is not a one-to-one relationship between secondary HVAC system components in the proposed design and the baseline building since the baseline building system is determined from building type, size, and heating source. Depending on the nature of the proposed design, any of the building descriptors could apply. The HVAC baseline systems are described in the summary tables below for reference. The details of individual building descriptor definitions can be found in Sections 3.7 and 3.8.

**Table 32.** System 1 and System 2 Descriptions

System Description	Packaged terminal air conditioner (#1) or packaged terminal heat pump (#2)
Supply Fan Power	Fan power integral to unit efficiency. Fan power = $0.3 \times \text{cfm}_s$ . Refer to building descriptor Fan Systems. Ventilation is provided through the system.
Supply Fan Control	Constant volume
Min Supply Temp	20°F below occupied space cooling setpoint
Cooling System	DX
Cooling Efficiency	Minimum seasonal energy efficiency ratio (SEER) or EER based on equipment type and output capacity of proposed unit(s). Adjusted EER is calculated to account for supply fan energy.
Maximum Supply Temp	20°F above occupied space heating setpoint
Heating System	Hot water boiler (#1) or heat pump (#2)
Heating Efficiency	Minimum annual fuel utilization efficiency (AFUE), thermal efficiency, COP, or heating seasonal performance factor (HSPF) based on equipment type and output capacity of baseline unit(s)
Economizer	None
Ducts	N/A (not ducted)

**Table 33.** System 3 and System 4 Descriptions

System Description	Packaged single zone with gas furnace/electric air conditioning (#3) or heat pump (#4)
Supply Fan Power	See building descriptor Fan Systems, Section 3.6.3 of this document
Supply Fan Control	Constant volume
Min Supply Temp	20°F below occupied space cooling setpoint
Cooling System	DX
Cooling Efficiency	Minimum SEER or EER based on equipment type and output capacity of baseline unit(s). Adjusted EER is calculated to account for supply fan energy.
Maximum Supply Temp	20°F above occupied space heating setpoint
Heating System	Fossil fuel furnace (#3) or heat pump (#4)
Heating Efficiency	Minimum AFUE, thermal efficiency, COP, or HSPF based on equipment type and output capacity of baseline unit(s)
Economizer	Integrated economizer with dry-bulb high limit by climate zone. Refer to building descriptor Outside Air Controls and Economizer for exceptions to this requirement.

**Table 34. System 5 Description**

System Description	Packaged VAV with DX cooling, fossil fuel Boiler and hot-water Reheat
Supply Fan Power	See Section 3.6.3
Supply Fan Control	<ul style="list-style-type: none"> <li>• Variable speed controlled by variable speed drives</li> <li>• The part load performance of VAV fans is required to be modeled in accordance to section Fan Part Load Curve in Fan Systems</li> </ul>
Return Fan Control	Same as supply fan
Minimum Supply Temp	20°F below occupied space cooling setpoint
Supply Temp Control	The air temperature for cooling shall be reset higher by 5°F under minimum cooling load conditions. This strategy is described in Section 3.6.2.3 of this document.
Cooling System	DX
Cooling Efficiency	Minimum efficiency based on average output capacity of equipment unit(s)
Maximum Supply Temp	20°F above occupied space heating setpoint
Heating System	Hot water boiler, with hot water (HW) reheat
Reheat Terminal Airflow	System 5: Minimum volume setpoint for reheat is highest of 30% of zone peak flow, minimum outdoor airflow rate or airflow rate required by applicable rating authority. See Section 3.6.5 for details.
Hot Water Pumping System	The pumping system shall be modeled as primary-only with continuous variable flow. Hot-water systems serving 120,000 ft <sup>2</sup> or more shall be modeled with variable-speed drives, and systems serving less than 120,000 ft <sup>2</sup> shall be modeled as riding the pump curve.
Heating Efficiency	Minimum efficiency based on average output capacity of baseline equipment unit(s)
Economizer	Integrated economizer with dry-bulb high limit by climate zone

**Table 35. System 6 Description**

System Description	Packaged VAV, with DX cooling, electric heating and parallel fan-powered boxes with electric heat
Supply Fan Power	See Section 3.6.3
Supply Fan Control	<ul style="list-style-type: none"> <li>• Variable speed controlled by variable speed drives</li> <li>• The part load performance of VAV fans is required to be modeled in accordance to section Fan Part Load Curve in Fan Systems</li> <li>• Power induction unit (PIU) fan would be constant volume</li> </ul>
Return Fan Control	Same as supply fan
Minimum Supply Temp:	20°F below occupied space cooling setpoint
Supply Temp Control	The air temperature for cooling shall be reset higher by 5°F under minimum cooling load conditions. This strategy is described in Section 3.6.2.3 of this document.
Cooling System	DX cooling
Cooling Efficiency	Minimum efficiency based on average output capacity of equipment unit(s)
Maximum Supply Temp	20°F above occupied space heating setpoint
Heating System	Electric resistance, electric reheat terminals

Heating Efficiency	NA
Reheat Terminal Airflow	Fans for PIU units are sized for 50% of peak design primary air. Minimum volume setpoint for reheat is highest of 30% of peak design primary airflow rate, minimum outdoor airflow rate or airflow rate required by applicable rating authority. See Section 3.6.5 for details.
Economizer	Integrated economizer with dry-bulb high limit by climate zone

**Table 36. System 7 Description**

System Description	VAV system with HW boiler, HW reheat and chilled water (CHW) cooling
Supply Fan Power	See building descriptor Fan Systems, Section 3.6.3 of this document.
Supply Fan Control	Variable speed controlled by variable speed drives. The part load performance of VAV fans is required to be modeled in accordance with Fan Part Load Curve in Fan Systems.
Minimum Supply Temp	20°F below occupied space cooling setpoint
Supply Temp Control	The air temperature for cooling shall be reset higher by 5°F under minimum cooling load conditions. This strategy is described in Section 3.6.2.3 of this document.
Cooling System	Chiller
Cooling Efficiency	Minimum efficiency based on the output capacity of specific equipment unit(s)
Chilled Water Pumping System	The baseline building design pump power shall be 22 W/gpm. Chilled-water systems with a cooling capacity of 300 tons or more shall be modeled as primary/secondary systems with variable-speed drives on the secondary pumping loop. Chilled-water pumps in systems serving less than 300 tons cooling capacity shall be modeled as a primary/ secondary system with secondary pump riding the pump curve.
Chiller Type and Number	Electric chillers shall be used in the baseline building design. The baseline building design's chiller plant shall be modeled with chillers having the number and type as indicated in Standard 90.1-2010, Table G3.1.3.7, as a function of building peak cooling load.
Maximum Supply Temp	20°F above occupied space heating setpoint
Reheat Terminal Flow	System 5: Minimum volume setpoint for reheat is highest of 30% of zone peak flow, minimum outdoor airflow rate or airflow rate required by applicable rating authority. See Section 3.6.5 for details.
Heating System	Hot water boiler (system 8), hot water reheat
Hot Water Pumping System	The pumping system shall be modeled as primary-only with continuous variable flow. Hot-water systems serving 120,000 ft <sup>2</sup> or more shall be modeled with variable-speed drives, and systems serving less than 120,000 ft <sup>2</sup> shall be modeled as riding the pump curve.
Heating Efficiency	Minimum efficiency based on the output capacity of specific baseline equipment unit(s)
Economizer	Integrated economizer with dry-bulb high limit by climate zone and cooling capacity of the proposed design as modeled in the software if over 54,000 Btu/hr. Refer to building descriptor Outside Air Controls and Economizer for exceptions to this requirement.

**Table 37. System 8 Description**

System Description	VAV with CHW cooling, electric resistance heating, and PFP boxes with electric heat
Supply Fan Power	See building descriptor Fan Systems, Section 3.6.3 of this document
Supply Fan Control	Variable speed controlled by variable speed drives. The part load performance of VAV

	fans is required to be modeled in accordance with section Fan Part Load Curve in Fan Systems.
Minimum Supply Temp	20°F below occupied space cooling setpoint
Supply Temp Control	The air temperature for cooling shall be reset higher by 5°F under minimum cooling load conditions. This strategy is described in Section 3.6.2.3 of this document.
Cooling System	Chiller
Cooling Efficiency	Minimum efficiency based on the proposed output capacity of specific equipment unit(s)
Chilled Water Pumping System	The baseline building design pump power shall be 22 W/gpm. Chilled-water systems with a cooling capacity of 300 tons or more shall be modeled as primary/secondary systems with variable-speed drives on the secondary pumping loop. Chilled-water pumps in systems serving less than 300 tons cooling capacity shall be modeled as a primary/secondary system with secondary pump riding the pump curve.
Chiller Type and Number	Electric chillers shall be used in the baseline building design. The baseline building design's chiller plant shall be modeled with chillers having the number and type as indicated in Standard 90.1-2010, Table G3.1.3.7, as a function of building peak cooling load.
Maximum Supply Temp	20°F above occupied space heating setpoint
Heating System	Electric resistance, electric resistance reheat
Reheat Terminal Airflow	Fans for PIU units are sized for 50% of peak design primary air. Minimum volume setpoint for reheat is highest of 30% of peak design primary airflow rate, minimum outdoor airflow rate or airflow rate required by applicable rating authority. See Section 3.6.5 for details.
Hot Water Pumping System	N/A
Heating Efficiency	N/A
Economizer	Integrated dry bulb economizer with dry-bulb high limit based on climate zone and cooling capacity of the baseline design as modeled in the software if over 54,000 Btu/hr. Refer to building descriptor Outside Air Controls and Economizer for exceptions to this requirement.

**Table 38.** System 9 and System 10 Description

System 9 Description	Heating and ventilation only system
Supply Fan Power	See building descriptor Fan Systems
Supply Fan Control	Constant volume
Minimum Supply Temp	N/A
Cooling System	None
Cooling Efficiency	N/A
Maximum Supply Temp	20°F above occupied space heating setpoint
Heating System	Gas furnace
Hot Water Pumping System	N/A
Heating Efficiency	Minimum efficiency based on the baseline output capacity of specific equipment unit(s)
Economizer	Not required for system 9
System 10 Description	Heating and ventilation only system
Supply Fan Power	See building descriptor Fan Systems

Supply Fan Control	Constant volume
Minimum Supply Temp:	N/A
Cooling System	None
Cooling Efficiency	N/A
Maximum Supply Temp	20°F above occupied space heating setpoint
Heating System	Electric resistance
Hot Water Pumping System	N/A
Heating Efficiency	Minimum efficiency based on the baseline output capacity of specific equipment unit(s)
Economizer	Not required for system 10

### 3.6.1 Basic System Information

#### *HVAC System Name*

<i>Applicability</i>	All system types
<i>Definition</i>	A unique descriptor for each HVAC system
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	When applicable, this input should match the tags that are used on the plans
<i>Baseline Building</i>	None

#### *System Type*

<i>Applicability</i>	All system types
<i>Definition</i>	A unique descriptor that identifies the following attributes of an HVAC system: <ul style="list-style-type: none"> <li>• Number of air decks (one to three);</li> <li>• Constant or variable airflow;</li> <li>• Type of terminal device; and</li> <li>• Fan configuration for multiple deck systems.</li> </ul>
<i>Units</i>	None
<i>Input Restrictions</i>	As designed. List: <ul style="list-style-type: none"> <li>PTAC – Packaged Terminal Air Conditioner</li> <li>PTHP – Packaged Terminal Heat Pump</li> <li>PSZ-AC – Packaged Single Zone Air Conditioner</li> <li>PSZ-HP – Packaged Single Zone Heat Pump</li> <li>PVAV – Packaged VAV with Reheat</li> <li>VAV – VAV with Reheat</li> </ul>



PSZVAV – Packaged Single Zone VAV  
 PSZVAVHP – Packaged Single Zone VAV Heat Pump  
 HV – Heating and Ventilation Only  
 CRAC – Computer Room Air Conditioner  
 CRAH – Computer Room Air Handler  
 FPFC – Four-Pipe Fan Coil  
 DFDD – Dual-Fan Dual Duct  
 RADFLR – Radiant Floor Heating And Cooling  
 WSHP – Water-Source Heat Pump

*Baseline Building* Based on the prescribed system type in the HVAC system map. The baseline system types are shown in the table below.

**Table 39.** Baseline Building System Type

System Number	System Type
1	PTAC
2	PTHP
3	PSZ AC
4	PSZ HP
5	PVAV reheat
6	Packaged VAV with PFP boxes
7	VAV with reheat
8	VAV with PFP boxes
9	Heating and ventilation
10	Heating and ventilation

***Air Distribution Type***

*Applicability* All system types  
*Definition* Type of air distribution system that is coupled with the HVAC system. The choices are (overhead) mixing ventilation system, UFAD, and DV system.  
*Units* List: Mixing, UFAD, DV  
*Input Restrictions* As designed  
*Baseline Building* Mixing

### ***Thermal Zone List***

<i>Applicability</i>	All system types
<i>Definition</i>	Comprehensive list of all thermal zones served by a given HVAC system
<i>Units</i>	None
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	For systems 1, 2, 3, 4, 9, and 10, each zone shall have its own system. For systems 5, 6, 7, and 8, all zones on each floor shall be assigned to a single system.

### ***Total Cooling Capacity***

<i>Applicability</i>	All system types
<i>Definition</i>	The installed cooling capacity of the project. This includes all: <ul style="list-style-type: none"><li>• Chillers,</li><li>• Built-up DX, and</li><li>• Packaged cooling units.</li></ul>
<i>Units</i>	Cooling tons
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Autosize. The cooling capacity shall be oversized by 15%. If the number of UMLH exceeds 150, increase the cooling capacity according to the procedures in Chapter 2.

### ***Total Heating Capacity***

<i>Applicability</i>	All system types
<i>Definition</i>	The installed cooling capacity of the project. This includes all: <ul style="list-style-type: none"><li>• Boilers,</li><li>• Electric Resistance,</li><li>• Heat Pumps,</li><li>• Gas Furnaces.</li></ul>
<i>Units</i>	Btu/hr
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Autosize. The heating capacity shall be oversized by 25%. If the number of UMLH exceeds 300, increase the heating capacity according to the procedures in Chapter 2.

## 3.6.2 System Controls

### 3.6.2.1 Control System Type

<i>Control System Type</i>	
<i>Applicability</i>	All buildings
<i>Definition</i>	<p>The type of control system for the building. This input affects baseline system specification for zone level controls, SAT reset controls, ventilation controls and fan and pump static pressure part-load curves. See the following building descriptors:</p> <ul style="list-style-type: none"><li>• Ventilation Control Method (Section 3.6.5 of this document)</li><li>• Terminal Heating Control Type (Section 3.6.2 of this document)</li><li>• Supply Air Temperature Reset Controls (Section 3.7.2.3 of this document)</li><li>• Pump Part-Load Curve (Section 3.8.5 of this document)</li><li>• Fan Part-load Curve (Section 3.7.3 of this document)</li><li>• Static Pressure Controls (Section 3.7.3 of this document)</li><li>• Dehumidification and Humidification Controls (Section 3.7.7 of this document)</li></ul>
<i>Units</i>	None
<i>Input Restrictions</i>	As designed. Refer to the individual sections mentioned above for applicable input restrictions.
<i>Baseline Building</i>	Refer to the individual sections mentioned above for applicable baseline building requirements.

### 3.6.2.2 Schedules

<i>Cooling Schedule</i>	
<i>Applicability</i>	All cooling systems
<i>Definition</i>	A schedule that represents the availability of cooling
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	<p>Schedules should be typical of the proposed building type or as assumed for the building design. The cooling availability schedule shall be consistent with the supply fan schedule and thermostat schedules to reduce the likelihood of UMLH. This schedule is not needed for all simulation tools. Other methods (outdoor conditions, zone conditions) may be used to control cooling availability in most systems. If cooling is truly not available during certain times (school vacations, weekends) the zone thermostat cooling setpoints need to be modified to reflect this and the HVAC availability schedule (see below), which defines fan operation based on occupancy, needs to be set to zero.</p>
<i>Baseline Building</i>	Same as the proposed design

### **Heating Schedule**

<i>Applicability</i>	All systems
<i>Definition</i>	A schedule that represents the availability of heating
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	Schedules should be typical of the proposed building type or assumed for the building design. COMNET Appendix C (COMNET, 2011) can be used as a default. When schedules other than the default values are used, supporting documentation shall be required. The heating availability schedule shall be consistent with the supply fan schedule.
<i>Baseline Building</i>	Same as the proposed design

### **HVAC Availability Schedule**

<i>Applicability</i>	All systems
<i>Definition</i>	A schedule that indicates when the air handler operates continuously
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	Schedules should be typical of the proposed building type or assumed for the building design. The fan schedule can be defaulted to the applicable schedule from COMNET Appendix C (COMNET, 2011). Other schedules may be used when detailed information is known about the proposed design.
<i>Baseline Building</i>	Same as the proposed design unless one baseline HVAC system serves a combination of systems in the proposed design with varying HVAC availability schedules. For those systems the HVAC availability schedule is determined by the most inclusive schedule represented in the proposed building design. If the most inclusive schedule does not cover the full range of availability, a hybrid schedule that does shall be created.

### **Air Handler Fan Cycling**

<i>Applicability</i>	All fan systems
<i>Definition</i>	This building descriptor indicates whether the system supply fan operates continuously or cycles with building loads. The fan systems in most commercial buildings operate continuously during occupied hours.
<i>Units</i>	List: Continuous or Cycles with Loads
<i>Input Restrictions</i>	Schedules for HVAC fans that provide outdoor air for ventilation shall run continuously whenever spaces are occupied and shall be cycled on and off to meet heating and cooling loads during unoccupied hours.  Exceptions: <ul style="list-style-type: none"><li>• Where no heating and/or cooling system is to be installed and a heating or cooling system is being simulated only to meet the requirements described in Standard 90.1-2010 PRM, heating and/or cooling system fans shall not be simulated as running continuously during occupied hours but shall be cycled on and off to meet heating and cooling loads during all hours.</li></ul>

- HVAC fans shall remain on during occupied and unoccupied hours in spaces that have health and safety mandated minimum ventilation requirements during unoccupied hours.

*Baseline Building* Same as proposed design except if the proposed building has natural ventilation. HVAC fans should run continuously during occupied hours and cycle on to meet loads during unoccupied hours.

HVAC fans shall remain on during occupied and unoccupied hours in spaces that have health and safety mandated minimum ventilation requirements during unoccupied hours.

### ***Optimal Start Control***

*Applicability* Systems with the control capability for flexible scheduling of system start time based on building loads

*Definition* Optimal start control adjusts the start time of the HVAC unit such that the space is brought to setpoint just prior to occupancy. This control strategy modifies the heating, cooling, and fan schedules.

*Units* Boolean (Yes/No)

*Input Restrictions* As designed

Heating and cooling systems with design air capacities greater than 10,000 cfm served by one or more supply fans are required to have optimum start controls.

*Baseline Building* Heating and cooling systems with design air capacity greater than 10,000 cfm served by one or more supply fans are required to have optimum start controls.

### ***Optimal Start Control: Control Zone***

*Applicability* Systems with optimal start controls that serve multiple zones

*Definition* The zone that governs the start time for applying optimal start controls

*Units* Boolean (Yes/No)

*Input Restrictions* List: “Any Zone,” all zones served by the system

*Baseline Building* Same as proposed

If optimal start controls are not required by the proposed design, but required in the baseline building, then this input will be set to “Any Zone”

### ***Night-Cycle HVAC Fan Control***

*Applicability* All systems

*Definition* The control of an HVAC system that is triggered by the heating or cooling temperature setpoint for thermal zones during periods when the heating, cooling, and fan systems are scheduled to be off. Night cycle control is required for both baseline and proposed buildings in accordance to Standard 90.1-2010, Appendix G, Section G3.1.2.5.

For this control, the space is controlled to the setback or setup temperature only; this control

is not equivalent to a night purge control. The choices are:

- Cycle on call from any zone
- Cycle on call from the primary control zone
- Stay off
- Cycle zone fans (for systems with fan-powered boxes). Restart zone fan on a call for heating (see Section 3.5.5.2). The air handling unit (AHU) primary supply fans do not run to meet night cycle heating setpoint, but are required to cycle to satisfy cooling demand on a call for cooling from any zone served by the system.

<i>Units</i>	None
<i>Input Restrictions</i>	HVAC fans shall be cycled on and off to meet heating and cooling loads during unoccupied hours. Exception: <ul style="list-style-type: none"><li>• HVAC fans shall remain on during unoccupied hours in spaces that have health and safety mandated minimum ventilation requirements during unoccupied hours.</li></ul>
<i>Baseline Building</i>	Same as proposed design

### 3.6.2.3 Cooling Control

#### *Cooling Supply Air Temperature*

<i>Applicability</i>	Applicable to all systems
<i>Definition</i>	The SAT setpoint at design cooling conditions
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	20°F below the space temperature setpoint, except in laboratories, where it is to be set at 17°F below the space temperature

#### *Cooling Supply Air Temperature Control*

<i>Applicability</i>	Any cooling system
<i>Definition</i>	The method of controlling the SAT. Choices are: <ul style="list-style-type: none"><li>• No control – for this scheme the cooling coils are energized whenever there is a call for cooling</li><li>• Fixed (constant)</li><li>• Reset by warmest zone, airflow first</li></ul>

This control strategy resets the cooling SAT of a central forced air HVAC system according to the cooling demand of the warmest zone. The airflow first control approach tries to find the lowest supply airflow rate that will satisfy all the zone cooling

loads at the maximum setpoint temperature. If this flow is greater than the maximum, the flow is set to the maximum and the setpoint temperature is reduced to satisfy the cooling loads. The airflow first strategy minimizes zone reheat coil energy (or overcooling) and central chiller energy consumption at the cost of possible increased fan energy.

- Reset by warmest zone, temperature first

This control strategy resets the cooling SAT of a central forced air HVAC system according to the cooling demand of the warmest zone. The temperature first control approach tries to find the highest setpoint temperature that will satisfy all the zone cooling loads at the minimum supply airflow rate. If this setpoint temperature is less than the minimum, the setpoint temperature is set to the minimum, and the supply airflow rate is increased to meet the loads.

The temperature first strategy minimizes fan energy consumption at the cost of possible increased zone reheat coil energy (or overcooling) and central chiller energy consumption.

- Reset by outside air dry-bulb temperature
- Scheduled setpoint
- Staged setpoint (for single zone VAV and DX with multiple stages)

*Units* List (see above)

*Input Restrictions* As designed

*Baseline Building* For baseline building systems 1 through 4, there is no SAT control. The cooling coil modulates based on the zone thermostat setpoint.

For systems 5 through 8, the air temperature for cooling shall be reset higher by 5°F under the minimum cooling load conditions using a reset by warmest zone, airflow first strategy.

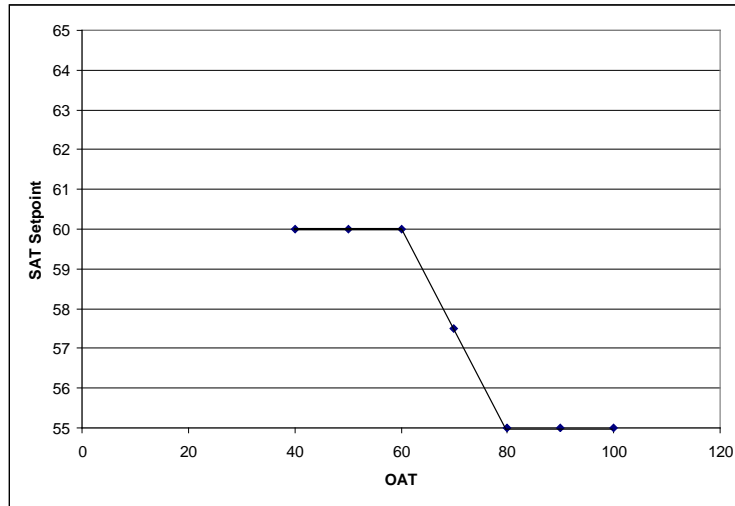
For systems 9 and 10 (heating and ventilation), this input is not applicable.

### ***Cooling Reset Schedule by Outside Air Temperature***

*Applicability* When the proposed design resets SAT by outside air dry-bulb temperature

*Definition* A linear reset schedule that represents the SAT setpoint as a function of outdoor air dry-bulb temperature. This schedule is defined by the following data points (see Figure 10):

- The coldest cooling SAT
- The corresponding (hot) outdoor air dry-bulb setpoint
- The warmest cooling SAT
- The corresponding (cool) outdoor air dry-bulb setpoint



**Figure 10.** SAT Cooling Setpoint Reset based on Outdoor Air Temperature (OAT)

- Units*                      Data structure (two matched pairs of SAT and OAT, see above)
- Input Restrictions*      As designed
- Baseline Building*        Not applicable

### 3.6.2.4 Heating Control

This section addresses building descriptors related to heating and preheating control. Section 3.6.6 addresses all other details related to heating systems.

#### ***Preheat Setpoint***

- Applicability*            Systems with a preheat coil located in the outside air or mixed air stream
- Definition*                The control temperature leaving the preheat coil
- Units*                        Degrees Fahrenheit (°F)
- Input Restrictions*      As designed
- Baseline Building*        The baseline will be modeled with preheat coil in the mixed air stream controlled to a fixed setpoint 20°F less than the design room heating temperature setpoint



### ***Heating Supply Air Temperature***

<i>Applicability</i>	All systems
<i>Definition</i>	The SAT leaving the air handler when the system is in design heating mode (not the air temperature leaving the reheat coils in VAV boxes)
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	20°F above space temperature setpoint for systems 1 through 4. Same as maximum reset cooling SAT for systems 5 through 8 and 105°F for systems 9 and 10.

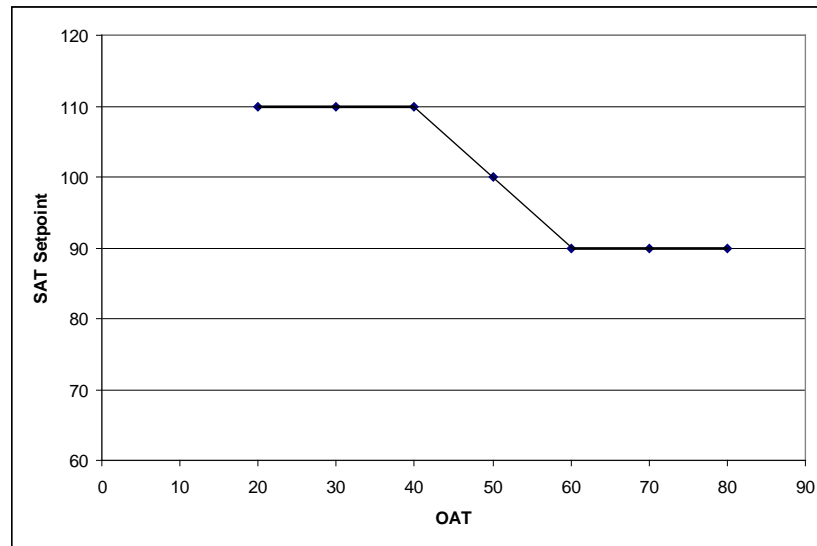
### ***Heating Supply Air Temperature Controls***

<i>Applicability</i>	Systems with the capability to vary heating SAT setpoint
<i>Definition</i>	<p>The method of controlling heating SAT. Choices are:</p> <ul style="list-style-type: none"><li>• No control – the heating coil is energized on a call for heating, and the SAT is not directly controlled, but instead is dependent on the entering air temperature, the heating capacity and the airflow rate</li><li>• Fixed (constant)</li><li>• Reset by coldest zone, airflow first</li><li>• Reset by coldest zone, temperature first</li><li>• Reset by outside air dry-bulb temperature</li><li>• Staged setpoint</li><li>• Scheduled setpoint</li></ul>
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	No control is specified for heating SAT for systems 1 through 4 and 9 and 10. For systems 5 through 8, the heating SAT is fixed to the maximum reset cooling SAT.

### ***Heating Reset Schedule by Outside Air***

<i>Applicability</i>	Systems that reset the heating SAT by outside dry-bulb temperature (this typically applies to dual-duct systems or to single zone systems with hydronic heating coils)
<i>Definition</i>	<p>A linear reset schedule that represents the heating SAT or hot deck SAT (for dual duct systems) as a function of outdoor air dry-bulb temperature. This schedule is defined by the following data points (see Figure 11):</p> <ul style="list-style-type: none"><li>• The hottest heating SAT</li><li>• The corresponding (cold) outdoor air dry-bulb threshold</li><li>• The coolest heating SAT</li></ul>

- The corresponding (mild) outdoor air dry-bulb threshold



**Figure 11.** Example of SAT Heating Setpoint Reset based on Outdoor Air Temperature.

*Units* Data structure (°F)

*Input Restrictions* As designed

*Baseline Building* Not applicable

### 3.6.2.5 Night Purge

The baseline building does not have night purge controls. If the software supports it and the proposed design has the features, the following keywords may be used to model night purge. Note that night purge is coupled with thermal mass in the building, which is specified by other building descriptors.

#### *Night Purge Availability Schedule*

*Applicability* Systems that operate the fans for nighttime purge of heat gains

*Definition* A schedule that represents the availability of night purge controls

*Units* Data structure: schedule, on/off

*Input Restrictions* As designed. The default is no night purge control.

*Baseline Building* Not applicable

### ***Night Purge Control***

<i>Applicability</i>	Systems that operate the fans for nighttime purge of heat gains
<i>Definition</i>	The control strategy for operation of nighttime purge. The control strategy may account for indoor temperature, season, and other factors.
<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Night Purge Fan Ratio***

<i>Applicability</i>	Systems that operate the fans for nighttime purge of heat gains
<i>Definition</i>	The ratio of fan speed for a night purge cycle
<i>Units</i>	Fraction (0 to 1)
<i>Input Restrictions</i>	As designed. The default is 100% (or fans available at full speed).
<i>Baseline Building</i>	Not applicable

## **3.6.3 Fan Systems**

### **3.6.3.1 Baseline Building Fan System Summary**

The baseline building fan system is summarized in this section. See Table 1 for the HVAC baseline building system mapping.

Total baseline building fan system power for the baseline building fan systems is given in the following sections as well as Table 41 and Table 42. Table 40 summarizes all descriptors for fan systems and their applicability to supply, return/relief, and exhaust fans.

- In these tables, CFM<sub>s</sub> is the supply fan airflow at peak design conditions.
- This brake horsepower includes the supply fan, the return fan, and exhaust fans.
- Exhaust fans include kitchen hoods, toilets, fume hoods, and other miscellaneous fans that operate at design conditions.

When the proposed design has return fans, exhaust fans (toilets or kitchens), or fume hood exhaust systems, the baseline building has the same systems.

**Table 40. Building Descriptor Applicability for Fan Systems**

Inputs	Supply Fan	Return/Relief Fan	Exhaust Fans (Hoods)
Modeling Method	✓	Same as supply	✓
Air Rated Capacity	✓	✓	✓
Plenum Zone	X	✓	X
Return Air Path	X	✓	X
Fan Control Method	✓	Same as supply	✓
Brake Horsepower	✓	✓	✓
Static Pressure	✓	✓	✓
Fan Efficiency	✓	✓	✓
Motor Efficiency	✓	✓	✓
Fan Position	✓	X	X
Motor Position	✓	✓	X
Part-Load Power Curve	✓	✓	✓
Fan KW	✓	✓	✓

**Table 41. Baseline Fan System Details for Systems Using the Brake Horsepower Method**

	Systems 1-2	Systems 3-4	Systems 5-8	Systems 9-10
Brake Horsepower (bhp)	Not applicable	$0.00094 \times \text{CFMs} + A$	$0.0013 \times \text{CFMs} + A$	Not applicable
Fan Motor Efficiency ( $\eta_m$ )	80%	Standard 90.1-2010, Table 10.8*	Standard 90.1-2010, Table 10.8*	80%
Fan Power (W)	$0.3 \times \text{CFMs}$	$(\text{bhp} \times 746)/\eta_m$	$(\text{bhp} \times 746)/\eta_m$	$0.3 \times \text{CFMs}$ OR $0.054 \times \text{CFM}_{\text{nmc}}^{**}$

The term “A” for system types 3 through 8 is calculated based on equipment in the proposed design using the procedure in Table 6.5.3.1.1 of ASHRAE Standard 90.1-2010. This accounts for various additional fan pressure drops associated with special conditions.

\*Fan motor efficiency is the efficiency from Table 10.8 of Standard 90.1-2010 for the next motor size greater than the bhp using a totally enclosed fan cooled motor at 1,800 RPM.

\*\*CFM<sub>nmc</sub> is the baseline non-mechanical cooling fan airflow in cfm. This alternate equation is only used if there is a non-mechanical cooling system in place.

**Table 42.** Baseline System Details for Systems using Static Pressure Method

	cfm Range	DPD (Design Pressure Drop) in w.c.	Fan Efficiency	Motor Efficiency $\eta_m$	bhp	Fan Power (kW)
Systems 1, 2, 9 and 10	All	1.33	65%	80%	$DPD / (6356 \times 0.65) = 0.00032$	$(bhp \times 746) / \eta_m$
Systems 9 and 10 (non-mechanical cooling fan if required by 90.1-2010)	All	0.24	65%	80%	$DPD / (6356 \times 0.65) = 0.000058$	$(bhp \times 746) / \eta_m$
Systems 3 and 4	All	4.09	65%	Table 10.8 of Standard 90.1-2010	$DPD / (6356 \times 0.65) = 0.00099$	$(bhp \times 746) / \eta_m$
Systems 5 through 8	All	5.58	65%	Table 10.8 of Standard 90.1-2010	$DPD / (6356 \times 0.65) = 0.00135$	$(bhp \times 746) / \eta_m$

***Process and Filtration Pressure Drop***

<i>Applicability</i>	Any system with special requirements for filtration or other process requirements
<i>Definition</i>	Additional system pressure drop related to application-specific filtration requirements or other process requirements. Special documentation requirements may apply.
<i>Units</i>	List
<i>Input Restrictions</i>	Default is 0. Special documentation is required to claim any credit for filtration or other process requirements. Filtration shall be associated with process requirements (such as clean room or hospital areas).
<i>Baseline Building</i>	Calculated from Section 6.5.3.1.1 of Standard 90.1-2010 for baseline system fans

**Table 43. Baseline Building: Fan Power Limitation Pressure Drop Adjustment**

Device	Adjustment
<b>Credits</b>	
Fully ducted return and/or exhaust air systems	0.5 in. w.c. (2.15 in. w.c. for laboratory and vivarium systems)
Return and/or exhaust airflow control devices	0.5 in. w.c.
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate filtration credit: MERV 9 through 12	0.5 in. w.c.
Particulate filtration credit: MERV 13 through 15	0.9 in. w.c.
Particulate filtration credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at 2x clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Biosafety cabinet	Pressure drop of device at fan system design condition
Energy recovery device and other coil runaround loop	(2.2 × Energy Recovery Effectiveness)—0.5 in w.c. for each airstream
Coil runaround loop	0.6 in. w.c. for each airstream
Evaporative humidifier/cooler in series with another cooling coil	Pressure drop of device at fan system design condition
Sound attenuation section	0.15 in. wc.
Exhaust systems serving fume hoods	0.35 in. wc.
Laboratory and vivarium exhaust systems in high-rise buildings	0.25 in. wc./100 ft of vertical duct exceeding 75 ft.

***Pressure Drop Adjustment***

<i>Applicability</i>	All fan systems with special requirements for filtration or other process requirements
<i>Definition</i>	Standard 90.1-2010 specifies a “pressure drop adjustment” for fan systems with requirements for filtration or other process requirements.
<i>Units</i>	List
<i>Input Restrictions</i>	Derived from other building descriptors
<i>Baseline Building</i>	Pressure drop adjustment is calculated separately for each applicable device. Credit for each device is specified in the section above.

$$A = \text{sum of } (PD \times CFM_d / 4131)$$

Where:

- $PD$  = Each applicable pressure drop adjustment from the proposed design
- $CFM_d$  = The design airflow through each applicable device in cfm from the baseline building

### ***Fan Ratio***

<i>Applicability</i>	Systems that serve thermal blocks that have exhaust, fume hoods, kitchen exhaust, or return fans
<i>Definition</i>	The ratio of supply fan brake horsepower in the proposed design to total fan system brake horsepower for the proposed design at design conditions.
<i>Units</i>	Unitless fraction (0 to 1)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed

### ***Return Fan Ratio***

<i>Applicability</i>	Systems that serve thermal blocks that have exhaust, fume hoods, kitchen exhaust, or return fans
<i>Definition</i>	The ratio of return fan brake horsepower in the proposed design to total fan system brake horsepower for the proposed design at design conditions
<i>Units</i>	Unitless fraction (0 to 1)
<i>Input Restrictions</i>	Derived from other building descriptors
<i>Baseline Building</i>	Same as proposed

### ***Exhaust Fan Ratio***

<i>Applicability</i>	Systems that serve thermal blocks that have exhaust, fume hoods, kitchen exhaust, or return fans
<i>Definition</i>	<p>The ratio of exhaust fan brake horsepower in the proposed design to total fan system brake hp for the proposed design at design conditions. Exhaust fans include toilet exhaust, kitchen hoods, and other miscellaneous exhaust.</p> <p>For fan systems with multiple exhaust fans, the exhaust fan ratios shall be calculated separately for each exhaust fan.</p>
<i>Units</i>	Unitless ratio
<i>Input Restrictions</i>	Derived from other building descriptors. In the event that a common exhaust system serves thermal blocks that are served by different HVAC systems, the brake horsepower shall be divided in proportion to design cfm.
<i>Baseline Building</i>	Same as proposed

### 3.6.3.2 Supply Fans

#### *Fan System Modeling Method*

<i>Applicability</i>	All fan systems
<i>Definition</i>	Software commonly models fans in three ways. The simple method is for the user to enter the electric power per unit of flow (W/cfm). This method is commonly used for unitary equipment and other small fan systems. A more detailed method is to model the fan as a system whereby the static pressure, fan efficiency, and motor efficiency are specified at design conditions. A third method is to specify brake horsepower at design conditions instead of fan efficiency and static pressure. This is a variation of the second method whereby brake horsepower is specified in lieu of static pressure and fan efficiency.
<i>Units</i>	List: Power-Per-Unit-Flow, Static Pressure, or Brake Horsepower
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Baseline building shall use the bhp method

#### *Supply Fan Design Air Rated Capacity*

<i>Applicability</i>	All fan systems
<i>Definition</i>	The design airflow rate of the supply fan(s) at design conditions. This building descriptor sets the 100% point for the fan part-load curve.
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed. For multiple deck systems, a separate entry should be made for each deck.
<i>Baseline Building</i>	<p>The program shall automatically size the airflow at each thermal zone to meet the loads. The design airflow rate calculation shall be based on a 20°F temperature differential between the supply air and the return air for zones. The design supply airflow rate is the larger of the flow rate required to meet space conditioning requirements and the required ventilation flow rate. (The ventilation requirements may dictate supply airflow rate requirements for laboratory spaces and other spaces with special process requirements.) The supply fan design airflow rate shall be the sum of the calculated design airflow for the thermal zones served by the fan system.</p> <p>For laboratory spaces, the design airflow rate calculation shall be based on a 17°F temperature differential rather than 20°F. For baseline systems 9 and 10, the design airflow rate calculation shall be based on a SAT setpoint of 105°F.</p> <p>For baseline systems 9 and 10, the design supply airflow rates shall be based on the temperature difference between a SAT setpoint of 105°F and the design space heating temperature setpoint, the minimum outdoor airflow rate or the airflow rate required to comply with applicable codes, whichever is greater.</p>



### ***Fan Control Method***

<i>Applicability</i>	All fan systems
<i>Definition</i>	A description of how the supply (and return/relief) fan(s) is controlled. The options include: <ul style="list-style-type: none"> <li>• Constant volume</li> <li>• Variable-flow, inlet or discharge dampers</li> <li>• Variable-flow, inlet guide vanes</li> <li>• Variable-flow, variable speed drive (VSD)</li> <li>• Variable-flow, variable pitch blades</li> <li>• Variable-flow, other</li> <li>• Two-speed</li> <li>• Constant volume, cycling (fan cycles with heating and cooling)</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Based on the baseline system type, summarized in Table 44.

**Table 44.** Baseline Building Fan Control Method

System No.	System Type	Fan Control
System 1	Package terminal air conditioner	Constant volume
System 2	Packaged terminal heat pump	Constant volume
System 3	Packaged roof top air conditioner	Constant volume
System 4	Packaged roof top heat pump	Constant volume
System 5	Packaged rooftop VAV with reheat	Variable volume, variable speed drive (VSD)
System 6	Packaged rooftop VAV with PFP boxes and reheat	Variable volume, VSD
System 7	Packaged rooftop VAV with reheat	Variable volume, VSD
System 8	VAV with parallel fan-powered boxes and reheat	Variable volume, VSD
System 9	Warm air furnace, gas fired	Constant volume
System 10	Warm air furnace, electric	Constant volume

### ***Supply Fan Brake Horsepower***

<i>Applicability</i>	All fan systems, except those specified using the power-per-unit-flow method
<i>Definition</i>	The design shaft brake horsepower of the supply fan(s). This input does not need to be supplied if the supply fan kW is supplied.
<i>Units</i>	Horsepower (hp)
<i>Input Restrictions</i>	As designed. If this building descriptor is specified for the proposed design, then the static pressure and fan efficiency are not required.

*Baseline Building* Fans for parallel fan-powered boxes are not included in fan power calculations. Table 41 of this document gives the baseline building fan system brake horsepower. The brake horsepower for the supply fan is this value times the supply fan ratio (see above).

### **Supply Fan Static Pressure**

*Applicability* All fan systems, except those specified using the power-per-unit-flow method

*Definition* The design static pressure for the supply fan. This is important for both fan electric energy usage and duct heat gain calculations.

*Units* Inches of water column (in. H<sub>2</sub>O)

*Input Restrictions* As designed. The design static pressure for the supply fan does not need to be specified if the supply fan brake horsepower (bhp) is specified.

*Baseline Building* The baseline building is defined by Table 45. This approach only works if the system has only a supply fan. If return/exhaust fans are also present in the system, then the supply fan bhp needs to be calculated and divided amongst the supply, return, and exhaust fans.

**Table 45.** Fan Static Pressure Drop for Baseline Systems

System	cfm Range	DPD (Design Pressure Drop) in w.c.
Systems 1, 2, 9 and 10	All	1.33
Systems 3 and 4	All	4.09
Systems 5 through 8	All	5.58
Ventilation fan for nmc	All	0.24

Supply fan static pressure = (Supply fan BHP × 6356 × 0.65)/cfm<sub>s</sub>

Total system static pressure is determined in accordance with Table 42 according to baseline system type.

### **Supply Fan Efficiency**

*Applicability* All fan systems, except those specified using the power-per-unit-flow method

*Definition* The efficiency of the fan at design conditions; this is the static efficiency and does not include motor losses

*Units* Unitless

*Input Restrictions* As designed. The supply fan efficiency does not need to be specified if the supply fan brake horsepower (bhp) is specified.

*Baseline Building* The baseline supply fan efficiency shall be 65%.

### **Supply Motor Efficiency**

<i>Applicability</i>	All supply fans, except those specified using the power-per-unit-flow method
<i>Definition</i>	The full-load efficiency of the motor serving the supply fan
<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed. Not applicable when the power-per-unit-flow method is used.
<i>Baseline Building</i>	For systems 1,2, 9, and 10, motor efficiency is assumed to be 80%. The motor efficiency for systems 3 through 8 is determined from Table 10.8 of ASHRAE Standard 90.1-2010 (Table 46 of this document) for the next motor size greater than the bhp calculated, through the process described above, using a totally enclosed fan cooled motor at 1800 rpm.

**Table 46.** Minimum Nominal Efficiency for Electric Motors (%)

Motor Horse Power	Motor Efficiency
1	85.5
1.5	86.5
2	86.5
3	89.5
5	89.5
7.5	91.7
10	91.7
15	92.4
20	93.0
25	93.6
30	93.6
40	94.1
50	94.5
60	95.0
75	95.4
100	95.4
125	95.4
150	95.8
200	96.2
250	96.2
300	96.2
350	96.2
400	96.2
450	96.2
500	96.2

### **Fan Position**

<i>Applicability</i>	All supply fans
<i>Definition</i>	The position of the supply fan relative to the cooling coil. The configuration is either draw through (fan is downstream of the coil) or blow through (fan is upstream of the coil).
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Draw through

### Motor Position

<i>Applicability</i>	All supply fans
<i>Definition</i>	The position of the supply fan motor relative to the cooling air stream. The choices are: in the air stream or out of the air stream.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	In the air stream

### Fan Part-Flow Power Curve

<i>Applicability</i>	All variable flow fan systems
<i>Definition</i>	A part-load power curve that represents the percentage full-load power draw of the supply fan as a function of the percentage full-load airflow. The curve is typically represented as a cubic equation with an absolute minimum power draw specified.
<i>Units</i>	Unitless ratio
<i>Input Restrictions</i>	The fan curve shall be selected from Equation (4) and Table 47 for the type of fan specified in the proposed design.

Greater of

$$PLR = a + b \cdot FanRatio + c \cdot FanRatio^2 + d \cdot FanRatio^3$$

$$PLR = PowerMin$$

(4)

Where:

*PLR* = Ratio of fan power at part load conditions to full load fan power

*PowerMin* = Minimum fan power ratio

*FanRatio* = Ratio of cfm at part-load to full-load cfm

*a, b, c* and *d* = Constants from Table 47.

**Table 47.** Fan Curve Default Values

Fan Type - Control Type	A	B	c	d	%Power <sub>Min</sub>
Multi Zone VAV with Airfoil (AF) or Backward Incline (BI) riding the curve <sup>a</sup>	0.1631	1.5901	-0.8817	0.1281	70%
Multi Zone VAV with AF or BI with inlet vanes <sup>a</sup>	0.9977	-0.659	0.9547	-0.2936	50%
Multi Zone VAV with Forward Curved (FC) fans riding the curve <sup>a</sup>	0.1224	0.612	0.5983	-0.3334	30%
Multi Zone VAV with FC with inlet vanes <sup>a</sup>	0.3038	-0.7608	2.2729	-0.8169	30%
Multi Zone VAV with vane-axial with variable	0.1639	-0.4016	1.9909	-0.7541	20%

pitch blades <sup>a</sup>					
Multi Zone VAV with VSD and fixed SP setpoint <sup>b</sup>	0.0013	0.1470	0.9506	-0.0998	20%
Multi zone VAV with static pressure reset <sup>c</sup>	0.04076	0.0881	-0.0729	0.9437	10%
Single zone VAV fan <sup>d</sup>	0.027828	0.026583	-0.087069	1.030920	10%

Data Sources:

a. ECB Compliance Supplement, public review draft, Version 1.2, March 1996, but adjusted to be relatively consistent with the curve specified in the PRM.

b. The fan curve for VSD is specified in Table G3.1.3.15.

c. This is the good SP reset VSD fan curve from the advanced VAV design guide used for SZVAV systems.

d. This is the perfect SP reset VSD fan curve from the advanced VAV design guide used for MZVAV systems.

<http://www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-11.PDF>

**Baseline Building** Not applicable for baseline building systems 1 through 4. The curve for “Multi zone VAV with static pressure reset curve” shall be used for baseline building systems 5 through 8. Constant volume fans are used for systems 9 and 10 and hence the descriptor is not applicable.

#### **Supply Fan Power Index (kW/cfm)**

<b>Applicability</b>	Fan systems that use the power-per-unit-flow method
<b>Definition</b>	The supply fan power per unit of flow
<b>Units</b>	kW/cfm
<b>Input Restrictions</b>	As designed or specified in the manufacturers’ literature
<b>Baseline Building</b>	Applicable when the baseline building uses the power-per-unit-flow method. Fan power is determined using Table 41 of this document. This power is then multiplied by the supply fan ratio.

#### **Static Pressure Reset Controls**

<b>Applicability</b>	All VAV fan systems. Baseline systems 5 through 8.
<b>Definition</b>	Static pressure reset controls, reset the fan static pressure for VAV systems-based zone damper position. For systems with DDC of individual zone boxes reporting to the central control panel, static pressure setpoint shall be reset based on the zone requiring the most pressure.
<b>Units</b>	Unitless
<b>Input Restrictions</b>	As designed. If static pressure reset is implemented in the proposed system, the curve for “Multi zone VAV with static pressure reset curve” shall be used.
<b>Baseline Building</b>	Not applicable for baseline building systems 1 through 4 or 9 and 10. The curve for “Multi zone VAV with static pressure reset curve” shall be used for baseline building systems 5 through 8.

### 3.6.3.3 Return/Relief Fans

System design supply airflow rates for the baseline building design shall be based on a supply-air-to-room-air temperature difference of 20°F or the minimum outdoor airflow rate, or the airflow rate required to comply with applicable codes or accreditation standards, whichever is greater. For Systems 3 and 4, if return or relief fans are specified for systems serving the corresponding zones in the proposed design, the baseline building design shall also be modeled with fans serving the same functions. For Systems 5 through 8, if return or relief fans are specified in the proposed building, then the baseline systems serving the corresponding zones will be modeled with a return/relief fan.

#### ***Plenum Zone***

<i>Applicability</i>	Any system with return ducts or return air plenum
<i>Definition</i>	A reference to the thermal zone that serves as return plenum or where the return ducts are located
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Applicable when the baseline building has a return fan. Same as the proposed design when the proposed design has a plenum; otherwise, the return air ducts are assumed to be located in the space.

#### ***Return Air Path***

<i>Applicability</i>	Any system with return ducts or return air plenum
<i>Definition</i>	Describes the return path for air. This can be one of the following: ducted return; plenum return; or direct-to-unit.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>baseline building</i>	For baseline building systems 1 and 2, the return air path shall be direct-to-unit. For baseline building systems 3 through 8 and when the proposed design is direct-to-unit, the baseline building shall be ducted return, otherwise the baseline building return air path shall be the same as proposed design.

#### ***Return/Relief Air Rated Capacity***

<i>Applicability</i>	All systems with a return or relief fan
<i>Definition</i>	The design airflow fan capacity of the return or relief fan(s). This sets the 100% fan flow point for the part-load curve (see below).
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Applicable when the baseline building has a return fan. Return or relief fans shall be sized

for the baseline system supply fan air quantity less the minimum outdoor air, or 90% of the supply fan air quantity, whichever is larger.

#### ***Return/Relief Fan Brake Horsepower***

<i>Applicability</i>	Any system with return or relief fans that uses the brake horsepower method
<i>Definition</i>	The design shaft brake horsepower of the return/relief fan(s)
<i>Units</i>	Brake horsepower (bhp)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Applicable when the baseline building has a return fan. The bhp of the return fan shall be the system fan brake horsepower multiplied by the return fan ratio. In other words, brake horsepower is allocated in proportion to the proposed design.

#### ***Return/Relief Design Static Pressure***

<i>Applicability</i>	Any system with return or relief fans that uses the static pressure method
<i>Definition</i>	The design static pressure for return fan system. This is important for both fan electric energy usage and duct heat gain calculations.
<i>Units</i>	Inches of water column (in. H <sub>2</sub> O gauge)
<i>Input Restrictions</i>	As designed. The design static pressure for the return fan does not need to be specified if the return fan brake horsepower (bhp) is specified.
<i>Baseline Building</i>	Return fan static pressure = (Return fan BHP × 6356 × 0.65)/cfm return

#### ***Return/Relief Fan Efficiency***

<i>Applicability</i>	Any system with return or relief fans that uses the static pressure method
<i>Definition</i>	The efficiency of the fan at design conditions; this is the static efficiency and does not include the efficiency loss of the motor.
<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed. The return/relief fan efficiency does not need to be specified if the return fan brake horsepower (bhp) is specified.
<i>Baseline Building</i>	65%

### ***Return/Relief Motor Efficiency***

<i>Applicability</i>	All return fans, except those specified using the power-per-unit-flow method
<i>Definition</i>	The full-load efficiency of the motor serving the supply fan
<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed. Not applicable when the power-per-unit-flow method is used.
<i>Baseline Building</i>	For baseline systems 1, 2, 9, and 10 is 80%. For baseline systems 3 through 8, fan motor efficiency is determined from Table 10.8 of Standard 90.1-2010 for the next motor size greater than the bhp calculated, through the process described above, using a totally enclosed fan motor at 1800 rpm.

### ***Motor Position***

<i>Applicability</i>	All return fans
<i>Definition</i>	The position of the supply fan motor relative to the cooling air stream. The choices are in the air stream or out of the air stream.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	In the air stream

### ***Fan Part-Flow Power Curve***

<i>Applicability</i>	All return fans for variable flow fan systems
<i>Definition</i>	A part-load power curve that represents the percentage full-load power draw of the return fan as a function of the percentage full-load airflow
<i>Units</i>	Unitless ratio
<i>Input Restrictions</i>	As designed. The default fan curve shall be selected from Equation (4) and Table 47 for the type of fan specified in the proposed design.
<i>Baseline Building</i>	Not applicable for baseline building systems 1 through 4. The curve for “Multi zone VAV with static pressure reset curve” shall be used for Baseline Building systems 5 through 8.

### ***Return/Relief Fan Power Index***

<i>Applicability</i>	Any system with a return fan
<i>Definition</i>	The return fan power per unit of flow
<i>Units</i>	kW/cfm
<i>Input Restrictions</i>	As specified in the manufacturers’ literature
<i>Baseline Building</i>	Applicable when the baseline building uses the power-per-unit-flow method. Fan power is determined using Table 41. This power is then multiplied by the return fan ratio.



### 3.6.3.4 Exhaust Fan Systems

Exhaust fans include toilet, kitchen and laboratory exhaust. Some systems typically operate at constant flow, while flow varies for other systems depending on, for instance, the position of the sash for fume hoods. Exhaust fan flow is specified and scheduled for each thermal zone. An exhaust fan system may serve multiple thermal zones. The baseline building has exhaust fans when the proposed design has exhaust fans. The design exhaust airflow is the same for the baseline building and the proposed building.

#### ***Exhaust Fan Name***

<i>Applicability</i>	All exhaust systems serving multiple thermal zones
<i>Definition</i>	A unique descriptor for each exhaust fan. This should be keyed to the construction documents, if possible, to facilitate plan checking. Exhaust rates and schedules at the thermal zone level refer to this name.
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	Where applicable, this should match the tags that are used on the plans
<i>Baseline Building</i>	The baseline building will have an exhaust system that corresponds to the proposed design. The name can be identical to that used for the proposed design or some other appropriate name may be used.

#### ***Exhaust Fan System Modeling Method***

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	Software commonly models fans in three ways. See definition for supply system modeling method.
<i>Units</i>	List: Power-Per-Unit-Flow, Static Pressure, or Brake Horsepower
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	If the proposed design uses the power-per-unit-flow method, the baseline building shall also use this method, otherwise the baseline building shall use the static pressure method.

#### ***Exhaust Fan Rated Capacity***

<i>Applicability</i>	All exhaust systems
<i>Definition</i>	The rated design airflow rate of the exhaust fan system. This building descriptor defines the 100% flow case for the part-flow curve. Actual airflow is the sum of the flow specified for each thermal zone, as modified by the schedule for each thermal zone.
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as the proposed design except that baseline building kitchen exhaust rate may not exceed the maximum levels defined by Section 3.5.5.3 of this document.

### ***Fan Control Method***

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	A description of how the exhaust fan(s) are controlled. The options include: <ul style="list-style-type: none"><li>• Constant volume</li><li>• Two-speed</li><li>• Variable-flow, inlet or discharge dampers</li><li>• Variable-flow, inlet guide vanes</li><li>• Variable-flow, VSD</li><li>• Variable-flow, variable pitch blades</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed, however, when exhaust fan flow at the thermal zone level is varied through a schedule, one of the variable-flow options shall be specified.
<i>Baseline Building</i>	The baseline building exhaust fan control shall generally be the same as the proposed design. Exceptions: <ul style="list-style-type: none"><li>• For laboratories that have exhaust flow of 5,000 cfm or more, the baseline building exhaust flow shall be designed in accordance to Section 3.5.5.3 of this document.</li><li>• For kitchens that have exhaust rate is greater than 5,000 cfm, the baseline building system shall be defined in accordance to Section 3.5.5.3 of this document.</li></ul>

### ***Exhaust Fan Schedule***

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	A schedule that indicates when the exhaust fan system is available for operation. Exhaust fan flow is specified at the thermal zone level.
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as the proposed design for exhaust fans not serving kitchen or laboratory spaces. For kitchen and laboratory zone exhaust, refer to Section 3.5.5.3 of this document.

### ***Exhaust Fan Brake Horsepower***

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	The design shaft brake horsepower of the exhaust fan(s)
<i>Units</i>	Brake horsepower (bhp)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The bhp for the baseline building is the total system fan horsepower from Table 41 of this

document multiplied by the exhaust fan ratio.

#### ***Exhaust Fan Design Static Pressure***

<i>Applicability</i>	Any system with return or relief fans that uses the static pressure method
<i>Definition</i>	The design static pressure for exhaust fan system. This is important for both fan electric energy usage and duct heat gain calculations.
<i>Units</i>	Inches of water column (in. H <sub>2</sub> O)
<i>Input Restrictions</i>	As designed for exhaust fans not serving kitchens. The design static pressure for the exhaust fan does not need to be specified if the exhaust fan bhp is specified.
<i>Baseline Building</i>	The exhaust fan static pressure for the baseline building would be equal to the total fan system static pressure (specified in section Supply Fan Static Pressure) multiplied by the exhaust fan ratio.  Exhaust Fan Static Pressure = (Exhaust Fan BHP × 6356 × 0.65)/cfm exhaust

#### ***Exhaust Fan Efficiency***

<i>Applicability</i>	Any exhaust fan system that uses the static pressure method
<i>Definition</i>	The efficiency of the exhaust fan at rated capacity; this is the static efficiency and does not include losses through the motor
<i>Units</i>	Unitless
<i>Input Restrictions</i>	For kitchen exhaust fans, the fan efficiency is prescribed at 50%.  For all other exhaust fans, as designed. The exhaust fan efficiency does not need to be specified if the return fan bhp is specified.
<i>Baseline Building</i>	For baseline system, fan efficiency is 65%.

#### ***Exhaust Fan Motor Efficiency***

<i>Applicability</i>	All exhaust fan systems
<i>Definition</i>	The full-load efficiency of the motor serving the exhaust fan
<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	From Table 10.8 of Standard 90.1-2010 for the next motor size greater than the bhp calculated, through the process described above, using a totally enclosed fan motor at 1800 rpm.

### ***Fan Part-Flow Power Curve***

<i>Applicability</i>	All variable flow exhaust fan systems
<i>Definition</i>	A part-load power curve that represents the power draw of the exhaust fan as a function of the airflow
<i>Units</i>	Unitless ratio
<i>Input Restrictions</i>	As designed. The default fan curve shall be selected from Equation (4) and Table 47 for the type of fan specified in the proposed design.
<i>Baseline Building</i>	The baseline building fan curve shall be selected from Equation (4) and Table 47 for the type of fan specified in the proposed design.

### ***Exhaust Fan Power Index***

<i>Applicability</i>	All exhaust systems
<i>Definition</i>	The fan power of the exhaust fan per unit of flow. This building descriptor is applicable only with the power-per-unit-flow method.
<i>Units</i>	kW/cfm
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The fan system power from Table 41 multiplied by the exhaust fan ratio

## **3.6.4 Outdoor Air Controls and Economizers**

### **3.6.4.1 Outside Air Controls**

#### ***Maximum Outside Air Ratio***

<i>Applicability</i>	All systems with modulating outside air dampers
<i>Definition</i>	The descriptor is used to limit the maximum amount of outside air that a system can provide as a percentage of the design supply air. It is used where the installation has a restricted intake capacity.
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed. Maximum of 1.0.
<i>Baseline Building</i>	1.0 for all systems with economizers. For others, equal to the ratio of required outdoor air to the peak supply airflow at design conditions.

### ***Design Outside Airflow***

<i>Applicability</i>	All systems with outside air dampers
<i>Definition</i>	The rate of outside air that needs to be delivered by the system at design conditions. This input may be derived from the sum of the design outside airflow for each of the zones served by the system.
<i>Units</i>	cfm
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed. This input along with occupant density determines if the zones served by this system are required to have demand control ventilation. This value might also be different for buildings using the ASHRAE 62.1 Ventilation Rate Procedure as described in Section 3.5.5.5 of this document.  See Section 3.5.5.4 of this document for ventilation control method at the zone level.

### ***Outdoor Air Control Method***

<i>Applicability</i>	All HVAC systems that deliver outside air to multiple zones. (These requirements don't apply to systems supplying air to single zones.)
<i>Definition</i>	<p>The method of determining the amount of outside air that needs to be delivered by the system. Each of the zones served by the system reports its outside air requirements hourly. The options for determining the outside air at the zone level are discussed above. This control method addresses how the system responds to this information hourly. Options include:</p> <ul style="list-style-type: none"><li>• Average flow: The outside air delivered by the system is the sum of the outside air requirement for each zone, without taking into account the position of the VAV damper in each zone. The assumption is that there is mixing between zones through the return air stream.</li><li>• Critical zone: The critical zone is the zone with the highest ratio of outside air to supply air. The assumption is that there is no mixing between zones. This method will provide greater outside air than the average flow method because when the critical zone sets the outside air fraction at the system, the other zones are getting more outside air than required.</li></ul> <p>The quantity of outside air can be controlled in a number of ways, but a common method is to install a flow station at the outside air supply that modulates the position of the outside air and return dampers to maintain the desired outside airflow. With the average flow, a CO<sub>2</sub> sensor in the return air duct is another way to control the position of the outside air and return dampers.</p>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed

### ***Outdoor Air Minimum Flow Schedule***

<i>Applicability</i>	All HVAC systems that deliver outside air
<i>Definition</i>	<p>The schedule shall allow the system to provide the minimum system outdoor air requirements based on a time of day schedule. This input is specifically helpful when ventilation intake needs to be modified for fan cycling operation during unoccupied hours.</p> <p>This schedule would be an “on/off” schedule that determines when the design outside air is supplied by the system.</p>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	<p>Automatic outside air dampers are not required in climate zones 1 through 3; in this case outside air shall be provided anytime the system operates.</p> <p>For climate zones 4 through 8, minimum design ventilation will be provided based on the HVAC availability schedule and outside air dampers shall be closed during night cycle and morning warm-up.</p>

### **3.6.4.2 Air Side Economizers**

#### ***Economizer Control Type***

<i>Applicability</i>	All systems with an air-side economizer
<i>Definition</i>	<p>An air-side economizer increases outside air ventilation during periods when cooling loads can be reduced from increased outside airflow. The control types include:</p> <ul style="list-style-type: none"><li>• No economizer</li><li>• Fixed dry-bulb. The economizer is enabled when the temperature of the outside air is lower than a fixed setpoint.</li><li>• Differential dry-bulb. The economizer is enabled when the temperature of the outside air is lower than the return air temperature.</li><li>• Fixed enthalpy. The economizer is enabled when the enthalpy of the outside air is lower than a fixed setpoint</li><li>• Differential enthalpy. The economizer is enabled when the enthalpy of the outside air is lower than the return air enthalpy.</li><li>• Differential dry-bulb and enthalpy. The economizer is enabled when the outside air dry-bulb is less than the return air dry-bulb AND the outside air enthalpy is less than the return air enthalpy.</li><li>• Fixed dewpoint and dry-bulb. The economizer is enabled when the dewpoint and dry-bulb temperature of the outside air are below the specified setpoints.</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed

*Baseline Building* Outdoor air economizers shall not be included in baseline HVAC systems 1, 2, 9, and 10. Outdoor air economizers shall be included in baseline HVAC systems 3 through 8 based on climate as specified in the table below.

Exceptions: Economizers shall not be included for systems meeting one or more of the exceptions listed below.

- a. Systems that include gas-phase air cleaning to meet the requirements of Section 6.1.2 in Standard 62.1. In the scenario, where there isn't a one-to-one mapping between the systems in the proposed and Baseline Building, all systems serving the zones that qualify for the exception in the proposed building will not have economizers.
- b. Where the use of outdoor air for cooling will affect supermarket open refrigerated casework systems. This exception shall only be used if the system in the proposed design does not use an economizer.
- c. Economizers are not required in hospitals and ambulatory surgery centers, where more than 75% of the air designed to be supplied by the system is to spaces that are required to be humidified above 35°F dew-point temperature to comply with applicable codes or accreditation standards. In all other buildings, where more than 25% of the air designed to be supplied by the system is to spaces that are designed to be humidified above 35°F dew-point temperature to satisfy process needs. This exception does not apply to computer rooms.
- d. Systems serving computer rooms which are baseline systems 3-6 where either:
  - The total design cooling load of all computer rooms in the building is less than 3,000,000 Btu/h
  - The room total design cooling load is less than 600,000 Btu/h
  - The local water authority does not allow cooling towers, or
  - Less than 600,000 Btu/h of computer room cooling equipment capacity is being added to an existing building

Dedicated systems for computer rooms where the computer room in the proposed design does not include an economizer.

**Table 48.** Standard 90.1-2010 Economizer Requirement

System	Economizer Requirement
System 1 – PTAC	None
System 2 – PTHP	None
System 3 – PSZ AC	Fixed dry-bulb None in climate zones 1a, 1b, 2a, 3a, 4a.
System 4 – PSZ HP	Fixed dry-bulb None in climate zones 1a, 1b, 2a, 3a, 4a.
System 5 – PVAV Reheat	Fixed dry-bulb None in climate zones 1a, 1b, 2a, 3a, 4a.
System 6 – PVAV with PFP Boxes	Fixed dry-bulb None in climate zones 1a, 1b, 2a, 3a, 4a.
System 7 – VAV with Reheat	Fixed dry-bulb None in climate zones 1a, 1b, 2a, 3a, 4a.
System 8 – VAV with PFP Boxes	Fixed dry-bulb None in climate zones 1a, 1b, 2a, 3a, 4a.
System 9 – Heating and Ventilation	None
System 10 – Heating and Ventilation	None

### ***Economizer Integration Level***

<i>Applicability</i>	Airside economizers
<i>Definition</i>	<p>This input specifies whether or not the economizer is integrated with mechanical cooling. It is up to the modeling software to translate this into software-specific inputs to model this feature. The input could take the following values:</p> <ul style="list-style-type: none"><li>• Non-integrated: The system runs the economizer as the first stage of cooling. When the economizer is unable to meet the load, the economizer returns the outside air damper to the minimum position and the compressor turns on as the second stage of cooling.</li><li>• Integrated: The system can operate with the economizer fully open to outside air and mechanical cooling active (compressor running) simultaneously, even on the lowest cooling stage.</li></ul>
<i>Units</i>	List
<i>Input Restrictions</i>	List: Non-integrated, Integrated
<i>Baseline Building</i>	Integrated. Standard 90.1-2010 has no minimum requirement for economizer integration.

### ***Economizer High-Temperature Lockout***

<i>Applicability</i>	Systems with fixed dry-bulb economizer
<i>Definition</i>	The outside air setpoint temperature above which the economizer will return to minimum position
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	As specified in accordance with Table 49.

**Table 49.** Economizer High-Limit Shut Off Requirement for 90.1

Climate Zone	High-Limit Shutoff
2b, 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	75°F
5a, 6a	70°F
Others	65°F

### ***Economizer Low-Temperature Lockout***

<i>Applicability</i>	Systems with air-side economizers
<i>Definition</i>	A feature that permits the lockout of economizer operation (return to minimum outside air position) when the outside air temperature is below the lockout setpoint.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not used



### ***Economizer High Enthalpy Lockout***

<i>Applicability</i>	Systems with fixed enthalpy or differential enthalpy economizers
<i>Definition</i>	The outside air enthalpy above which the economizer will return to minimum position
<i>Units</i>	Btu/lb
<i>Input Restrictions</i>	As designed. The default is 28 Btu/lb. (High altitude locations may require different setpoints.) The software shall apply a fixed offset and add 2 Btu/lb to the user-entered value.
<i>Baseline Building</i>	No lockout limit

## **3.6.5 Cooling Systems**

### **3.6.5.1 General**

This group of building descriptors applies to all cooling systems.

### ***Cooling Source***

<i>Applicability</i>	All systems
<i>Definition</i>	The source of cooling for the system. The choices are: <ul style="list-style-type: none"><li>• Chilled water</li><li>• DX</li><li>• Other</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The baseline building cooling source is shown in Table 50. See Section 3.1.2 of this document for HVAC system mapping.

**Table 50.** Cooling Source for Baseline Building System

<b>Baseline Building System</b>	<b>Cooling Type</b>
1 – PTAC	Direct expansion
2 – PTHP	Direct expansion
3 – PSZ AC	Direct expansion
4 – PSZ HP	Direct expansion
5 – PVAV Reheat	Direct expansion
6 – Packaged VAV with PFP Boxes	Direct expansion
7 – VAV with Reheat	Chilled water
8 – VAV with PFP Boxes	Chilled water
9 – Heating and Ventilation	None
10 – Heating and Ventilation	None

## Total Cooling Capacity

**Applicability** All cooling systems

**Definition** The total cooling capacity (both sensible and latent) of a cooling coil or packaged DX system at Air-Conditioning, Heating and Refrigeration Institute (AHRI) conditions. The building descriptors defined in this chapter assume that the fan is modeled separately, including any heat it adds to the air stream. The cooling capacity specified by this building descriptor should not consider the heat of the fan.

Note that most CHW coils, and coils in custom DX equipment, particularly those serving high outside air fractions, will have capacities provided in HVAC schedules and submittals at entering air conditions very different from AHRI conditions. For these units, when entered in software using the following simulation methods, custom performance curves will generally be needed, or the capacities and efficiencies recalculated at the AHRI conditions.

**Units** kBtu/h

**Input Restrictions** As designed. For packaged equipment that has the fan motor in the air stream such that it adds heat to the cooled air, the software shall adjust the *total cooling capacity* as follows:

$$Q_{t,net,rated} = Q_{t,gross,rated} - Q_{fan,rated} \quad (5)$$

Where:

$Q_{t,net,rated}$  = The net total cooling capacity of a packaged unit as rated by AHRI (Btu/h)

$Q_{t,gross,rated}$  = The AHRI rated total cooling capacity of a packaged unit (Btu/h)  
 $Q_{fan,rated}$

$Q_{t,fan,rated}$  = The heat generated by the fan and fan motor (if fan motor is in airstream) at AHRI rated conditions

The heat added by the fan, for packaged systems, would be calculated as follows:

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

$$Input W_{nf} = Q / (COP_{nfcooling} * 3.413)$$

$$Input W_{total} = Q / EER$$

$$W_{fan} = Input W_{total} - Input W_{nf}$$

$$Gross Cooling Capacity (Btu/hr) = Q + W_{fan} * 3.413$$

Where:

$EER$  = Rated EER of packed system at AHRI rating conditions

$Q$  = Net rated capacity of cooling system (Btu/h)

$COP_{nfcooling}$  = Cooling efficiency of packaged HVAC system, which excludes supply fan power

$Input W_{nf}$  = Input power for compressor (excludes power supplied for fan)

$Input W_{total}$  = Input power for total system

$W_{fan}$  = Input power for the supply fan at rated conditions

Fan energy shall be modeled separately according to Section 3.6.3 of this document.

**Baseline Building** The total cooling capacity of the systems in the baseline building is oversized by 15%. Sizing calculations shall be based on 1% design dry-bulb and 1% wet-bulb design conditions. Oversizing would be carried out at zone level where the sizing parameters would be applied to the zone design cooling airflow rates and zone loads. The system sizing calculations would sum the zone design airflow rates to obtain a system level airflow rate. Refer to Section 2.6.2 of this document for more details.

### Sensible Cooling Capacity

**Applicability** All cooling systems

**Definition** The sensible cooling capacity of the coil or packaged equipment at Air-conditioning and Refrigeration Institute (ARI) conditions. The building descriptors defined in this chapter assume that the fan is modeled separately, including any heat it adds to the air stream. The cooling capacity specified by this building descriptor should not consider the heat of the fan.

Note that the sensible heat ratio (SHR) used by some energy simulation tools can be calculated from the sensible cooling capacity and total cooling capacity:

$$\text{SHR} = \text{Sensible Cooling Capacity} / \text{Total Cooling Capacity}$$

**Units** kBtu/h

**Input Restrictions** As designed. For packaged equipment that has the fan motor located in the air stream such that it adds heat to the cooled air, the software shall adjust the *sensible cooling capacity* as follows:

$$Q_{s,adj} = Q_{s,rated} + BHP_{supply} \times 2.545 \quad (6)$$

Where:

$Q_{s,adj}$  = The adjusted sensible cooling capacity of a packaged unit (kBtu/h)

$Q_{s,rated}$  = The ARI rated sensible cooling capacity of a packaged unit (kBtu/h)

$BHP_{supply}$  = The supply fan brake horsepower (bhp) in the proposed building design.

If the number of UMLH in the proposed design exceeds 300, the software shall warn the user to resize the equipment.

**Baseline Building** The sensible cooling capacity of the systems serving baseline building is oversized by 15%. Sizing calculations shall be based on 1% design dry-bulb and 1% wet-bulb design conditions.

### Cooling Capacity Adjustment Curves

**Applicability** All cooling systems

**Definition** The sensible cooling capacity of the coil or packaged equipment at ARI conditions. The building descriptors defined in this chapter assume that the fan is modeled separately, including any heat it adds to the air stream. The cooling capacity specified by this building descriptor should not consider the heat of the fan.

Note that the SHR used by some energy simulation tools can be calculated from the sensible

cooling capacity and total cooling capacity:

$$\text{SHR} = \text{Sensible Cooling Capacity} / \text{Total Cooling Capacity}$$

A curve that represents the available total cooling capacity as a function of rated cooling coil capacity and/or condenser conditions. The common form of these curves is given as follows:

$$Q_{t,available} = \text{CAP\_FT} \times Q_{t,adj} \quad (7)$$

For air-cooled DX

$$\text{CAP\_FT} = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{odb} + e \times t_{odb}^2 + f \times t_{wb} \times t_{odb} \quad (8)$$

For water-cooled DX

$$\text{CAP\_FT} = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{wt} + e \times t_{wt}^2 + f \times t_{wb} \times t_{wt} \quad (9)$$

For chilled water coils

$$\text{CAP\_FT} = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{db} + e \times t_{db}^2 + f \times t_{wb} \times t_{db} \quad (10)$$

Where:

$Q_{t,available}$  = Available cooling capacity at specified evaporator and/or condenser conditions (thousand British thermal units per hour [MBH])

$Q_{t,adj}$  = Adjusted capacity at ARI conditions (Btu/h) (see Equation 5)

$\text{CAP\_FT}$  = A multiplier to adjust  $Q_{t,adj}$

$t_{wb}$  = The entering coil wet-bulb temperature (°F)

$t_{db}$  = The entering coil dry-bulb temperature (°F)

$t_{wt}$  = The water supply temperature (°F)

$t_{odb}$  = The outside-air dry-bulb temperature (°F)

Note: If an air-cooled unit employs an evaporative condenser,  $t_{odb}$  is the effective dry-bulb temperature of the air leaving the evaporative cooling unit.

Software may represent the relationship between cooling capacity and temperature in ways other than the equations given above.

**Table 51.** Cooling Capacity Curve Coefficients

Coefficient	Air Cooled DX		Water Cooled DX		Chilled Water Coils	
	Air-Source (PTAC)	Air-Source (Other DX)	Water-Source (Heat Pump)	Water-Source (Other DX)	Fan-Coil	Other Chilled Water
a	1.1839345	0.8740302	-0.2780377	0.9452633	0.5038866	2.5882585
b	-0.0081087	-0.0011416	0.0248307	-0.0094199	-0.0869176	-0.2305879
c	0.0002110	0.0001711	-0.0000095	0.0002270	0.0016847	0.0038359
d	-0.0061435	-0.0029570	-0.0032731	0.0004805	0.0336304	0.1025812

e	0.0000016	0.0000102	0.0000070	-0.0000045	0.0002478	0.0005984
f	-0.0000030	-0.0000592	-0.0000272	-0.0000599	-0.0010297	-0.0028721

Note: These curves are the DOE-2.1E defaults, except for Water-Source (Other DX), which is taken from the ECB Compliance Supplement, public review draft prepared by the SSPC 90.1 ECB Panel, Version 1.2, March 1996.

<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed. The equations and coefficients given above are the defaults.
<i>Baseline Building</i>	Default curves will be used for baseline building

### **Coil Latent Modeling Method**

<i>Applicability</i>	All DX cooling systems
<i>Definition</i>	The method of modeling coil latent performance at part-load conditions
<i>Units</i>	List
<i>Input Restrictions</i>	One of the following values: Bypass factor – used by DOE-2 based programs NTU-effectiveness – used by EnergyPlus
<i>Baseline Building</i>	Same as proposed

### **Coil Bypass Factor**

<i>Applicability</i>	All DX cooling systems (optional input)
<i>Definition</i>	The ratio of air that bypasses the cooling coil at design conditions to the total system airflow
<i>Units</i>	Ratio
<i>Input Restrictions</i>	Prescribed values as shown in Table 52

**Table 52.** Default Coil Bypass Factors

System Type	Default Bypass Factor
Packaged Terminal Air-conditioners and Heat Pumps	0.241
Other Packaged Equipment	0.190
Multi-Zone Systems	0.078
All Other	0.037

Source : (COMNET, 2011)

<i>Baseline Building</i>	Defaults
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### Coil Bypass Factor Adjustment Curve

**Applicability** All DX cooling systems (optional input)

**Definition** Adjustments for the amount of coil bypass due to the following factors:

- Coil airflow rate as a percentage of rated system airflow
- Entering air wet-bulb temperature
- Entering air dry-bulb temperature
- Part load ratio

**Units** Data structure

**Input Restrictions** Where applicable, prescribed (fixed) simulation engine defaults based on HVAC system type. The following default values shall be used for the adjustment curves:

$$CBF_{adj} = CBF_{rated} \times COIL - BF - FFLOW \times COIL - BF - FT \times COIL - BF - FPLR \quad (11)$$

$$COIL - BF - FFLOW = a + b \times CFMR + c \times CFMR^2 + d \times CFMR^3 \quad (12)$$

$$COIL - BF - FT = a + b \times T_{wb} + c \times T_{wb}^2 + d \times T_{db} + e \times T_{db}^2 + f \times T_{wb} \times T_{db} \quad (13)$$

$$COIL - BF - FPLR = a + b \times PLR \quad (14)$$

Where:

- $CBF_{rated}$  = The coil bypass factor at ARI rating conditions
- $CBF_{adj}$  = The coil bypass factor adjusted for airflow and coil conditions
- $CFMR$  = The ratio of airflow to design airflow
- $COIL-BF-FFLOW$  = A multiplier on the rated coil bypass factor to account for variation in airflow across the coil (take coefficients from Table 53)
- $COIL-BF-FT$  = A multiplier on the rated coil bypass factor to account for a variation in coil entering conditions (take coefficients from Table 54)
- $COIL-BF-FPLR$  = A multiplier on the rated coil bypass factor to account for the part load ratio (take coefficients from Table 55)
- $T_{wb}$  = The entering coil wet-bulb temperature (°F)
- $T_{db}$  = The entering coil dry-bulb temperature (°F)
- $PLR$  = Part load ratio

And the coefficients are listed in the tables below.

**Table 53.** Coil Bypass Factor Airflow Adjustment Factor

Coefficient	COIL-BF-FFLOW (PTAC)	COIL-BF-FFLOW (HP)	COIL-BF-FFLOW (PSZ/other)
a	-2.277	-0.8281602	-0.2542341
b	5.21140	14.3179150	1.2182558
c	-1.93440	-21.8894405	0.0359784
d		9.3996897	

**Table 54.** Coil Bypass Factor Temperature Adjustment Factor

Coefficient	COIL-BF-FT (PTAC)	COIL-BF-FT (HP)	COIL-BF-FT (PSZ, other)
a	-1.5713691	-29.9391098	1.0660053
b	0.0469633	0.8753455	-0.0005170
c	0.0003125	-0.0057055	0.0000567
d	-0.0065347	0.1614450	-0.0129181
e	0.0001105	0.0002907	-0.0000017
f	-0.0003719	-0.0031523	0.0001503

**Table 55.** Coil Bypass Factor Part Load Adjustment Factor

Coefficient	COIL-BF-FPLR (All Systems)
a	0.00
b	1.00

Source: (California Energy Commission 2013)

*Baseline Building* Use defaults as described above

### Cooling Capacity Airflow Adjustment Curve

<i>Applicability</i>	All DX cooling systems using the NTU Effectiveness Coil Latent Modeling Method
<i>Definition</i>	Normalized curve that varies cooling capacity as a function of airflow, which affects system latent capacity
<i>Units</i>	Data structure
<i>Input Restrictions</i>	Where applicable, prescribed (fixed) simulation engine defaults based on HVAC system type. The following default values shall be used for the adjustment curves:

$$CoolCapacity_{adj} = CoolCapacity_{rated} \times COOL-CAP-FFLOW \times COOL-CAP-FT \quad (15)$$

Where:

<i>CFMR</i>	= The ratio of airflow to design airflow
<i>COOL-CAP-FFLOW</i>	= A multiplier on the rated coil capacity to account for variation in airflow across the coil (take coefficients from Table 52)
<i>COOL-CAP-FT</i>	= A multiplier on the rated coil bypass factor to account for a variation in coil entering conditions (take coefficients from Table 53)

The curve takes the form:

$$\text{COOL-CAP-FFLOW} = a + b \times \text{CFMR} + c \times \text{CFMR}^2 + d \times \text{CFMR}^3 \quad (16)$$

And the coefficients are listed in the table below.

**Table 56.** Cooling Capacity Airflow Adjustment Factor

Coefficient	COOL-CAP-FFLOW
a	0.47278589
b	1.2433415
c	-1.0387055
d	0.32257813

Source: (California Energy Commission 2013)

*Baseline Building* Use defaults as described above.

### 3.6.5.2 Direct Expansion

#### *Direct Expansion Cooling Efficiency*

*Applicability* Packaged DX equipment

*Definition* The cooling efficiency of a DX cooling system at ARI rated conditions as a ratio of output over input in Btu/h per W, excluding fan energy. The abbreviation used for this full-load efficiency is EER.

For all unitary and applied equipment where the fan energy is part of the equipment efficiency rating, the equipment COP shall be calculated as follows:

$$\text{COP}_{\text{nfcooling}} = 7.84\text{E-}8 \times \text{EER} \times Q + 0.338 \times \text{EER} \quad (17)$$

$$\text{COP}_{\text{nfcooling}} = -0.0076 \times \text{SEER}^2 + 0.3796 \times \text{SEER} \quad (18)$$

Where:

$\text{COP}_{\text{nfcooling}}$  = Packaged equipment cooling energy efficiency

$Q$  is the AHRI-rated cooling capacity in Btu/h.

EER, SEER, and COP shall be at AHRI test conditions.

Source: (ANSI/ASHRAE/IES, 2013)

Fan energy shall be modeled separately according to Section 3.6.3 of this document.

*Units* Unitless.

*Input Restrictions* As designed. Specify the  $\text{COP}_{\text{nf}}$  as described above based on SEER for packaged equipment with net cooling capacity less than 65,000 Btu/h from manufacturer's literature. For equipment with capacity above 65,000 Btu/h, use EER.

*Baseline Building* Calculate  $\text{COP}_{\text{nfcooling}}$  using the minimum cooling efficiency (EER or SEER) from tables in Standard 90.1-2010, Table 6.8.1A and Table 6.8.1D. Use the minimum efficiency reduction for non-electric heating section types. Use the total net cooling capacity of the baseline



design to determine the size category.

### Direct Expansion Cooling Efficiency Temperature Adjustment Curve

**Applicability** Packaged DX equipment

**Definition** A curve that varies the cooling efficiency of a DX coil as a function of evaporator conditions, condenser conditions, For air cooled DX systems:

$$EIR\_FT = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{odb} + e \times t_{odb}^2 + f \times t_{wb} \times t_{odb} \quad (19)$$

For water cooled DX systems:

$$EIR\_FT = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{wt} + e \times t_{wt}^2 + f \times t_{wb} \times t_{wt} \quad (20)$$

$$P_{operating} = P_{rated} \times EIR\_FPLR \times EIR\_FT \times CAP\_FT \quad (21)$$

Where:

- $PLR$  = Part load ratio based on available capacity (not rated capacity)
- $EIR-FT$  = A multiplier on the EIR to account for the wet-bulb temperature entering the coil and the outdoor dry-bulb temperature
- $Q_{operating}$  = Present load on heat pump (Btu/h)
- $Q_{available}$  = Heat pump available capacity at present evaporator and condenser conditions (in Btu/h)
- $t_{wb}$  = The entering coil wet-bulb temperature (°F)
- $t_{wt}$  = The water supply temperature (°F)
- $t_{odb}$  = The outside-air dry-bulb temperature (°F)
- $P_{rated}$  = Rated power draw at ARI conditions (kW)
- $P_{operating}$  = Power draw at specified operating conditions (kW)

Note: If an air cooled unit employs an evaporative condenser,  $t_{odb}$  is the effective dry-bulb temperature of the air leaving the evaporative cooling unit.

**Table 57.** Cooling System Coefficients for EIR-FT

Coefficient	Water-Source (Heat Pump)	Water-Source (Other)	Air-Source (PTAC)	Air-Source (Other)
a	2.0280385	-1.8394760	-0.6550461	-1.0639310
b	-0.0423091	0.0751363	0.0388910	0.0306584
c	0.0003054	-0.0005686	-0.0001925	-0.0001269
d	0.0149672	0.0047090	0.0013046	0.0154213
e	0.0000244	0.0000901	0.0001352	0.0000497
f	-0.0001640	-0.0001218	-0.0002247	-0.0002096
Rated <sub>CWT</sub>	Max 85°F, Min 60°F	Max 85°F, Min 60°F	NA	NA
Rated <sub>EWBT</sub>	Max 57°F, Min 77°F	Max 57°F, Min 77°F	Max 77°F, Min 57°F	Max 77°F, Min 57°F
Rated <sub>OASDT</sub>	NA	NA	Max 115°F, Min 75°F	Max 115°F, Min 75°F

Source: (California Energy Commission 2013)

<i>Units</i>	Data structure
<i>Input Restrictions</i>	User may input curves or use default curves. If defaults are overridden, the software must indicate that supporting documentation is required on the output forms.
<i>Baseline Building</i>	Use default curves specified above, also documented in COMNET Appendix H (COMNET, 2011).

### **Direct Expansion Part-Load Efficiency Adjustment Curve**

<i>Applicability</i>	Packaged systems with DX cooling
<i>Definition</i>	A normalized performance adjustment curve to the rated efficiency (energy input ratio [EIR]) that describes how the efficiency varies at part-load conditions. At a value of 1 (full load), the normalized efficiency is 1.

The default curves are given as follows as adjustments to the EIR<sup>6</sup>:

$$PLR = \frac{Q_{operating}}{Q_{available}(t_{wb}, t_{odb}/wt)} \quad (22)$$

$$EIR_{FPLR} = a + b \times PLR + c \times PLR^2 + d \times PLR^3$$

$$PLF_{FPLR} = a + b \times PLR + c \times PLR^2 + d \times PLR^3 \quad (23)$$

Where:

*PLR* = Part load ratio based on available capacity (not rated capacity)

*EIR-FPLR* = A multiplier on the EIR to account for the part load ratio

*Q<sub>operating</sub>* = Present load on heat pump (Btu/h)

*Q<sub>available</sub>* = Heat pump available capacity at present evaporator and condenser conditions (in Btu/h)

*t<sub>wb</sub>* = The entering coil wet-bulb temperature (°F)

*t<sub>wt</sub>* = The water supply temperature (°F)

*t<sub>odb</sub>* = The outside-air dry-bulb temperature (°F)

This curve may take the form of a part-load factor (PLF) or EIR-FLPR, which is the fraction of time the unit must run to meet the part-load for that hour. For example, at 40% of full load, the equipment might need to run 50% of the hour (for cycling losses).

Note that for small packaged equipment with SEER ratings <65,000 Btu/h, the part-load efficiency curve is set to no degradation, since the part-load degradation is built-into the DX cooling efficiency temperature adjustment curve (Air Source, other)

Default curves are provided for the different major classes of equipment.

<sup>6</sup> The EIR is the ratio of energy used by the system to cooling capacity in the same units. It is the reciprocal of the coefficient of performance (COP). EnergyPlus uses a part-load factor correlation for PLF as a function of PLR. The EnergyPlus PLF is related to the DOE-2 EIR(PLR) by the following:  $EIR-FPLR = PLR / PLF$ .

*Units* Coefficients

*Input Restrictions* The coefficients should sum to 1 (within a small tolerance). This corresponds to a curve output of 1 for an input of 1. User may input curves or use default curves. If defaults are overridden, the software must indicate that supporting documentation is required on the output forms.

*Baseline Building* The baseline part-load efficiency adjustment curves are shown in the tables below:

**Table 58.** Cooling System Coefficients for EIR-FPLR

Coefficient	Water-Source (Heat Pump)	Water-Source (Other)	Air-Source (PTAC)	Air-Source (PSZ with Cap<65,000 Btu/h)	Air-Source (Other)
a	0.1250000	0.2012301	0.1250000	0	0.2012301
b	0.8750000	-0.0312175	0.8750000	1	-0.0312175
c	0.0000000	1.9504979	0.0000000	0	1.9504979
d	0.0000000	-1.1205105	0.0000000	0	-1.1205105

**Table 59.** Cooling System Coefficients for Part-Load Factor (PLF) Correlation (EnergyPlus)

Coefficient	Water-Source (Heat Pump)	Water-Source (Other)	Air-Source (PTAC)	Air-Source (PSZ with Cap<65,000 Btu/h)	Air-Source (Other)
a	0.85	0	0.85	1	0
b	0.15	5.1091	0.15	0	5.1091
c	0	-8.5515	0	0	-8.5515
d	0	4.4744	0	0	4.4744

Source: (California Energy Commission 2013)

### **Direct Expansion Cooling Efficiency**

*Applicability* DX systems with multiple stages

*Definition* This applies to systems with multiple compressors or multiple discrete stages of cooling. This system is a packaged unit with multiple stages of cooling. Systems with unequally sized compressors may have additional cooling stages.

*Units* None (integer)

*Input Restrictions* As designed

*Baseline Building* System types 1 through 4 are single stage. Baseline systems 5 and 6 would have two stages of cooling for cooling capacity  $\geq 75,000$  Btu/hr.

### ***Total Cooling Capacity by Stage***

<i>Applicability</i>	DX systems with multiple stages
<i>Definition</i>	This provides the total cooling capacity of each cooling stage, at ARI rated conditions. The capacity is expressed as an array, with each entry a fraction of the total rated cooling capacity for the unit. For example, if the stage cooling capacity is 4 tons (48,000 Btu/h) and the total cooling capacity is 8 tons (96,000 Btu/h), the capacity is expressed as “0.5” for that stage.
<i>Units</i>	Array of fractions
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Applicable to baseline systems 5 and 6. For these systems, the low-stage capacity is assigned to be half the high-stage capacity.

### ***Sensible Cooling Capacity by Stage***

<i>Applicability</i>	DX systems with multiple stages
<i>Definition</i>	Provides the sensible cooling capacity of each cooling stage, at ARI rated conditions. The capacity is expressed as an array, with each entry a fraction of the total rated sensible cooling capacity for the unit. For example, if the stage sensible cooling capacity is 3.5 tons (42,000 Btu/h) and the total sensible cooling capacity is 7 tons (72,000 Btu/h), the capacity is expressed as “0.5” for that stage."
<i>Units</i>	Array of fractions
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Applicable baseline systems 1 through 6. The sensible cooling capacity of the baseline building is oversized by 15%. Sizing calculations shall be based on 1% dry-bulb and 1% wet-bulb design conditions.

### ***Supply Fan Low Speed Ratio***

<i>Applicability</i>	Single zone DX systems with multiple stages and two-speed fans or VAV fans
<i>Definition</i>	Specifies the low fan speed setting on a single zone VAV system or DX system with multiple cooling stages
<i>Units</i>	None (fraction)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Supply Fan Low Power Ratio***

<i>Applicability</i>	Single zone DX systems with multiple stages and two-speed fans or VAV fans
<i>Definition</i>	Specifies the fraction of full load fan power corresponding to low fan speed operation on a single zone VAV system or DX system with multiple cooling stages
<i>Units</i>	None (fraction)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Piping Insulation***

<i>Applicability</i>	All projects
<i>Definition</i>	Thermal insulation on piping systems for service hot water, steam piping, chilled water for cooling, and hot water for space heating
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	Not modeled
<i>Baseline Building</i>	Not modeled

### ***Minimum Unloading Ratio***

<i>Applicability</i>	Packaged systems that use hot-gas bypass during low load conditions
<i>Definition</i>	<p>The minimum unloading ratio is where the equipment capacity can no longer be reduced by unloading and must be false loaded to meet smaller cooling loads. A typical false loading strategy is hot-gas bypass.</p> <p>The minimum unloading ratio is the upper end of the hot-gas bypass operating range. This is the percentage of peak cooling capacity below the range in which hot-gas bypass will operate.</p> <p>The actual unloading ratio shall be set to 50% of the user-entered minimum unloading ratio, with hot-gas-bypass operating below this level.</p>
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed. The user must enter this descriptor for each DX cooling system. If hot-gas bypass is not employed, a value of 0 may be entered.
<i>Baseline Building</i>	Not applicable

### **Minimum HGB Ratio**

<i>Applicability</i>	Packaged systems that use hot-gas bypass during low load conditions
<i>Definition</i>	The lower end of the hot-gas bypass operating range. The percentage of peak cooling capacity below which hot-gas bypass will no longer operate (i.e., the compressor will cycle).
<i>Units</i>	Fraction (between 0 and 1)
<i>Input Restrictions</i>	As designed. The user must enter this descriptor for each DX cooling system. If hot-gas bypass is not employed, a value of 0 may be entered.
<i>Baseline Building</i>	Not applicable

### **Condenser Type**

<i>Applicability</i>	All DX systems including heat pumps
<i>Definition</i>	The type of condenser for a DX cooling system. The choices are: <ul style="list-style-type: none"><li>• Air-cooled</li><li>• Water-cooled</li><li>• Air-cooled with evaporative pre-cooler</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Based on prescribed system type

**Table 60.** Baseline Building Condenser Type

Baseline Building System	Condenser Type
1 – PTAC	Air cooled
2 – PTHP	Air cooled
3 – PSZ AC	Air cooled
4 – PSZ HP	Air cooled
5 – PVAV reheat	Air cooled
6 – Packaged VAV with PFP Boxes	Air cooled
7 – VAV with Reheat	N/A
8 – VAV with PFP Boxes	N/A
9 – Heating and Ventilation	N/A
10 – Heating and Ventilation	N/A

### **Condenser Flow Type**

<i>Applicability</i>	All DX systems including heat pumps
<i>Definition</i>	Describes water flow control for a water cooled condenser. The choices are: <ul style="list-style-type: none"><li>• Fixed flow</li><li>• Two-position</li><li>• Variable flow</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed. For variable or staged capacity equipment, the minimum-unload ratio must be set properly for the simulation program.  <b>NOTE:</b> If the variable-flow is selected, the software must indicate that supporting documentation is required on the output forms.
<i>Baseline Building</i>	Not applicable

### **3.6.5.3 Evaporative Cooler**

This is equipment that pre-cools the outside air that is brought into the building. It may be used with any type of cooling system that brings in outside air. This equipment is not applicable for the baseline building. The analyst must be careful to input evaporative cooler and outside air controls, as allowed by the software, that reasonably reflect anticipated operation as indicated in sequences of operation, and review the simulation outputs, particularly zone or return air relative humidity, to ensure that the simulated sensible cooling from the evaporative cooler is realistic.

### **Evaporative Cooling Type**

<i>Applicability</i>	Systems with evaporative pre-cooling
<i>Definition</i>	The type of evaporative pre-cooler, including: <ul style="list-style-type: none"><li>• None</li><li>• Non-integrated indirect</li><li>• Non-integrated direct/indirect</li><li>• Integrated indirect</li><li>• Integrated direct/indirect</li></ul> <p>An integrated pre-cooler can operate together with the compression or CHW cooling. A non-integrated pre-cooler will shut down the evaporative cooling whenever it is unable to provide 100% of the cooling required.</p> <p>In all cases, the evaporative pre-cooler must be modeled with 100% of the outside air routed through the pre-cooler.</p>
<i>Units</i>	None

<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Evaporative Cooling System Capacity***

<i>Applicability</i>	Systems with evaporative cooling
<i>Definition</i>	The total sensible cooling capacity of the evaporative cooling system at design outdoor dry-bulb conditions. This value may be derived from other inputs of supply fan design air rated capacity (5.7.3), direct stage effectiveness, indirect stage effectiveness, and design outdoor conditions.
<i>Units</i>	None
<i>Input Restrictions</i>	Not applicable. This is a derived input. If there are excessive UMLH in any zone served by the evaporative cooling system, a supplementary DX cooling unit must be defined by the user. See Section 3.6.5.2 of this document for descriptors related to DX cooling units.
<i>Baseline Building</i>	Not applicable

### ***Direct Stage Effectiveness***

<i>Applicability</i>	Systems with evaporative pre-cooling
<i>Definition</i>	The effectiveness of the direct stage of an evaporative cooling system. Effectiveness is defined as follows:

$$DirectEFF = \frac{T_{db} - T_{direct}}{T_{db} - T_{wb}} \quad (24)$$

Where:

- $DirectEFF$  = The direct stage effectiveness
- $T_{db}$  = The entering air dry-bulb temperature
- $T_{wb}$  = The entering air wet-bulb temperature
- $T_{direct}$  = The direct stage leaving dry-bulb temperature

<i>Units</i>	Numeric (0 <= eff <=1)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable



### Indirect Stage Effectiveness

**Applicability** Systems with evaporative pre-cooling

**Definition** The effectiveness of the indirect stage of an evaporative cooling system. Effectiveness is defined as follows:

$$IndEFF = \frac{T_{db} - T_{ind}}{T_{db} - T_{wb}} \quad (25)$$

Where:

- $IndEFF$  = The indirect stage effectiveness
- $T_{db}$  = The entering air dry-bulb temperature of the supply air
- $T_{wb}$  = The entering air wet-bulb temperature of the “scavenger air”
- $T_{ind}$  = The supply air leaving dry-bulb temperature

**Units** Numeric (0 <= eff <=1)

**Input Restrictions** As designed

**Baseline Building** Not applicable

### Evaporative Cooling Performance Curves

**Applicability** Systems with evaporative cooling

**Definition** A curve that varies the evaporative cooling effectiveness as a function of primary air stream airflow. The default curves are given as follows:

$$PLR = \frac{CFM_{operating}}{CFM_{design}}$$

$$EFF\_FFLOW = a + b \times PLR + c \times PLR^2 \quad (26)$$

Where:

- $PLR$  = Part load ratio of airflow based on design airflow
- $EFF\_FFLOW$  = A multiplier on the evaporative cooler effectiveness to account for variations in part load
- $CFM_{operating}$  = Operating primary air stream airflow (cfm)
- $CFM_{design}$  = Design primary air stream airflow (cfm)

**Table 61.** Part Load Curve Coefficients – Evaporative Cooler Effectiveness

Coefficient	Direct	Indirect
a	1.1833000	1.0970000
b	-0.2575300	-0.1650600
c	0.0742450	0.0680690

Source: COMnet 2011

<i>Units</i>	Data structure
<i>Input Restrictions</i>	User may input curves or use default curves. If defaults are overridden, the software must indicate that supporting documentation is required on the output forms.
<i>Baseline Building</i>	Not used

#### ***Auxiliary Evaporative Cooling Power***

<i>Applicability</i>	Systems with evaporative cooling
<i>Definition</i>	The auxiliary energy of the indirect evaporative cooler fan, and the pumps for both direct and indirect stages
<i>Units</i>	watts
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

#### ***Evaporative Cooling Scavenger Air Source***

<i>Applicability</i>	Systems with evaporative cooling
<i>Definition</i>	The source of scavenger air for an indirect section of an evaporative cooler. Options include: <ul style="list-style-type: none"> <li>• Return air</li> <li>• Outside air</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### **3.6.5.4 Evaporative Condenser**

#### ***Evaporative Condenser Power***

<i>Applicability</i>	DX systems with an evaporatively cooled condenser
<i>Definition</i>	The power of the evaporative precooling unit. This includes any pump(s) and/or fans that are part of the precooling unit.
<i>Units</i>	watts
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Evaporative Condenser Effectiveness***

<i>Applicability</i>	DX systems with an evaporatively cooled condenser
<i>Definition</i>	The effectiveness of the evaporative precooling unit for a condenser. Effectiveness is defined as follows: $DirectEFF = \frac{T_{db} - T_{direct}}{T_{db} - T_{wb}} \quad (27)$ Where: <i>DirectEFF</i> = The direct stage effectiveness <i>T<sub>db</sub></i> = The outside air dry-bulb temperature <i>T<sub>wb</sub></i> = The outside air wet-bulb temperature <i>T<sub>direct</sub></i> = The direct stage leaving dry-bulb temperature (at the condenser inlet)
<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Evaporative Condenser Operation Range***

<i>Applicability</i>	DX systems with an evaporatively cooled condenser
<i>Definition</i>	The temperature range within which the evaporative condenser operates. Two values are provided: <i>T<sub>maximum</sub></i> = The threshold outside air dry-bulb temperature below which evaporative condenser operates. <i>T<sub>minimum</sub></i> = The threshold outside air dry-bulb temperature above which evaporative condenser operates.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

#### **3.6.5.5 Four-Pipe Fan Coil Systems**

This section contains building descriptors required to model four-pipe fan coil systems. Note that this system requires an outside air ventilation source to serve the zones and that an airside economizer is not available.

Note that additional HVAC components (chiller, boiler, pumps) are needed to fully define this system.

### Capacity Control Method

<i>Applicability</i>	Four-pipe fan coil systems
<i>Definition</i>	<p>The control method for the fan coil unit at the zone. The following choices are available:</p> <ul style="list-style-type: none"> <li>• Constant fan variable flow: The fan speed is held constant to produce a fixed airflow rate whenever the unit is scheduled on. The hot water or chilled flow rate is varied so that the unit output matches the zone heating or cooling requirement.</li> <li>• Constant fan constant flow: The fan speed is held constant to produce a fixed flow rate whenever the unit is scheduled on. The chilled water and hot water flow rates are kept constant at full flow.</li> <li>• Cycling fan: The fan speed is chosen so that the unit capacity is greater than or equal to the heating/cooling load and the fan is cycled to match unit output with the load.</li> <li>• Variable fan constant flow: The water flow rate is at full flow and the fan speed varies to meet the load.</li> <li>• Variable fan variable flow: Both air and water flow rates are varied to match the load.</li> </ul>
<i>Units</i>	List (with choices above)
<i>Input Restrictions</i>	Not a user input – Derived from building descriptors for fan control and chiller loop flow control.
<i>Baseline Building</i>	Four pipe fan coil systems are applicable for proposed buildings with the system type defined in Table 62. The capacity control for the baseline building will be specified as “Constant Fan Constant Flow.”

**Table 62.** Baseline Systems Using Fan Coil Units

Proposed		Baseline System Type
Heating	Cooling	
Boiler/Electric Resistance or Gas Furnace	Purchased Chilled Water	Proposed buildings qualifying for System 1 and 2 will be constant volume fan coil units
Purchased Heat	Purchased Chilled Water	Proposed buildings qualifying for System 1 will be constant volume fan coil units

#### 3.6.5.6 Radiant Cooling

This section describes a floor-based radiant cooling system and the inputs required for Standard 90.1-2010 evaluation.

### ***Hydronic Tubing Length***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The length of the hydronic tubing in the slab
<i>Units</i>	ft
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Hydronic Tubing Inside Diameter***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The inside diameter of the hydronic tubing in the slab
<i>Units</i>	ft
<i>Input Restrictions</i>	As designed, between a minimum of 1/2 in. and a maximum of 3/4 in.
<i>Baseline Building</i>	Not applicable

### ***Temperature Control Type***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature used for control (operative temperature, mean air temperature, mean radiant temperature, ODB, OWB)
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at mean air temperature for calculations
<i>Baseline Building</i>	Not applicable

### ***Rated Flow Rate***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature used for control (operative temperature, mean air temperature, mean radiant temperature, ODB, OWB)
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at mean air temperature for calculations
<i>Baseline Building</i>	Not applicable

### ***Cooling Control Temperature***

<i>Applicability</i>	Variable flow systems
<i>Definition</i>	The temperature used for control (operative temperature, mean air temperature, mean radiant temperature, ODB, OWB)
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at mean air temperature for calculations
<i>Baseline Building</i>	Not applicable

### ***Condensation Control Type***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature used for control (operative temperature, mean air temperature, mean radiant temperature, ODB, OWB)
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at mean air temperature for calculations
<i>Baseline Building</i>	Not applicable

### ***Condensation Control Dewpoint Offset***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature difference above dewpoint that is the minimum cold water supply temperature
<i>Units</i>	None
<i>Input Restrictions</i>	Fixed at 2°F above dewpoint
<i>Baseline Building</i>	Not applicable

### ***Rated Pump Power Consumption***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The rated pump power at design conditions
<i>Units</i>	watts
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Motor Efficiency***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The pump motor efficiency
<i>Units</i>	Decimal fraction
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Default motor efficiency from Standard 90.1-2010, Table 10.8 (table numbering may change) based on motor nameplate hp

### ***Fraction of Motor Heat to Fluid***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	Fraction of the heat from the motor inefficiencies that enters the fluid stream
<i>Units</i>	None
<i>Input Restrictions</i>	As designed. Default is 0.
<i>Baseline Building</i>	Not applicable

### ***Cooling High Water Temperature***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The high temperature used for control. If the water temperature is above the high temperature, the control temperature is set to the low control temperature.
<i>Units</i>	°F
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Cooling Low Water Temperature***

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The temperature used for control of the water temperature. If the water temperature of the radiant cooling is below this temperature, cooling is disabled.
<i>Units</i>	°F
<i>Input Restrictions</i>	Fixed at 55°F
<i>Baseline Building</i>	Not applicable

### *Condensation of Control Type*

<i>Applicability</i>	Floor-based radiant cooling systems
<i>Definition</i>	The simulation program may have a means of detecting when condensation is likely to occur on floor surfaces in the space. When this occurs, the simulation can shut off the system to prevent condensation from occurring.
<i>Units</i>	List: None, Simple, Variable
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

#### **3.6.5.7 Chilled Beams**

Building descriptors will be added to define how chilled beams can be modeled for the proposed design. Chilled beams are not applicable to the baseline building system.

#### **3.6.5.8 Ground-Source Heat Pumps**

Building descriptors will be added to define how ground-source heat pumps can be modeled for the proposed design. Chilled beams are not applicable to the baseline building system.

#### **3.6.5.9 Variable Refrigerant Flow**

Building descriptors will be added to define how VRF systems can be modeled for the proposed design. Chilled beams are not applicable to the baseline building system.

#### **3.6.5.10 Underfloor Air Distribution**

Building descriptors will be added to define how UFAD systems can be modeled for the proposed design. Chilled beams are not applicable to the baseline building system.

### **3.6.6 Heating Systems**

#### **3.6.6.1 General**

##### *Heating Source*

<i>Applicability</i>	All systems that provide heating
<i>Definition</i>	The source of heating for the heating and preheat coils. The choices are: <ul style="list-style-type: none"><li>• Hot water</li><li>• Steam</li><li>• Electric resistance</li><li>• Electric heat pump</li></ul>



- Gas furnace
- Gas heat pump (optional feature)
- Oil furnace
- Heat recovery (for preheat coils in proposed designs)

*Units* List (see above)

*Input Restrictions* As designed

*Baseline Building* Based on the prescribed system type

**Table 63.** Heating Source for Baseline Building

Baseline Building System	Heating Type
1 – PTAC	Hot water fossil fuel boiler
2 – PTHP	Electric heat pump
3 – PSZ AC	Fossil fuel furnace
4 – PSZ HP	Electric heat pump
5 – PVAV reheat	Hot water fossil fuel boiler
6 – Packaged VAV with PFP Boxes	Electric resistance
7 – VAV with Reheat	Hot water fossil fuel boiler
8 – VAV with PFP Boxes	Electric resistance
9– Heating and Ventilation	Fossil fuel furnace
10 – Heating and Ventilation	Electric Resistance

### **Total Heating Coil Capacity**

*Applicability* All systems with heating coils

*Definition* The heating capacity of a heating coil at ARI conditions

*Units* Btu/h

*Input Restrictions* As designed. The capacity would need to be adjusted if the number of UMLH exceeds 300.

*Baseline Building* Autosize with a heating oversizing factor of 25%. Sizing calculations shall be based on 1% design dry-bulb and 1% wet-bulb design conditions. Oversizing would be carried out at zone level where the sizing parameters would be applied to the zone design cooling airflow rates and zone loads. The system sizing calculations would sum the zone design airflow rates to obtain a system level airflow rate. Refer to Section 2.6.2 of this document for more details.

### **Number of Heating Stages**

*Applicability* Heating systems with multiple stages

*Definition* The number of heating stages provided by the system. Multiple stages could be provided via a heat pump or via a multiple-stage gas furnace.

*Units* Integer

*Input Restrictions* As designed

Baseline Building Single stage

### **Heating Capacity by Stage**

<i>Applicability</i>	Heating systems with multiple stages
<i>Definition</i>	Provides the total heating capacity of each heating stage, at ARI rated conditions. The capacity is expressed as an array, with each entry a fraction of the total rated cooling capacity for the unit. For example, if the stage heating capacity is 48,000 Btu/h and the heating capacity is 96,000 Btu/h, the capacity is expressed as “0.5” for that stage.
<i>Units</i>	Array of fractions
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### **3.6.6.2 Preheat Coil**

If the proposed design has a preheat coil and it can be modeled in the baseline building system, then the baseline building also has a preheat coil sized to meet the preheat coil temperature specified for the proposed design.

### **Preheat Coil Capacity**

<i>Applicability</i>	Baseline systems 5 through 8
<i>Definition</i>	The heating capacity of a preheating coil at design conditions
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	<p>For baseline systems 5 through 8, the baseline will be modeled with preheat coil controlled to a fixed setpoint 20°F less than the design room heating temperature setpoint. The rule will apply for the baseline building irrespective of the percentage of spaces with preheat in the proposed building.</p> <p>The preheat coil capacity will be oversized by 25%. Sizing calculations shall be based on 1% design dry-bulb and 1% wet-bulb design conditions. Oversizing would be carried out at zone level where the sizing parameters would be applied to the zone design cooling airflow rates and zone loads. The system sizing calculations would sum the zone design airflow rates to obtain a system level airflow rate. Refer to Section 2.6.2 of this document for more details.</p>

### **Preheat Coil Type**

<i>Applicability</i>	Baseline systems 5 through 8
<i>Definition</i>	The heating source of a preheating coil. The preheat coil could be electric resistance, gas fired, or a hydronic heating coil.

<i>Units</i>	List: Electric Resistance, Gas Fired, Hydronic
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The heating source for the baseline preheating coil is the same as the baseline system. For baseline systems 5 and 7, the preheat coils will be hydronic. Buildings with baseline systems 6 and 8 will be modeled with electric resistance preheat coils.

### ***Preheat Coil Efficiency***

<i>Applicability</i>	Systems with a preheat coil with gas heating
<i>Definition</i>	The heating efficiency of a preheating coil at design conditions
<i>Units</i>	Percentage
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable. Baseline building would have preheat coils only for systems 5 through 8 that would either be electric resistance or hydronic.

### **3.6.6.3 Hydronic/Steam Heating Coils**

Systems with boilers have heating coils, including baseline building systems 1, 5, and 7. Two-way valves are assumed at the heating coils with a three-way bypass valve at the end of the loop.

### ***Heating Coil Capacity***

<i>Applicability</i>	All systems with a heating coil
<i>Definition</i>	The heating capacity of a heating coil at ARI conditions
<i>Units</i>	But/h
<i>Input Restrictions</i>	As designed. Adjust the capacity if the number of UMLH exceeds 300.
<i>Baseline Building</i>	<p>Autosized, with a heating oversizing factor of 25%. Sizing calculations shall be based on 1% design dry-bulb and 1% wet-bulb design conditions. Oversizing would be carried out at zone level where the sizing parameters would be applied to the zone design cooling airflow rates and zone loads. The system sizing calculations would sum the zone design airflow rates to obtain a system level airflow rate. Refer to Section 2.6.2 of this document for more details.</p> <p>If the number of UMLH for the baseline exceeds 300, heating coil capacity may need to be increased along with system airflow as described in Section 2.6.2. of this document.</p>

### 3.6.6.4 Furnace

#### ***Furnace Capacity***

<i>Applicability</i>	Systems with a furnace
<i>Definition</i>	The full load heating capacity of the unit
<i>Units</i>	But/h
<i>Input Restrictions</i>	As designed. Adjust the capacity if the number of UMLH exceeds 300.
<i>Baseline Building</i>	<p>Autosized, with a heating oversizing factor of 25%. Sizing calculations shall be based on 1% design dry-bulb and 1% wet-bulb design conditions. Oversizing would be carried out at zone level where the sizing parameters would be applied to the zone design cooling airflow rates and zone loads. The system sizing calculations would sum the zone design airflow rates to obtain a system level airflow rate. Refer to Section 2.6.2 of this document for more details.</p> <p>If the number of UMLH for the baseline exceeds 300, heating coil capacity may need to be increased along with system airflow as described in Section 2.6.2. of this document.</p>

#### ***Furnace Fuel Heating Efficiency***

<i>Applicability</i>	Systems with a furnace
<i>Definition</i>	The full load thermal efficiency of either a gas or oil furnace at design conditions. The software must accommodate input in either <i>Thermal Efficiency</i> ( $E_t$ ) or <i>Annual Fuel Utilization Efficiency</i> (AFUE). Where AFUE is provided, $E_t$ shall be calculated as follows for both packaged and split systems:

$$E_t = (0.0051427 * AFUE) + 0.3989 \quad (28)$$

Source: (California Energy Commission 2013)

Where:

AFUE = The annual fuel utilization efficiency (%)

$E_t$  = The thermal efficiency (fraction)

<i>Units</i>	Fraction
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The baseline efficiency requirement is located in Table 6.8.1E of the ASHRAE Standard. Use the heating input of the proposed design system to determine the size category.

#### ***Furnace Fuel Heating Part Load Efficiency Curve***

<i>Applicability</i>	Systems with furnaces
<i>Definition</i>	An adjustment factor that represents the percentage of full load fuel consumption as a function of the percentage full load capacity. This curve shall take the form of a quadratic equation as follows:

$$Fuel_{partload} = Fuel_{rated} \times FHeatPLC \quad (29)$$

$$FHeatPLC = \left( a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left( \frac{Q_{partload}}{Q_{rated}} \right)^2 \right) \quad (30)$$

Where:

$FHeatPLC$  = The fuel heating part load efficiency curve

$Fuel_{partload}$  = The fuel consumption at part load conditions (Btu/h)

$Fuel_{rated}$  = The fuel consumption at full load (Btu/h)

$Q_{partload}$  = The capacity at part load conditions (Btu/h)

$Q_{rated}$  = The capacity at rated conditions (Btu/h)

**Table 64.** Furnace Efficiency Curve Coefficients

Coefficient	Furnace
a	0.0186100
b	1.0942090
c	-0.1128190

Source: COMnet 2011

*Units* Data structure

*Input Restrictions* As designed when data is available, otherwise defaults curves are required to be used

*Baseline Building* Default curves are required to be used

#### ***Furnace Fuel Heating Pilot***

*Applicability* Systems that use a furnace for heating

*Definition* The fuel input for a pilot light on a furnace

*Units* Btu/h

*Input Restrictions* As designed

*Baseline Building* Zero (pilotless ignition)

#### ***Furnace Fuel Heating Fan/Auxiliary Power***

*Applicability* Systems that use a furnace for heating

*Definition* The fan energy in forced draft furnaces and the auxiliary (pumps and outdoor fan) energy in fuel-fired heat pumps

*Units* kilowatts (kW)

<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### 3.6.6.5 Electric Heat Pump

#### ***Electric Heat Pump Heating Capacity***

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The full load heating capacity of the unit, excluding supplemental heating capacity at ARI rated conditions
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	<p>Autosized, with a heating oversizing factor of 25%. Sizing calculations shall be based on 1% design dry-bulb and 1% wet-bulb design conditions. Oversizing would be carried out at zone level where the sizing parameters would be applied to the zone design cooling airflow rates and zone loads. The system sizing calculations would sum the zone design airflow rates to obtain a system level airflow rate. Refer to Section 2.6.2 of this document for more details.</p> <p>If the number of UMLH for the baseline exceeds 300, heating coil capacity may need to be increased along with system airflow as described in Section 2.6.2. of this document.</p>

#### ***Electric Heat Pump Supplemental Heating Source***

<i>Applicability</i>	All heat pumps
<i>Definition</i>	<p>The auxiliary heating source for a heat pump heating system. The common control sequence is to lock out the heat pump compressor when the supplemental heat is activated. Other building descriptors may be needed if this is not the case. Choices for supplemental heat include:</p> <ul style="list-style-type: none"> <li>• Electric resistance</li> <li>• Gas furnace</li> <li>• Oil furnace</li> <li>• Hot water</li> <li>• Other</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Electric resistance

### Electric Heat Pump Heating Efficiency

**Applicability** All heat pumps

**Definition** The heating efficiency of a heat pump at ARI rated conditions as a dimensionless ratio of output over input. The software must accommodate user input in terms of either the COP or the heating season performance factor (HSPF).

$$COP_{nfheating} = 1.48E-7 \times COP_{47} \times Q + 1.062 \times COP_{47} \quad (31)$$

(applies to heat-pump heating efficiency only)

Where HSPF is provided, COP shall be calculated as follows:

$$COP_{nfheating} = -0.0296 \times HSPF^2 + 0.7134 \times HSPF \quad (32)$$

Source: (ANSI/ASHRAE/IES 2013)

Where:

$COP_{nfheating}$  = The packaged HVAC heating energy efficiency. These are used baseline building, which excludes supply fan power.

$Q$  = AHRI-rated cooling capacity in Btu/h.

EER, SEER, COP shall be at AHRI test conditions.

Fan energy shall be modeled separately according to Section 3.6.3 of this document.

**Units** Unitless

**Input Restrictions** As designed

**Baseline Building** The minimum requirement is defined in Table 6.8.1B (packaged single zone heat pumps) and Table 6.8.1D (packaged terminal heat pumps) of the Standards. Use the heating capacity of the proposed design to determine the size category.

### Electric Heat Pump Heating Capacity Adjustment Curve(s)

**Applicability** All heat pumps

**Definition** A curve or group of curves that represent the available heat-pump heating capacity as a function of evaporator and condenser conditions. The default curves are given as follows:

$$Q_{available} = CAP\_FT \times Q_{rated} \quad (33)$$

(applies to heat-pump heating efficiency only)

For air cooled heat pumps:

$$CAP\_FT = a + b \times t_{odb} + c \times t_{odb}^2 + d \times t_{odb}^3 \quad (34)$$

For water cooled heat pumps:

$$CAP\_FT = a + b \times t_{db} + d \times t_{wt} \quad (35)$$

Where:

$Q_{available}$  = Available heating capacity at present evaporator and condenser conditions (kBtu/h)

$t_{db}$  = The entering coil dry-bulb temperature (°F)

$t_{wt}$  = The water supply temperature (°F)

$t_{odb}$  = The outside-air dry-bulb temperature (°F)

$Q_{rated}$  = Rated capacity at ARI conditions (in kBtu/h)

**Table 65.** Heat Pump Capacity Adjustment Curves (CAP-FT)

Coefficient	Water-Source	Air-Source
a	0.4886534	0.2536714
b	-0.0067774	0.0104351
c	N/A	0.0001861
d	0.0140823	-0.0000015

Source: COMnet 2011

*Units* Data structure

*Input Restrictions* User may input curves or use default curves. If defaults are overridden, supporting documentation shall be provided.

*Baseline Building* Use default curves

**Electric Heat Pump Heating Efficiency Adjustment Curve(s)**

*Applicability* All heat pumps

*Definition* A curve or group of curves that varies the heat-pump heating efficiency as a function of evaporator conditions, condenser conditions and part-load ratio. The default curves are given as follows:

$$PLR = \frac{Q_{operating}}{Q_{available}(t_{db}, t_{odb}/wt)} \quad (36)$$

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3 \quad (37)$$

Air source heat pumps:

$$EIR\_FT = a + b \times t_{odb} + c \times t_{odb}^2 + d \times t_{odb}^3 \quad (38)$$



Water source heat pumps:

$$P_{operating} = P_{rated} \times EIR\_FPLR \times EIR\_FT \times CAP\_FT \quad (39)$$

$$EIR\_FT = a + b \times t_{odb} + c \times t_{odb}^2 + d \times t_{odb}^3 \quad (40)$$

Source: COMnet 2011

Where:

- $PLR$  = Part load ratio based on available capacity (not rated capacity)
- $EIR-FPLR$  = A multiplier on the EIR of the heat pump as a function of part load ratio
- $EIR-FT$  = A multiplier on the EIR of the heat pump as a function of the wet-bulb temperature entering the coil and the outdoor dry-bulb temperature
- $Q_{operating}$  = Present load on heat pump (Btu/h)
- $Q_{available}$  = Heat pump available capacity at present evaporator and condenser conditions (Btu/h)
- $t_{db}$  = The entering coil dry-bulb temperature (°F)
- $t_{wt}$  = The water supply temperature (°F)
- $t_{odb}$  = The outside air dry-bulb temperature (°F)
- $P_{rated}$  = Rated power draw at ARI conditions (kW)
- $P_{operating}$  = Power draw at specified operating conditions (kW)

**Table 66. Heat Pump Heating Efficiency Adjustment Curves**

Coefficient	Air-and Water-Source EIR-FPLR	Water-Source EIR-FT	Air-Source EIR-FT
a	0.0856522	1.3876102	2.4600298
b	0.9388137	0.0060479	-0.0622539
c	-0.1834361	N/A	0.0008800
d	0.1589702	-0.0115852	-0.0000046
Rated $T_{odb}$			Max = 50°F, Min = -10 °F
Rated $T_{wt}$			NA

Source: (California Energy Commission 2013)

- Units** None
- Input Restrictions** User may input curves or use default curves. If defaults are overridden, documentation shall be provided.
- Baseline Building** Use default curves

### ***Electric Heat Pump Supplemental Heating Capacity***

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The design heating capacity of a heat pump supplemental heating coil at ARI conditions
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Autosize

### ***Electric Supplemental Heating Control Temp***

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The outside dry-bulb temperature below which the heat pump supplemental heating is allowed to operate
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. Default to 40°F.
<i>Baseline Building</i>	The space is required to be controlled with multistage space thermostats and an outdoor air thermostat that would energize the auxiliary heat on the last thermostat stage and when the OAT is less than 40°F

### ***Heat Pump Compressor Minimum Operating Temp***

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The outside dry-bulb temperature below which the heat pump compressor is disabled
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. Default to 35°F.
<i>Baseline Building</i>	For baseline system 4, the compressor minimum operating temperature would be 0°F, and for system 2 it would be 35°F

### ***Coil Defrost***

<i>Applicability</i>	Air cooled electric heat pump
<i>Definition</i>	<p>The defrost control mechanism for an air cooled heat pump. The choices are:</p> <ul style="list-style-type: none"><li>• Hot-gas defrost, on-demand</li><li>• Hot-gas defrost, timed 3.5 minute cycle</li><li>• Electric resistance defrost, on-demand</li><li>• Electric resistance defrost, timed 3.5 minute cycle</li></ul> <p>Defrost shall be enabled whenever the outside air dry-bulb temperature drops below 40°F.</p>
<i>Units</i>	List (see above)

<i>Input Restrictions</i>	Default to use hot-gas defrost, timed 3.5 minute cycle. User may select any of the above.
<i>Baseline Building</i>	The baseline building uses the default

#### ***Coil Defrost kW***

<i>Applicability</i>	Heat pumps with electric resistance defrost
<i>Definition</i>	The capacity of the electric resistance defrost heater
<i>Units</i>	kilowatts (kW)
<i>Input Restrictions</i>	As designed. This descriptor defaults to 0 if nothing is entered.
<i>Baseline Building</i>	Not applicable

#### ***Crank Case Heater kW***

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The capacity of the electric resistance heater in the crank case of a DX compressor. The crank case heater operates only when the compressor is off.
<i>Units</i>	kilowatts (kW)
<i>Input Restrictions</i>	As designed. This descriptor defaults to 0 if nothing is entered.
<i>Baseline Building</i>	Zero (0)

#### ***Crank Case Heater Shutoff Temperature***

<i>Applicability</i>	All heat pumps
<i>Definition</i>	The outdoor air dry-bulb temperature above which the crank case heater is not permitted to operate
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. This descriptor defaults to 50°F.
<i>Baseline Building</i>	50°F

### **3.6.6.6 Energy Recovery**

For baseline systems requiring energy recovery, the heat exchanger is assumed to be integral with the AHU. The system fan power or pressure drop will be adjusted according to the methods in Section 3.6.3.1 of this document.

For proposed systems with heat recovery, the analyst must be careful to set all descriptors, particularly those for control, parasitic energy, and exhaust airflows, to realistically represent the equipment components, operation, and maintenance of building pressurization.

When exhaust air energy recovery systems are installed in cold climates, frost control may significantly affect total recovered energy during subfreezing conditions. Pumps and dedicated fans will consume parasitic energy. Simulation program inputs and hourly reports should be reviewed to ensure all items are represented as close as possible to the actual result of the proposed control sequences.

### **Exhaust Air Energy Recovery**

<i>Applicability</i>	Any system with outside air heat recovery
<i>Definition</i>	Provision of exhaust air energy recovery system. Provisions shall be made to bypass heat recovery system to permit air-side economizer operation as specified in Section 3.6.4.2 of this document.
<i>Units</i>	Unitless
<i>Input Restrictions</i>	As designed. This descriptor defaults to 50°F.
<i>Baseline Building</i>	Each fan system shall have an energy recovery system when the system's supply airflow rate exceeds the value listed in Table 67 based on the climate zone and percentage of outdoor airflow rate at design conditions.

**Table 67.** Standard 90.1-2010 Energy Recovery Ventilation Requirement

Zone	% Outdoor Air at Full Design Airflow Rate					
	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and <80%	≥80%
Design Supply Fan Airflow Rate (cfm)						
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥5000	≥5000
1B, 2B, 5C	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥5500	≥4500	≥3500	≥2000	≥1000	>0
7, 8	≥2500	≥1000	>0	>0	>0	>0

Energy recovery is not required in baseline systems for:

- a. Laboratory systems simulated in accordance to Section 3.5.5.3 of this document
- b. Systems serving spaces that are not cooled and that are heated to less than 60°F
- c. Systems exhausting toxic, flammable, paint, or corrosive fumes or dust
- d. Commercial kitchen hoods used for collecting and removing grease vapors and smoke
- e. Heating energy recovery in climate zones 1 and 2; cooling energy recovery in climate zones 3c, 4c, 5b, 5c, 6b, 7, and 8
- f. Where the largest source of air exhausted at a single location at the building exterior is less than 75% of the design outdoor airflow rate
- g. Systems requiring dehumidification that employ energy recovery in series with the cooling coil
- h. Systems expected to operate less than 20 hr per week at the outdoor air percentage covered by Table 6.5.6.1 of Standard 90.1-2010

### ***Exhaust Air Total Energy Recovery Effectiveness***

<i>Applicability</i>	Any system with outside air heat recovery
<i>Definition</i>	The effectiveness of an air-to-air heat exchanger between the building exhaust and entering outside air streams. Effectiveness is defined as follows:

$$HREFF = \frac{(EEAH - ELAH)}{(EEAH - OSAH)} \quad (41)$$

Where:

$HREFF$	=	The air-to-air heat exchanger effectiveness
$EEAH$	=	The total enthalpy of the exhaust air entering the heat exchanger
$ELAH$	=	The total enthalpy of the exhaust air leaving the heat exchanger
$OSAH$	=	The total enthalpy of the outside air

<i>Units</i>	Fraction (between 0 and 1)
<i>Input Restrictions</i>	As designed in accordance to the formula above
<i>Baseline Building</i>	The baseline would have 50% energy recovery effectiveness based on design conditions. Fifty percent energy recovery effectiveness shall mean a change in the enthalpy of the outdoor air supply equal to 50% of the difference between the outdoor air and return air enthalpies at design conditions.

### ***Exhaust Air Energy Recovery Economizer Interaction***

<i>Applicability</i>	Any system with outside air enthalpy heat recovery
<i>Definition</i>	Energy recovery control during economizer operation
<i>Units</i>	Lockout, no lockout
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Lockout. The baseline system should bypass the energy recovery device during economizer operation. Refer to Section 3.6.4 of this document for baseline economizer requirements. During economizer operation, parasitic losses of energy recovery device and fan energy impact of pressure drop through energy recovery device should not occur.

### ***Heat Exchanger Parasitic Energy***

<i>Applicability</i>	Systems that use heat recovery
<i>Definition</i>	This input is used to model electric power consumption by controls (transformers, relays, etc.) and/or a motor for a rotary heat exchanger. None of this electric power contributes thermal load to the supply or exhaust air streams.
<i>Units</i>	watts (W)
<i>Input Restrictions</i>	As designed. A default of 50W is assumed which can be overridden by the user.

**Heat Exchanger Fan Energy Consumption**

*Applicability* Systems that use heat recovery

*Definition* The additional fan energy needed for the energy recovery device.  
 For all energy recovery ventilator (ERV) systems that include a bypass during economizer operations, the fan energy consumption for ERV systems should only be modeled when the ERV runs and should not be considered when the ERV is bypassed for economizer operation.

*Units* watts (W)

*Input Restrictions* As designed

*Baseline Building* The ERV fan power for the baseline system can be calculated as follows:

$$Bhp = [ (0.6 \times OAcfm) + (0.6 \times 0.9 \times OAcfm) ] / 4131$$

$$W = bhp \times 746/nm$$

This has been calculated from:

$$Bhp = [ ((2.2 \times HREFF) - dp_{oa}) \times OAcfm ] / 4131 + [ ((2.2 \times HREFF \times E_f) - dp_{ex}) \times OAcfm ] / 4131$$

Where:

*Bhp* = Fan brake horse power

*HREFF* = Heat exchanger effectiveness

*dp<sub>oa</sub>* = ERV pressure drop on the outdoor air side (is assumed to be 0.5 in. w.c.)

*dp<sub>ex</sub>* = ERV pressure drop on the exhaust air side (is assumed to be 0.5 in. w.c.)

*E<sub>f</sub>* = Exhaust airflow fraction (exhaust airflow is 90% of outdoor airflow after considering leakage and zone exhaust)

*W* = Fan power

*nm* = Fan motor efficiency of supply fan. For EnergyPlus fan, energy for an ERV is not an input of the ERV module and the ERV fan energy should not simply be added to the system supply fan if the ERV includes a bypass during economizer operations as required in the baseline. The following workaround should be used instead. The fan energy associated with energy recovery is modeled as additional ERV parasitic power. This results in the ERV fan energy occurring only when the ERV runs, which is the desired behavior. If there is not a bypass in the proposed design, ERV fan energy shall be included in the HVAC system fan so that its impact is accounted for whenever the fans are running.

### 3.6.7 Humidity Controls and Devices

Humidity control, devices, and sources are not represented fully in many simulation program, but humidification and dehumidification can result in significant energy consumption. A simulation program should be chosen that most adequately represents the components, or has adequate workarounds implemented, or supplemental calculations employed to determine the associated energy use. These methods should be documented in the manner required for “exceptional calculations.”

#### 3.6.7.1 General

<b><i>Humidifier Type</i></b>	
<i>Applicability</i>	Optional humidifier
<i>Definition</i>	The type of humidifier employed. Choices include: <ul style="list-style-type: none"><li>• Hot water</li><li>• Steam</li><li>• Electric</li><li>• Evaporative humidification</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed

<b><i>Humidistat Maximum Setting</i></b>	
<i>Applicability</i>	Systems with humidity control
<i>Definition</i>	The control setpoint for dehumidification
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	If the proposed design HVAC system(s) have humidistatic controls, then the baseline building design shall use mechanical cooling for dehumidification and shall have reheat available to avoid overcooling. Only 25% of the system reheat energy shall be included in the baseline building performance. The reheat type shall be the same as the system heating type.

<b><i>Humidistat Minimum Setting</i></b>	
<i>Applicability</i>	Systems with humidity control
<i>Definition</i>	The control setpoint for dehumidification
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed

### 3.6.7.2 Desiccant

<i>Desiccant Type</i>	
<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	<p>Describes the configuration of desiccant cooling equipment</p> <p>The following configurations for desiccant systems are allowed:</p> <ul style="list-style-type: none"><li>• A liquid desiccant dehumidifying unit</li><li>• A liquid desiccant dehumidifying unit combined with a gas-fired absorption chiller</li><li>• A solid desiccant dehumidifying unit</li><li>• NO-DESICCANT – the default, which indicates that no desiccant system is present</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable
<i>Desiccant Control Mode</i>	
<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	<p>The method of controlling the operation of the desiccant unit. For liquid-based systems this can be either:</p> <ul style="list-style-type: none"><li>• Dry-bulb: The desiccant unit is turned on whenever the outside air dry-bulb exceeds a set limit.</li><li>• Evaporative cooling: Cycles the desiccant unit on when an evaporative cooler is on to maintain a dewpoint setpoint.</li><li>• Dewpoint: Cycles the desiccant unit on and off to maintain the dewpoint temperature of the supply air.</li></ul> <p>For solid-based systems the following configurations are possible:</p> <ul style="list-style-type: none"><li>• Dehumidification only: The desiccant unit cycles on and off to maintain indoor humidity levels.</li><li>• Sensible heat exchanger plus regeneration: The desiccant unit includes a sensible heat exchanger to precool the hot, dry air leaving the desiccant unit. The air leaving the exhaust side of the heat exchanger is directed to the desiccant unit.</li><li>• Sensible heat exchanger: The desiccant unit includes a heat exchanger, but the air leaving the exhaust side of the heat exchanger is exhausted to the outdoors.</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable



### ***Desiccant Air Fraction***

<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	The fraction of the supply air that passes through the desiccant unit. Typically either the minimum outside air fraction or all of the air passes through the desiccant system.
<i>Units</i>	Fraction (between 0 and 1)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Desiccant Heat Source***

<i>Applicability</i>	Systems with desiccant dehumidification
<i>Definition</i>	The source of heat that is used to dry out the desiccant. This can be either: <ul style="list-style-type: none"><li>• Gas – hydronic: The regeneration heat load is met with a gas-fired heater.</li><li>• Hot water: The heat load is met with hot water from the plant.</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Liquid Desiccant Performance Curves***

<i>Applicability</i>	Systems with liquid-based desiccant dehumidification
<i>Definition</i>	A set of performance curves apply to liquid desiccant systems:

$$DESC-T-FTW = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w \quad (42)$$

$$DESC-W-FTW = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w \quad (43)$$

$$DESC-Gas-FTW = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w \quad (44)$$

$$DESC-kW-FTW = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w \quad (45)$$

Where:

*DESC-T-FTW* = Temperature leaving desiccant unit

*DESC-W-FTW* = Humidity ratio leaving desiccant unit

*DESC-Gas-FTW* = Gas usage of desiccant unit

*DESC-kW-FTW* = Electric usage of desiccant unit

$T$  = Entering air temperature  
 $w$  = Entering humidity ratio

**Table 68.** Liquid Desiccant Unit Performance Curves

Coefficient	DESC-T-FTW	DESC-W-FTW	DESC-Gas-FTW	DESC-kW-FTW
a	11.5334997	11.8993998	58745.8007813	3.5179000
b	0.6586730	-0.2695580	-1134.4899902	-0.0059317
c	-0.0010280	0.0044549	-3.6676099	0.0000000
d	0.2950410	0.0830525	3874.5900879	0.0040401
e	-0.0001700	0.0006974	-1.6962700	0.0000000
f	-0.0008724	0.0015879	-13.0732002	0.0000000

Source: COMnet 2011

*Units* Data structure  
*Input Restrictions* As designed, default to values in Table 68  
*Baseline Building* Not applicable

***Desiccant Dewpoint Temperature Setpoint***

*Applicability* Systems with desiccant dehumidification  
*Definition* The setpoint dewpoint temperature of the air leaving the desiccant system  
*Units* Degrees Fahrenheit (°F)  
*Input Restrictions* As designed. Defaults to 50°F.  
*Baseline Building* Not applicable

***Desiccant Heat Exchanger Effectiveness***

*Applicability* Systems with desiccant dehumidification  
*Definition* The effectiveness of a sensible heat exchanger used with a desiccant system  
*Units* Fraction (between 0 and 1)  
*Input Restrictions* As designed  
*Baseline Building* Not applicable

***Desiccant Heat Exchanger Pressure Drop***

*Applicability* Systems with desiccant dehumidification  
*Definition* The pressure drop across a sensible heat exchanger used with a desiccant system  
*Units* in. H<sub>2</sub>O  
*Input Restrictions* As designed. Defaults to 1.0 in. H<sub>2</sub>O.  
*Baseline Building* Not applicable

## 3.7 HVAC Primary Systems

### 3.7.1 Boilers

<b>Boiler Name</b>	
<i>Applicability</i>	All boilers
<i>Definition</i>	A unique descriptor for each boiler, heat pump, central heating heat-exchanger, or heat recovery device
<i>Units</i>	None
<i>Input Restrictions</i>	User entry
<i>Baseline Building</i>	Boilers are only designated in the baseline model if the baseline system is of type 1 (PTAC), type 5 (Packages VAV with reheat) or type 7 (VAV with reheat).

<b>Boiler Fuel</b>	
<i>Applicability</i>	All boilers
<i>Definition</i>	The fuel source for the central heating equipment. The choices are: <ul style="list-style-type: none"><li>• Gas</li><li>• Oil</li><li>• Electricity</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same fuel as the proposed design

<b>Boiler Type</b>	
<i>Applicability</i>	All boilers
<i>Definition</i>	The boiler type. Choices include: <ul style="list-style-type: none"><li>• Steam boiler</li><li>• Hot water boiler</li><li>• Heat-pump water heater</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The boiler type will be a hot water boiler for baseline systems 1, 5, and 7. All other baseline system types do not have a boiler.

### **Boiler Draft Type**

<i>Applicability</i>	All boilers
<i>Definition</i>	<p>How combustion airflow is drawn through the boiler. Choices are:</p> <ul style="list-style-type: none"><li>• Natural (sometimes called atmospheric)</li><li>• Mechanical</li></ul> <p>Natural draft boilers use natural convection to draw air for combustion through the boiler. Natural draft boilers are subject to outside air conditions and the temperature of the flue gases.</p> <p>Mechanical draft boilers enhance the airflow in one of three ways: 1) induced draft, which uses ambient air, a steam jet, or a fan to induce a negative pressure that pulls flow through the exhaust stack; 2) forced draft, which uses a fan and ductwork to create a positive pressure that forces air into the furnace; or 3) balanced draft, which uses both induced draft and forced draft methods to bring air through the furnace, usually keeping the pressure slightly below atmospheric.</p>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed. Default is natural draft.
<i>Baseline Building</i>	The boiler for the baseline system is assumed to be natural draft boiler

### **Number of Identical Boiler Units**

<i>Applicability</i>	All boilers
<i>Definition</i>	The number of identical units for staging
<i>Units</i>	Numeric: integer
<i>Input Restrictions</i>	As designed. Default is 1.
<i>Baseline Building</i>	The baseline building shall have one boiler when the baseline plant serves a conditioned floor area of 15,000 ft <sup>2</sup> or less, and have two equally size boilers for plants serving more than 15,000 ft <sup>2</sup> .

### **Boiler Heat Loss**

<i>Applicability</i>	All boilers
<i>Definition</i>	The boiler or heat-exchanger heat loss expressed as a percentage of full load output capacity. This loss only occurs when the boiler is firing.
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	Default is 2% for electric boilers and heat-exchangers and 0% for fuel-fired boilers. If the user overrides the default, supporting documentation is required.
<i>Baseline Building</i>	Prescribed at 2% for electric boilers and heat-exchangers. Prescribed at 0% for fuel-fired boilers, since this loss is already incorporated into the overall thermal efficiency, or AFUE of the boiler.

For boilers with efficiency rating prescribed as combustion efficiency, 2% jacket losses will be assumed. Hence:

$$Et = Ec - 2\%$$

Where:

$Et$  = Thermal efficiency

$Ec$  = Combustion efficiency

### ***Boiler Design Capacity***

<i>Applicability</i>	All boilers
<i>Definition</i>	The heating capacity at design conditions
<i>Units</i>	Btu/h
<i>Input Restrictions</i>	UMLH shall not exceed 300. If they do, the proposed boiler capacity shall be increased incrementally until the unmet loads are reduced to 300 or less.
<i>Baseline Building</i>	<p>Autosized, with a heating oversizing factor of 25%. Sizing calculations shall be based on 1% design dry-bulb and 1% wet-bulb design conditions. Oversizing would be carried out at zone level where the sizing parameters would be applied to the zone design cooling airflow rates and zone loads. The system sizing calculations would sum the zone design airflow rates to obtain a system level airflow rate. Refer to Section 2.6.2 of this document for more details.</p> <p>If the number of UMLH for the baseline exceeds 300, heating coil capacity may need to be increased along with system airflow as described in Section 2.6.2. of this document. Section 3.1.5 has more details regarding design day data to be used for equipment sizing.</p>

### ***Boiler Efficiency Type***

<i>Applicability</i>	All boilers
<i>Definition</i>	<p>The full load efficiency of a boiler is expressed as one of the following:</p> <ul style="list-style-type: none"> <li>• Annual fuel utilization efficiency (AFUE) is a measure of the boiler's efficiency over a predefined heating season.</li> <li>• Thermal efficiency (<math>Et</math>) is the ratio of the heat transferred to the water divided by the heat input of the fuel.</li> <li>• Combustion efficiency (<math>Ec</math>) is the measure of how much energy is extracted from the fuel and is the ratio of heat transferred to the combustion air divided by the heat input of the fuel.</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	<p>AFUE for all gas and oil-fired boilers with less than 300,000 Btu/h capacity</p> <p><math>Et</math> for all gas and oil-fired boilers with capacities between 300,000 and 2,500,000 Btu/h</p> <p><math>Ec</math> for all gas and oil-fired boilers with capacities above 2,500,000 Btu/h</p>
<i>Baseline Building</i>	Same efficiency type relationship with capacity as described for proposed design

## Boiler Efficiency

*Applicability* All boilers

*Definition* The full load efficiency of a boiler at rated conditions (see efficiency type above) expressed as a dimensionless ratio of output over input. The software must accommodate input in either thermal efficiency (Et), combustion efficiency (Ec), or annual fuel utilization efficiency (AFUE).

Where AFUE is provided, Et shall be calculated as follows:

$$\begin{aligned}
 &1) 75\% \leq AFUE < 80\% \\
 &E_t = 0.1 \times AFUE + 72.5\% \\
 &2) 80\% \leq AFUE \leq 100\% \\
 &E_t = 0.875 \times AFUE + 10.5\%
 \end{aligned}
 \tag{46}$$

Where Ec is provided, Et shall be calculated as follows:

$$E_t = E_c - 2\% \tag{47}$$

All electric boilers will have an efficiency of 100%.

For applicable software, heat input ratio shall be defined as the inverse of thermal efficiency.

*Units* Ratio

*Input Restrictions* As designed

*Baseline Building* Boilers for the baseline design are assumed to have the minimum efficiency as listed in Table 6.8.1F of Standard 90.1-2010

## Boiler Part-Load Performance Curve

*Applicability* All boilers

*Definition* An adjustment factor that represents the percentage full load fuel consumption as a function of the percentage full load capacity. This curve shall take the form of a quadratic equation as follows:

$$\begin{aligned}
 Fuel_{partload} &= Fuel_{design} \times FHeatPLC(Q_{partload}, Q_{rated}) \\
 FHeatPLC &= \left( a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left( \frac{Q_{partload}}{Q_{rated}} \right)^2 \right)
 \end{aligned}
 \tag{48}$$

Where

$FHeatPLC$  = The fuel heating part load efficiency curve

$Fuel_{partload}$  = The fuel consumption at part load conditions (Btu/h)

$Fuel_{design}$  = The fuel consumption at design conditions (Btu/h)

- $Q_{partload}$  = The boiler capacity at part load conditions (Btu/h)
- $Q_{rated}$  = The boiler capacity at design conditions (Btu/h)
- $a$  = Constant, 0.082597
- $b$  = Constant, 0.996764
- $c$  = Constant, -0.079361

*Units* Ratio

*Input Restrictions* As designed. Supporting documentation is required for use of different curves. Default part load performance curves provided in COMNET Appendix H (COMNET, 2011) can be used based on draft type.

*Baseline Building* The baseline building uses natural draft curve specified in Equation (48) above.

### **Boiler Forced Draft Fan Power**

*Applicability* All mechanical draft boilers

*Definition* The minimum unloading ratio is where the boiler capacity can no longer be reduced by unloading and must be false loaded to meet smaller heating loads. The minimum unloading capacity of a boiler expressed as a percentage of the rated capacity. Below this level the boiler must cycle to meet the load.

*Units* Horsepower

*Input Restrictions* As designed

The software shall convert the user entry of motor HP to fan power in watts by the following equation:

$$\text{Fan Power (W)} = \text{Motor HP} \times 746 \times 0.5$$

*Baseline Building* Not applicable

### **Boiler Minimum Unloading Ratio**

*Applicability* All boilers

*Definition* The minimum unloading capacity of a boiler expressed as a percentage of the rated capacity. Below this level the boiler must cycle to meet the load.

**Table 69.** Default Minimum Unloading Ratios

Boiler Type	Default Unloading Ratio
Electric Steam	1%
Electric Hot Water	1%
Fuel-Fired Steam	25%
Fuel-Fired Hot Water	25%

Source: COMnet 2011

*Units* Percent (%)

*Input Restrictions* As designed. If the user does not use the default value, the software must indicate that supporting documentation is required on the output forms.

*Baseline Building* Use defaults

#### ***Boiler Minimum Flow Rate***

*Applicability* All boilers

*Definition* The minimum flow rate recommended by the boiler manufacturer for stable and reliable operation of the boiler

*Units* gpm

*Input Restrictions* As designed

If the boiler(s) is piped in a primary only configuration in a variable flow system, then the software shall assume there is a minimum flow bypass valve that allows the HW pump to bypass water from the boiler outlet back to the boiler inlet to maintain the minimum flow rate when boiler is enabled. Note that the boiler entering water temperature must accurately reflect the mixed temperature (colder water returning from the coil(s) and hotter bypass water) in order to accurately model boiler efficiency as a function of boiler entering water temperature.

*Baseline Building* 0 gpm

#### ***Hot Water Supply Temperature***

*Applicability* All boilers

*Definition* The temperature of the water produced by the boiler and supplied to the hot water loop

*Units* Degrees Fahrenheit (°F)

*Input Restrictions* As designed

*Baseline Building* Use 180°F for baseline boiler

#### ***Hot Water Return Temperature***

*Applicability* All boilers

*Definition* The temperature of the water returning to the boiler from the hot water loop

*Units* Degrees Fahrenheit (°F)

*Input Restrictions* As designed

*Baseline Building* Use 130°F for baseline boiler design



### ***Hot Water Supply Temperature Reset***

<i>Applicability</i>	All boilers
<i>Definition</i>	Variation of the hot water supply temperature with OAT
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The hot water supply temperature should vary according to the following: <ul style="list-style-type: none"><li>• 180°F when outside air is &lt; 20°F</li><li>• ramp linearly between 180°F and 150°F when outdoor air is between 20°F and 50°F</li><li>• 150°F when outdoor air is &gt; 50°F</li></ul>

### **3.7.2 Chillers**

#### ***Chiller Name***

<i>Applicability</i>	All chillers
<i>Definition</i>	Unique descriptor for each chiller
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	User entry. Where applicable, this should match the tags that are used on the plans.
<i>Baseline Building</i>	Chillers are only designated when the baseline system is of type 7 (VAV with reheat) or 8 (VAV with PFP boxes).

#### ***Chiller Type***

<i>Applicability</i>	All chillers
<i>Definition</i>	<p>The type of chiller, either a vapor-compression chiller or an absorption chiller.</p> <p>Vapor compression chillers operate on the reverse-Rankine cycle, using mechanical energy to compress the refrigerant, and include:</p> <ul style="list-style-type: none"><li>• Positive displacement: Includes reciprocating (piston-style), scroll and screw compressors.</li><li>• Centrifugal: Uses rotating impeller blades to compress the refrigerant and impart velocity.</li><li>• Single effect absorption: Uses a single generator and condenser.</li><li>• Double effect absorption: Uses two generators/concentrators and condensers, one at a lower temperature and the other at a higher temperature. It is more efficient than the single effect, but it must use a higher temperature heat source.</li><li>• Double effect absorption, indirect-fired.</li><li>• Gas engine driven chiller.</li></ul>

- Positive displacement: Includes reciprocating (piston-style), scroll and screw compressors.

*Units* List (see above)

*Input Restrictions* As designed

*Baseline Building* The baseline building chiller is based on the baseline building peak cooling load, as follows:

**Table 70.** Type and Number of Chillers

Building Peak Cooling Load	Number and Type of Chiller(s)
<= 300 tons	1 water cooled screw chiller
>300 tons, < 600 tons	2 water cooled screw chillers, sized equally
>= 600 tons	A minimum of two (2) water cooled centrifugal chillers, sized to keep the unit size below 800 tons, all sized equally.

### ***Number of Identical Chiller Units***

*Applicability* All chillers

*Definition* The number of identical units for staging.

*Units* None

*Input Restrictions* As designed. Default is 1.

*Baseline Building* From Table 70 above, there is one chiller if the baseline system cooling load is 300 tons or less and two equally sized chillers for baseline system loads between 300 and 600 tons. For loads above 600 tons, two or more chillers of equal size are used, with no chiller larger than 800 tons.

### ***Chiller Fuel***

*Applicability* All chillers

*Definition* The fuel source for the chiller. The choices are:

- Electricity (for all vapor-compression chillers)
- Gas (absorption units only, designated as direct-fired units)
- Oil (absorption units only, designated as direct-fired units)
- Hot Water (absorption units only, designated as indirect-fired units)
- Steam (absorption units only, designated as indirect-fired units)

*Units* List (see above)

*Input Restrictions* As designed

This input is restricted, based on the choice of chiller type, according to the following rules:

	Electricity	Gas	Hot Water	Steam
Reciprocating	Allowed			
Scroll	Allowed			
Screw	Allowed			
Centrifugal	Allowed			
Single effect absorption		Allowed	Allowed	Allowed
Direct fired double effect absorption		Allowed	Allowed	Allowed
Indirect fired absorption		Allowed	Allowed	Allowed

*Baseline Building* Electricity

### **Chiller Fuel**

*Applicability* All chillers

*Definition* The cooling capacity of a piece of heating equipment at rated conditions

*Units* Btu/h or tones

*Input Restrictions* As designed. If UMLH are greater than 300, the chiller may have to be made larger.

*Baseline Building* The zone loads and airflow rates are oversized by 15% and the chiller is sized to the sum of the individual oversized zone peak loads. The zones shall be sized using weather files containing 1% dry-bulb and 1% wet-bulb cooling design temperatures. Section 3.1.5 has more details regarding design day data to be used for equipment sizing.

### **Chiller Rated Efficiency**

*Applicability* All chillers

*Definition* The efficiency of the chiller: EER for air cooled chillers, kW/ton for water cooled, positive displacement chillers, and COP for fuel-fired and heat driven chillers at ARI 550/590 rated full-load conditions

*Units* Ratio (kW/ton, EER, or COP based on chiller type and condenser type)

*Input Restrictions* As designed. Must meet the minimum requirements of Table 6.8.1C of Standard 90.1-2010.

*Baseline Building* Use the minimum efficiency requirements EER or kW/top values for Path A from Table 6.8.1C based on chiller equipment type and size category.

### **Integrated Part Load Value**

<i>Applicability</i>	All chillers
<i>Definition</i>	The part-load efficiency of a chiller developed from a weighted average of four rating conditions, according to AHRI Standard 550
<i>Units</i>	Ratio (kW/ton, COP, or EER, depending on chiller type and condenser type) Water cooled electric chiller: kW/ton Air cooled or evaporatively cooled electric chiller: EER All non-electric chillers: COP
<i>Input Restrictions</i>	As designed. Must meet the minimum requirements of Table 6.8.1C of Standard 90.1-2010.
<i>Baseline Building</i>	Not used

### **Chiller Minimum Unloading Ratio**

<i>Applicability</i>	All chillers
<i>Definition</i>	The minimum unloading capacity of a chiller expressed as a fraction of the rated capacity. Below this level the chiller must cycle to meet the load.

**Table 71.** Default Minimum Unloading Ratios

Chiller Type	Default Unloading Ratio
Reciprocating	25%
Screw	15%
Centrifugal	10%
Scroll	25%
Single Effect Absorption	10%
Double Effect Absorption	10%

Source: COMnet 2011

<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	As designed. If the user does not employ the default values, supporting documentation is required.
<i>Baseline Building</i>	Use defaults listed above

### Chiller Minimum Part Load Ratio

<i>Applicability</i>	All chillers
<i>Definition</i>	The minimum unloading capacity of a chiller expressed as a fraction of the rated capacity. Below this level the chiller must cycle to meet the load. If the chiller minimum part-load ratio (PLR) is less than the chiller minimum unloading ratio, then the software shall assume hot-gas bypass operation between the minimum PLR and the minimum unloading ratio.
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	As designed, but constrained to a minimum value of 10%. If the user does not employ the default values, supporting documentation is required.
<i>Baseline Building</i>	When the baseline design has a screw chiller, the minimum part load ratio is 15%. When the baseline design has a centrifugal chiller, the minimum part load ratio is 10%.

### Chiller Cooling Capacity Adjustment Curve

<i>Applicability</i>	All chillers
<i>Definition</i>	A curve or group of curves or other functions that represent the available total cooling capacity as a function of evaporator and condenser conditions and perhaps other operating conditions. The default curves are given as follows:

$$Q_{available} = CAP\_FT \times Q_{rated} \quad (49)$$

For air cooled chillers:

$$CAP\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{odb} + e \times t_{odb}^2 + f \times t_{chws} \times t_{odb} \quad (50)$$

For water cooled chillers:

$$CAP\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{cws} + e \times t_{cws}^2 + f \times t_{chws} \times t_{cws} \quad (51)$$

Where:

$Q_{available}$  = Available cooling capacity at present evaporator and condenser conditions (MBH)

$t_{chws}$  = The chilled water supply temperature (°F)

$t_{cws}$  = The condenser water supply temperature (°F)

$t_{odb}$  = The outside air dry-bulb temperature (°F)

$Q_{rated}$  = Rated capacity at ARI conditions (MBH)

Note: If an air cooled unit employs an evaporative condenser,  $t_{odb}$  is the effective dry-bulb temperature of the air leaving the evaporative cooling unit.

Separate curves are provided for Path A and Path B chillers in COMNET Appendix H (COMNET, 2011).

**Table 72.** Default Capacity Coefficients – Electric Air Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.40070684	0.57617295	-0.09464899	N/A
b	0.01861548	0.02063133	0.03834070	N/A
c	0.00007199	0.00007769	-0.00009205	N/A
d	0.00177296	-0.00351183	0.00378007	N/A
e	-0.00002014	0.00000312	-0.00001375	N/A
f	-0.00008273	-0.00007865	-0.00015464	N/A
Tchws	Min = 40°F, Max = 54°F	Min = 40°F, Max = 54°F	Min = 40°F, Max = 54°F	NA
Todb	Min = 40°F, Max = 115°F	Min = 40°F, Max = 115°F	Min = 40°F, Max = 115°F	NA

**Table 73.** Default Capacity Coefficients – Electric Water Cooled Chillers

Coefficient	Scroll	Recip	Screw	Centrifugal
a	0.36131454	0.58531422	0.33269598	-0.29861976
b	0.01855477	0.01539593	0.00729116	0.02996076
c	0.00003011	0.00007296	-0.00049938	-0.00080125
d	0.00093592	-0.00212462	0.01598983	0.01736268
e	-0.00001518	-0.00000715	-0.00028254	-0.00032606
f	-0.00005481	-0.00004597	0.00052346	0.00063139
Tchws	Min = 40°F, Max = 54°F	Min = 40°F, Max = 54°F	Min = 40°F, Max = 54°F	Min = 40°F, Max = 54°F
Tcws	Min = 60°F, Max = 85°F	Min = 60°F, Max = 85°F	Min = 60°F, Max = 85°F	Min = 60°F, Max = 85°F

**Table 74.** Default Capacity Coefficients – Fuel- and Steam-Source Water Cooled Chillers

Coefficient	Single Stage Absorption	Double Stage Absorption	Direct-Fired Absorption	Engine Driven Chiller
A	0.723412	-0.816039	1.000000	0.573597
B	0.079006	-0.038707	0.000000	0.0186802
C	-0.000897	0.000450	0.000000	0.000000
D	-0.025285	0.071491	0.000000	-0.00465325
E	-0.000048	-0.000636	0.000000	0.000000
F	0.000276	0.000312	0.000000	0.000000

Source: COMnet 2011

*Units* Data structure*Input Restrictions* The user may input curves or use default curves. If the default curves are overridden, supporting documentation is required.*Baseline Building* Use default curve**Electric Chiller Cooling Efficiency Adjustment Curves***Applicability* All chillers*Definition* A curve or group of curves that varies the cooling efficiency of an electric chiller as a function of evaporator conditions, condenser conditions, and part-load ratio. Note that for variable-speed chillers, the part-load cooling efficiency curve is a function of both part-load ratio and leaving condenser water temperature. The default curves are given as follows:

$$PLR = \frac{Q_{operating}}{Q_{available}(t_{chws}, t_{cws/odb})}$$

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2$$

variable - speed

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2 + d \times t_{cws} + e \times t_{cws}^2 + f \times PLR \cdot t_{cws} + g \times PLR^3 + h \times t_{cws}^3 + i \times PLR^2 \cdot t_{cws} + j \times t_{cws}^2 \cdot PLR$$

Air - Cooled :

$$EIR\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{odb} + e \times t_{odb}^2 + f \times t_{chws} \times t_{odb}$$

Water - Cooled :

$$EIR\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{cws} + e \times t_{cws}^2 + f \times t_{chws} \times t_{cws}$$

$$P_{operating} = P_{rated} \times EIR\_FPLR \times EIR\_FT \times CAP\_FT \tag{52}$$

Source: COMnet 2011

Where:

- $PLR$  = Part load ratio based on available capacity (not rated capacity)
- $Q_{operating}$  = Present load on chiller (Btu/h)
- $Q_{available}$  = Chiller available capacity at present evaporator and condenser conditions (Btu/h)
- $t_{chws}$  = The chilled water supply temperature (°F)
- $t_{cws}$  = The condenser water supply temperature (°F)
- $t_{odb}$  = The outside air dry-bulb temperature (°F)
- $P_{rated}$  = Rated power draw at ARI conditions (kW)
- $P_{operating}$  = Power draw at specified operating conditions (kW)

Note: If an air cooled chiller employs an evaporative condenser,  $t_{odb}$  is the effective dry-bulb temperature of the air leaving the evaporative cooling unit.

**Table 75.** Default Efficiency EIR-FT Coefficients – Air Cooled Chillers

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	0.99006553	0.66534403	0.13545636	N/A
b	-0.00584144	-0.01383821	0.02292946	N/A
c	0.00016454	0.00014736	-0.00016107	N/A
d	-0.00661136	0.00712808	-0.00235396	N/A
e	0.00016808	0.00004571	0.00012991	N/A
f	-0.00022501	-0.00010326	-0.00018685	N/A
Tchws	Min = 40°F, Max = 54°F	Min = 40°F, Max = 54°F	Min = 40°F, Max = 54°F	NA
Todb	Min = 40°F, Max = 115°F	Min = 40°F, Max = 115°F	Min = 40°F, Max = 115°F	NA

**Table 76.** Default Efficiency EIR-FT Coefficients – Water Cooled Chillers

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	1.00121431	0.46140041	0.66625403	0.51777196
b	-0.01026981	-0.00882156	0.00068584	-0.00400363
c	0.00016703	0.00008223	0.00028498	0.00002028
d	-0.00128136	0.00926607	-0.00341677	0.00698793
e	0.00014613	0.00005722	0.00025484	0.00008290
f	-0.00021959	-0.00011594	-0.00048195	-0.00015467

**Table 77.** Default Efficiency EIR-FPLR Coefficients – Air Cooled Chillers

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	0.06369119	0.11443742	0.03648722	N/A
b	0.58488832	0.54593340	0.73474298	N/A
c	0.35280274	0.34229861	0.21994748	N/A

**Table 78.** Default Efficiency EIR-FPLR Coefficients – Water Cooled Chillers

Coefficient	Scroll	Reciprocating	Screw	Centrifugal
a	0.04411957	0.08144133	0.33018833	0.17149273
b	0.64036703	0.41927141	0.23554291	0.58820208
c	0.31955532	0.49939604	0.46070828	0.23737257

Source: COMnet 2011

<i>Units</i>	Data structure
<i>Input Restrictions</i>	User may input curves or use default curves. If defaults are overridden, supporting documentation is required.
<i>Baseline Building</i>	Use default curve

**Chilled Water Supply Temperature**

<i>Applicability</i>	All chillers
<i>Definition</i>	The chilled water supply temperature of the chiller at design conditions
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The baseline chilled water supply temperature is set to 44°F



### ***Chilled Water Return Temperature***

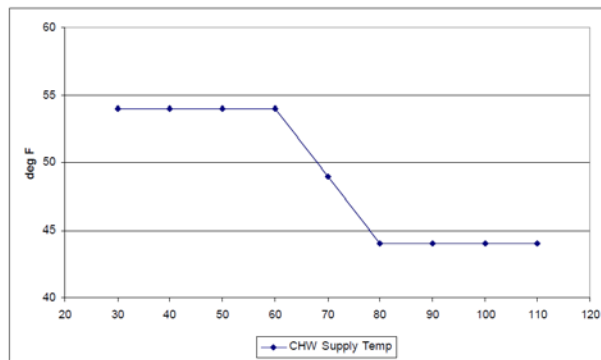
<i>Applicability</i>	All chillers
<i>Definition</i>	The chilled water return temperature setpoint
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The baseline chilled water return temperature is set to 56°F

### ***Chilled Water Supply Temperature Control Type***

<i>Applicability</i>	All chillers
<i>Definition</i>	The method by which the chilled water setpoint temperature is reset. The chilled water setpoint may be reset based on demand or OAT.
<i>Units</i>	List
<i>Input Restrictions</i>	None, can be either “outside air-based reset” or “demand-based reset”
<i>Baseline Building</i>	Outside air based reset

### ***Chilled Water Supply Temperature Reset***

<i>Applicability</i>	All chillers
<i>Definition</i>	The reset schedule for the chilled water supply temperature. The chilled water setpoint may be reset based on demand or OAT.
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. The default is as shown in the figure below.
<i>Baseline Building</i>	<p>The baseline chilled water supply temperature is reset from 44°F to 54°F based on OAT as shown in the figure below.</p> <p>The figure depicts a linear reset schedule that represents the chilled water setpoint as a function of outdoor air dry-bulb temperature. This schedule is defined by the following data points:</p> <ul style="list-style-type: none"><li>• 44°F at OAT 80°F and above</li><li>• 54°F at OAT 60°F and below</li><li>• Ramped linearly between 44°F and 54°F at temperatures between 80°F and 60°F</li></ul>



**Figure 12.** Chilled Water Supply Temperature Reset Schedule

### **Air Cooled Condenser Power**

<i>Applicability</i>	All chillers with air cooled condensers where fan energy is not part of the COP
<i>Definition</i>	The energy usage of the condenser fan(s) at design conditions on an air cooled chiller. This unit should only be used for chillers composed of separate evaporator and condenser sections where the fan energy is not part of the chiller COP.
<i>Units</i>	kilowatts (kW)
<i>Input Restrictions</i>	As designed. The user must enter data for remote air cooled condensing units.
<i>Baseline Building</i>	Not applicable, since all baseline chillers have water cooled condensers.

### **3.7.3 Cooling Towers**

Baseline building systems 7 and 8 have one or more cooling towers. One tower is assumed to be matched to each baseline building chiller. Each baseline building chiller has its own condenser water pump that operates when the chiller is brought into service. The range between the condenser water return (CWR) and condenser water supply (CWS) is 10°F so that condenser water flow is a constant 2.5 gpm per cooling ton.<sup>7</sup> The baseline building pumping energy is assumed to be 19 W/gpm. The baseline building cooling tower is assumed to have a two-speed fan that is controlled to provide a CWS equal to 70°F when weather permits. The tower fan cycles to one-speed or off to maintain a CWS of 70 °F at low wet-bulb conditions. Under cooling conditions closer to design conditions, the CWS floats up to a maximum of 85 °F (the design condition).

<sup>7</sup> Cooling capacity is related to flow and delta-T through the equation  $Q = 500 * GPM * \Delta T$ . When Q is one ton (12,000 Btu/h),  $GPM = 24 / \Delta T$  and  $\Delta T = 24 / GPM$

### **Cooling Tower Name**

<i>Applicability</i>	All cooling towers
<i>Definition</i>	A unique descriptor for each cooling tower
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	User entry. Where applicable, this should match the tags that are used on the plans.
<i>Baseline Building</i>	Descriptive name that keys the baseline building plant

### **Cooling Tower Type**

<i>Applicability</i>	All cooling towers
<i>Definition</i>	<p>The type of cooling tower employed. The choices are:</p> <ul style="list-style-type: none"><li>• Open tower, centrifugal fan</li><li>• Open tower, axial fan</li><li>• Closed tower, centrifugal fan</li><li>• Closed tower, axial fan</li></ul> <p>Open cooling towers collect the cooled water from the tower and pump it directly back to the cooling system. Closed towers circulate the evaporated water over a heat exchanger to indirectly cool the system fluid.</p>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The baseline cooling tower is an open tower axial fan device with a two speed fan

### **Cooling Tower Capacity**

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The tower thermal capacity per cell adjusted to CTI (Cooling Technology Institute) rated conditions of 95°F condenser water return, 85°F condenser water supply, and 78°F wet-bulb with a 3 gpm/nominal ton water flow. The default cooling tower curves below are at unity at these conditions.
<i>Units</i>	But/h
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The baseline building chiller is autosized and increased by 15%. The tower is sized to supply 85°F condenser water or 10°F approach to wet bulb, whichever is lower, at design conditions for the oversized chiller.

### ***Cooling Tower Number of Cells***

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The number of cells in the cooling tower. Each cell will be modeled as equal size. Cells are subdivisions in cooling towers, each with its own fan and water flow, and allow the cooling system to respond more efficiently to lower load conditions.
<i>Units</i>	Numeric: integer
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	One cell per tower and one tower per chiller

### ***Cooling Tower Total Fan Horse Power***

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The sum of the nameplate rated horsepower (hp) of all fan motors on the cooling tower. Pony motors should not be included.
<i>Units</i>	gpm/hp or unitless if EIR is specified. (If the nominal tons but not the condenser water flow is specified, the condenser design water flow shall be 2.4 gpm per nominal cooling ton.)
<i>Input Restrictions</i>	As designed, but the cooling towers shall meet minimum performance requirements in Table 6.8.1G of Standard 90.1-2010 and must be at least 38.2 gpm/hp for an axial fan cooling tower and at least 20 gpm/hp for a centrifugal fan cooling tower
<i>Baseline Building</i>	38.2 gpm/hp. Defined according to the minimum performance requirements for an axial fan cooling tower in Table 6.8.1G of Standard 90.1-2010 and rated gpm of the autosized tower.

### ***Cooling Tower Design Wet-Bulb***

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The design wet-bulb temperature that was used for selection and sizing of the cooling tower
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	1% wet-bulb design conditions if the proposed building has a cooling tower

### ***Cooling Tower Design Leaving Water Temperature***

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The design condenser water supply temperature (leaving tower) that was used for selection and sizing of the cooling tower
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. Default to 85°F.
<i>Baseline Building</i>	85°F or 10°F above the design wet-bulb temperature, whichever is lower

### Cooling Tower Design Entering Water Temperature

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The design leaving condenser water temperature (entering tower) that was used for selection and sizing of the cooling tower
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	As designed. Default to 95°F.
<i>Baseline Building</i>	Set to 10°F above the cooling tower design leaving water temperature

### Cooling Tower Capacity Adjustment Curve(s)

<i>Applicability</i>	All cooling towers
<i>Definition</i>	A curve or group of curves that represent the available total cooling capacity as a function of outdoor air wet-bulb, condenser water supply and condenser water return temperatures. The default curves are given as follows: Option 1 (DOE-2 based performance curves)

$$\begin{aligned}
 t_R &= t_{cwr} - t_{cws} \\
 t_A &= t_{cws} - t_{owb} \\
 t_A &= a + b \times t_R + c \times t_R^2 + d \times FRA + e \times FRA^2 + f \times t_R \times FRA \\
 FRA &= \frac{-d - f \times t_R + \sqrt{(d + f \times t_R)^2 - 4 \times e \times (a + b \times t_R + c \times t_R^2 - t_A)}}{2 \times e} \\
 FWB &= a + b \times FRA + c \times FRA^2 + d \times t_{owb} + e \times t_{owb}^2 + f \times FRA \times t_{owb} \\
 Q_{available} &= Q_{rated} \times FWB \times \left( \frac{t_R}{10} \right)
 \end{aligned} \tag{53}$$

Where:

$Q_{available}$	= Available cooling capacity at present outside air and condenser water conditions (MBH)
$Q_{rated}$	= Rated cooling capacity at CTI test conditions (MBH)
$t_{cws}$	= The condenser water supply temperature (in °F)
$t_{cwr}$	= The condenser water return temperature (in °F)
$t_{owb}$	= The outside air wet-bulb temperature (°F)
$t_R$	= The tower range (in °F)
$t_A$	= The tower approach (in °F)
$FRA$	= An intermediate capacity curve based on range and approach
$FWB$	= The ratio of available capacity to rated capacity (gpm/gpm)

**Table 79.** Default Capacity Coefficients – Cooling Towers

Coefficient	FRA	FWB
a	-2.22888899	0.60531402
b	0.16679543	-0.03554536
c	-0.01410247	0.00804083
d	0.03222333	-0.02860259
e	0.18560214	0.00024972
f	0.24251871	0.00490857

Option 2: CoolTools performance curve (EnergyPlus)

$$\begin{aligned}
 \text{Approach} = & \text{Coeff}(1) + \text{Coeff}(2) \cdot \text{FRair} + \text{Coeff}(3) \cdot (\text{FRair})^2 + \text{Coeff}(4) \cdot (\text{FRair})^3 + \\
 & \text{Coeff}(5) \cdot \text{FRwater} + \text{Coeff}(6) \cdot \text{FRair} \cdot \text{FRwater} + \text{Coeff}(7) \cdot (\text{FRair})^2 \cdot \text{FRwater} + \\
 & \text{Coeff}(8) \cdot (\text{FRwater})^2 + \text{Coeff}(9) \cdot \text{FRair} \cdot (\text{FRwater})^2 + \\
 & \text{Coeff}(10) \cdot (\text{FRwater})^3 + \text{Coeff}(11) \cdot \text{Twb} + \text{Coeff}(12) \cdot \text{FRair} \cdot \text{Twb} + \text{Coeff}(13) \cdot (\text{FRair})^2 \cdot \text{Twb} + \\
 & \text{Coeff}(14) \cdot \text{FRwater} \cdot \text{Twb} + \text{Coeff}(15) \cdot \text{FRair} \cdot \text{FRwater} \cdot \text{Twb} + \text{Coeff}(16) \cdot (\text{FRwater})^2 \cdot \text{Twb} + \\
 & \text{Coeff}(17) \cdot (\text{Twb})^2 + \text{Coeff}(18) \cdot \text{FRair} \cdot (\text{Twb})^2 + \text{Coeff}(19) \cdot \text{FRwater} \cdot (\text{Twb})^2 + \\
 & \text{Coeff}(20) \cdot (\text{Twb})^3 + \text{Coeff}(21) \cdot \text{Tr} + \text{Coeff}(22) \cdot \text{FRair} \cdot \text{Tr} + \text{Coeff}(23) \cdot \text{FRair} \cdot \text{FRair} \cdot \text{Tr} + \\
 & \text{Coeff}(24) \cdot \text{FRwater} \cdot \text{Tr} + \text{Coeff}(25) \cdot \text{FRair} \cdot \text{FRwater} \cdot \text{Tr} + \\
 & \text{Coeff}(26) \cdot (\text{FRwater})^2 \cdot \text{Tr} + \text{Coeff}(27) \cdot \text{Twb} \cdot \text{Tr} + \text{Coeff}(28) \cdot \text{FRair} \cdot \text{Twb} \cdot \text{Tr} + \\
 & \text{Coeff}(29) \cdot \text{FRwater} \cdot \text{Twb} \cdot \text{Tr} + \\
 & \text{Coeff}(30) \cdot (\text{Twb})^2 \cdot \text{Tr} + \text{Coeff}(31) \cdot (\text{Tr})^2 + \text{Coeff}(32) \cdot \text{FRair} \cdot (\text{Tr})^2 + \text{Coeff}(33) \cdot \text{FRwater} \cdot (\text{Tr})^2 + \\
 & \text{Coeff}(34) \cdot \text{Twb} \cdot (\text{Tr})^2 + \text{Coeff}(35) \cdot (\text{Tr})^3
 \end{aligned}$$

Where:

FRair = Ratio of airflow to airflow at design conditions

FRwater = Ratio of water flow to water flow at design conditions

Tr = Tower range (°F)

Twb = Wet-Bulb temperature

Coefficients for this performance curve are provided in COMNET Appendix H (COMNET, 2011).

*Units*

Data structure

*Input Restrictions*

User may input curves or use one of the two default curves. If defaults are overridden, the rating software must indicate that supporting documentation is required on the output forms.

*Baseline Building*

Use one of the two default curves

### **Cooling Tower Set Point Control**

*Applicability*

All cooling towers

*Definition*

The type of control for the condenser water supply. The choices are:

- Fixed
- Wet-bulb reset

A fixed control will modulate the tower fans to provide the design condenser water supply temperature at all times when possible. A wet-bulb reset control will reset the condenser

water setpoint according to the following control scheme:

$$t_{cws} = t_{owb} + t_A + RR \times (t_{dwb} - t_{owb})$$

Where:

$t_{cws}$  = The condenser water supply setpoint (in °F)

$t_{owb}$  = The outside air wet-bulb temperature (°F)

$t_{dwb}$  = The design outside air wet-bulb temperature (°F)

$t_A$  = The tower design approach (in °F)

$RR$  = The reset ratio (default is 0.29)

A reset ratio ( $RR$ ) of 0 will force the tower to always attempt a fixed approach to the outdoor wet-bulb temperature. An  $nRR$  of 1 will cause the system to perform as if it had fixed condenser water controls.

<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed. If the user does not use the default control, supporting documentation is required.
<i>Baseline Building</i>	Controlled to 70°F when weather permits, floating up to leaving water temperature at design conditions

### ***Cooling Tower Capacity Control***

<i>Applicability</i>	All cooling towers
<i>Definition</i>	Describes the modulation control employed in the cooling tower. Choices include: <ul style="list-style-type: none"> <li>• Fluid bypass: Provides a parallel path to divert some of the condenser water around the cooling tower at part-load conditions.</li> <li>• Fan cycling: A simple method of capacity control where the tower fan is cycled on and off. This is often used on multiple-cell installations.</li> <li>• Two-speed fan/pony motor: From an energy perspective, these are the same. A lower horsepower pony motor is an alternative to a two-speed motor; the pony motor runs at part-load conditions (instead of the full sized motor) and saves fan energy when the tower load is reduced. Additional building descriptors are triggered when this method of capacity control is selected.</li> <li>• Variable Speed fan: A variable frequency drive is installed for the tower fan so that the speed can be modulated.</li> </ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Two-speed fans

### Cooling Tower Low-Speed Airflow Ratio

<i>Applicability</i>	All cooling towers with variable speed, two-speed, or pony motors
<i>Definition</i>	The percentage full load airflow that the tower has at low speed or with the pony motor operating. This is equivalent to the percentage full load capacity when operating at low speed.
<i>Units</i>	Fraction (between 0 and 1)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	0.50

### Cooling Tower Low-Speed kW Ratio

<i>Applicability</i>	All cooling towers
<i>Definition</i>	The percentage full load power that the tower fans draw at low speed or with the pony motor operating
<i>Units</i>	Fraction (between 0 and 1)
<i>Input Restrictions</i>	Calculated, using the as-designed flow ratio and the cooling tower power adjustment curve below
<i>Baseline Building</i>	0.30

### Cooling Tower Fan Power Adjustment Curve

<i>Applicability</i>	All cooling towers with VSD control
<i>Definition</i>	A curve that varies the cooling tower fan energy usage as a function of part-load ratio for cooling towers with variable speed fan control. The default curve is given as follows:

$$\begin{aligned}
 PLR &= \frac{Q_{operating}}{Q_{available}(t_R, t_A, t_{OWB})} \\
 TWR\_FAN\_FPLR &= a + b \times PLR + c \times PLR^2 + d \times PLR^3 \\
 P_{operating} &= P_{rated} \times TWR\_FAN\_FPLR
 \end{aligned}
 \tag{54}$$

Where:

$PLR$	= Part load ratio based on available capacity (not rated capacity)
$Q_{operating}$	= Present load on tower (in Btu/h)
$Q_{available}$	= Tower available capacity at present range, approach, and outside wet-bulb conditions (in Btu/h).
$t_{owb}$	= The outside air wet-bulb temperature (°F)
$t_R$	= The tower range (°F)
$t_A$	= The tower approach (°F)
$P_{rated}$	= Rated power draw at CTI conditions (kW)



$P_{operating}$  = Power draw at specified operating conditions (kW)

**Table 80.** Default Efficiency TWR-FAN-FPLR Coefficients – VSD on Cooling Tower Fan

Coefficient	TWR-FAN-FPLR
a	0.33162901
b	-0.88567609
c	0.60556507
d	0.9484823

<i>Units</i>	Data structure
<i>Input Restrictions</i>	User may input curves or use default curves. If defaults are overridden, supporting documentation is required.
<i>Baseline Building</i>	Use default curves from DOE 2, given above

#### **Cooling Tower Minimum Speed**

<i>Applicability</i>	All cooling towers with a VSD control
<i>Definition</i>	The minimum fan speed setting of a VSD controlling a cooling tower fan expressed as a ratio of full load speed
<i>Units</i>	Fraction (between 0 and 1)
<i>Input Restrictions</i>	As designed. The default is 0.40.
<i>Baseline Building</i>	Not applicable

### **3.7.4 Water-side Economizers**

Baseline Building Summary:

None of the baseline building systems use a water-side economizer. Additional inputs to those below may be required to simulate actual control sequences.

#### **Water-Side Economizer Name**

<i>Applicability</i>	All water-side economizers
<i>Definition</i>	The name of a water-side economizer for a cooling system
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	No water economizer

### Water Economizer Type

<i>Applicability</i>	All water-side economizers
<i>Definition</i>	The type of water-side economizer. Choices include: <ul style="list-style-type: none"><li>• None</li><li>• Heat exchanger in parallel with chillers: This would be used with an open cooling tower often referred to as a non-integrated economizer, because the chillers are locked out when the plant is in economizer mode.</li><li>• Heat exchanger in series with chillers: This would be used with an open cooling tower and is often referred to as integrated because the chillers can operate simultaneously with water economizer operation.</li><li>• Direct water economizer: This would be used with a closed cooling tower. In this case, a heat exchanger is not needed. This type works only as a non-integrated economizer (also known as strainer-cycle).</li><li>• Thermo-cycle (also known as refrigerant migration): With thermo-cycle, bypass valves allow for the flow of vapor refrigerant to the condenser and allow gravity flow of liquid refrigerant to the evaporator without use of the compressor. Only some chillers have this capability and capacity may be limited under this mode. There is no additional piping; the cooler water from the tower is brought directly to the chiller(s) and the chiller(s) respond by shutting down the compressor and relying on thermal forces to drive the refrigerant. This method is also known as “thermosiphon” since thermal gradients passively move refrigerant between the evaporator and condenser.</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	No water economizer

### Water-Side Economizer HX Effectiveness

<i>Applicability</i>	Water-side economizers with an open cooling tower
<i>Definition</i>	The effectiveness of a water-side heat exchanger at design conditions. This is defined as:

$$WSE_{eff} = \frac{t_{ea} - t_{la}}{t_{ea} - t_{ew}} \quad (55)$$

Where:

$WSE_{eff}$  = The effectiveness of the water-side economizer coil

$t_{ea}$  = The entering coil air dry-bulb temperature (°F)

$t_{la}$  = The leaving coil air dry-bulb temperature (°F)

$t_{ew}$  = The entering coil water temperature (°F)

<i>Units</i>	Ratio
<i>Input Restrictions</i>	As designed. The default is 60%.

*Baseline Building* No water economizer

#### ***Water-Side Economizer Maximum $T_{db}$***

*Applicability* All water-side economizers

*Definition* The control temperature (outside air dry-bulb temperature) above which the water-side economizer is disabled

*Units* Degrees Fahrenheit (°F)

*Input Restrictions* As designed. Defaults to 65°F.

*Baseline Building* No water economizer

#### ***Water-Side Economizer Operating Range***

*Applicability* All water-side economizers

*Definition* The minimum temperature difference between the chilled water inlet to the heat exchanger and the condenser water inlet to the heat exchanger that is required to enable the water-side economizer

*Units* Degrees Fahrenheit (°F)

*Input Restrictions* As designed. Defaults to 4°F.

*Baseline Building* No water economizer

#### ***Water-Side Economizer Maximum CWS***

*Applicability* All water-side economizers

*Definition* The control temperature (condenser water supply temperature) above which the water-side economizer is disabled

*Units* Degrees Fahrenheit (°F)

*Input Restrictions* As designed. Defaults to 50°F.

*Baseline Building* No water economizer

#### ***Water-Side Economizer CWS Setpoint***

*Applicability* All water-side economizers

*Definition* The design condenser water supply temperature for the cooling tower in economizer mode

*Units* Degrees Fahrenheit (°F)

*Input Restrictions* As designed. Defaults to 45°F or 40°F for “Thermo Cycle.” If a strainer cycle is specified, changeover temperature from economizer to mechanical cooling shall be set at 50°F.

*Baseline Building* No water economizer

### ***Water-Side Economizer Availability Schedule***

<i>Applicability</i>	All water-side economizers
<i>Definition</i>	A schedule that represents the availability of the water-side economizer
<i>Units</i>	Data structure: schedule, on/off
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	No water economizer

### ***Water-Side Economizer Auxiliary kW***

<i>Applicability</i>	Water-side economizers with an open tower
<i>Definition</i>	The electrical input (pumps and auxiliaries) for a dedicated pump for the chilled water side of the heat exchanger. This power is in excess of the condenser water pumps and cooling tower fans for the system during water-side economizer operation.
<i>Units</i>	kW or kW/ton
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	No water economizer

## **3.7.5 Pumps**

Hot water pumping in the baseline building (systems 1, 5, and 7) shall be modeled as a primary only system with continuous variable flow, and a minimum of 25% of design flow rate. When the spaces served by the hot water system are greater than or equal to 120,000 ft<sup>2</sup>, the pump shall have a variable speed drive; otherwise, the pump “rides the curve.” Pumping energy shall be assumed to be 19 W/gpm. Two-way valves are assumed at the heating coils with a modulating bypass valve at the end of the loop. The bypass valve shall open as necessary to maintain minimum flow through the boiler when the system is activated. This will establish the minimum flow through the system.

District hot water systems shall follow the same rules as hot water pumps, except for pump energy, which shall be equal to 14 W/gpm.

Chilled water pumping in the baseline building (systems 7 and 8) is a primary/secondary system with constant flow primary loop and variable flow secondary loop. The minimum flow of the secondary loop is 25% of the design flow rate. Each chiller has its own primary and condenser water pumps that operate when the chiller is activated. All primary pumps shall be 9 W/gpm and secondary pump shall be 13 W/gpm, and the condenser water pump is assumed to be 19 W/gpm. For plants less than or equal to 300 tons, the secondary pump “rides the curve,” for larger plants, the pump has a variable speed drive. The primary chilled water pump is constant speed and the condenser water pump is fixed speed. District chilled water system pumps shall follow the same rules as secondary chilled water pumps and pump energy shall be assumed to be 16 W/gpm.

The building descriptors in this section are repeated for each pumping system. See the Pump Service building descriptor for a list of common pump services.

### ***Pump Name***

<i>Applicability</i>	All pumps
<i>Definition</i>	A unique descriptor for each pump
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	User entry. Where applicable, this should match the tags that are used on the plans.
<i>Baseline Building</i>	Same as the proposed design. If there is no equivalent in the proposed design, assign a sequential tag to each piece of equipment. The sequential tags should indicate the pump service as part of the descriptor (e.g., CW for condenser water, CHW for chilled water, or HHW for heating hot water).

### ***Pump Service***

<i>Applicability</i>	All pumps
<i>Definition</i>	The service for each pump. Choices include: <ul style="list-style-type: none"><li>• Chilled water</li><li>• Chilled water (primary)</li><li>• Chilled water (secondary)</li><li>• Heating water</li><li>• Heating water (primary)</li><li>• Heating water (secondary)</li><li>• Service hot water</li><li>• Condenser water</li><li>• Loop water (for hydronic heat pumps)</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	As needed by the baseline building system

### ***Number of Pumps***

<i>Applicability</i>	All pumps
<i>Definition</i>	The number of identical pumps in service in a particular loop, e.g., the heating hot water loop, chilled water loop, or condenser water loop
<i>Units</i>	Numeric: integer
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The number of pumps will be defined as specified below:

- One heating hot water pump for each boiler
- One primary chilled water pump for each chiller and one secondary chilled water pump for the chilled water loop
- One condenser water pump for each chiller
- One district hot water pump for each building served by a district hot water system
- One district chilled water pump for each building served by a district chilled water system

### ***Water Loop Design***

<i>Applicability</i>	All pumps
<i>Definition</i>	The heating and cooling delivery systems can consist of a simple primary loop system, or more complicated primary/secondary loops or primary/secondary/tertiary loops.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Heating water systems shall be modeled with primary loops only. Chilled water systems shall be modeled with primary/secondary loops.

### ***Pump Motor Modeling Method***

<i>Applicability</i>	All pumps
<i>Definition</i>	Software commonly models pumps in one of two ways: The simple method is for the user to enter the electric power per unit of flow (W/gpm). This method is commonly used for smaller systems. A more detailed method requires a specification of the pump head, design flow, impeller, and motor efficiency.
<i>Units</i>	List: Power-Per-Unit-Flow or Detailed
<i>Input Restrictions</i>	Either method may be used, as appropriate
<i>Baseline Building</i>	Detailed

### ***Pump Motor Power-Per-Unit-Flow***

<i>Applicability</i>	All proposed design pumps that use the power-per-unit-flow method
<i>Definition</i>	The electric power of the pump divided by the flow at design conditions
<i>Units</i>	W/gpm
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Detailed

### ***Pump Motor Horsepower***

<i>Applicability</i>	All pumps
<i>Definition</i>	The nameplate motor horsepower
<i>Units</i>	horsepower
<i>Input Restrictions</i>	Constrained to be a value from the following list of standard motor sizes: A standard motor size table (hp) is defined as: 1/12, 1/8, 1/4, 1/2, 3/4, 1, 1.5, 2, 3, 5, 7.5, 10, 15, 20, 25, 30, 40, 50, 60, 75, 100, 125, 150, 200
<i>Baseline Building</i>	Not applicable

### ***Pump Design Head***

<i>Applicability</i>	All baseline building pumps and proposed design pumps that use the detailed modeling method
<i>Definition</i>	The head of the pump at design flow conditions
<i>Units</i>	ft or wg
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	For the baseline building: <ul style="list-style-type: none"><li>• District chilled water<ul style="list-style-type: none"><li>– Pressure drop is 55 ft head</li></ul></li><li>• District hot water<ul style="list-style-type: none"><li>– Pressure drop is 44 ft head</li></ul></li><li>• Chilled water system<ul style="list-style-type: none"><li>– Pump power is 9 W/gpm for the primary loop and 13 W/gpm for the secondary loop<sup>8</sup>; this translates to 31 ft of head for the primary loop and 44 ft of head for the secondary loop</li></ul></li><li>• Condenser water system<ul style="list-style-type: none"><li>– Pressure drop is 60 ft of head</li></ul></li><li>• Hot water system<ul style="list-style-type: none"><li>– Pressure drop is 60 ft of head</li></ul></li></ul>

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<sup>8</sup> ASHRAE 90.1-2013 Addendum au

### ***Impeller Efficiency***

<i>Applicability</i>	All pumps in proposed design that use the detailed modeling method
<i>Definition</i>	The full load efficiency of the impeller
<i>Units</i>	Ratio (between 0 and 1)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	For the baseline building: <ul style="list-style-type: none"><li>• District chilled water system<ul style="list-style-type: none"><li>– Impeller efficiency = 72% (assuming motor efficiency of 90% and a total pump efficiency of 65%)</li></ul></li><li>• District hot water system<ul style="list-style-type: none"><li>– Impeller efficiency = 66.67% (assuming motor efficiency of 90% and a total pump efficiency of 60%)</li></ul></li><li>• Chilled water system<ul style="list-style-type: none"><li>– Impeller efficiency = 72% (assuming motor efficiency of 90% and total pump efficiency of 65%)</li></ul></li><li>• Condenser water system<ul style="list-style-type: none"><li>– Impeller efficiency = 66.67% (assuming motor efficiency of 90% and total pump efficiency of 60%)</li></ul></li><li>• Hot water system<ul style="list-style-type: none"><li>– Impeller efficiency = 66.67% (assuming motor efficiency of 90% and total pump efficiency of 60%)</li></ul></li></ul>

### ***Motor Efficiency***

<i>Applicability</i>	All pumps in proposed design that use the detailed modeling method
<i>Definition</i>	The full load efficiency of the pump motor
<i>Units</i>	Ratio (between 0 and 1)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	For the baseline building <ul style="list-style-type: none"><li>• District chilled water system<ul style="list-style-type: none"><li>– Motor efficiency = 90%</li></ul></li><li>• District hot water system<ul style="list-style-type: none"><li>– Motor efficiency = 90%</li></ul></li><li>• Chilled water system<ul style="list-style-type: none"><li>– Motor efficiency = 90%</li></ul></li></ul>



- Condenser water system
  - Motor efficiency = 90%
- Hot water system
  - Motor efficiency = 90%

### ***Pump Minimum Speed***

<i>Applicability</i>	All two-speed or variable-speed pumps
<i>Definition</i>	The minimum pump speed for a two-speed or variable-speed pump. A fraction of the pump design head. For two-speed pumps this is typically 0.67 or 0.5. Note that the pump minimum speed is not necessarily the same as the minimum flow ratio, since the system head may change.
	$Pump\ Speed_{min} = Pump\ Speed_{design} * \sqrt[3]{(Head_{min} / Head_{design})}$
<i>Units</i>	Ratio (between 0 and 1)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	When the baseline pumps are required to have variable speed drives in accordance with descriptor Pump Control Type, the pump minimum speed shall be 0.10.

### ***Pump Design Flow (gpm)***

<i>Applicability</i>	All pumps
<i>Definition</i>	The flow rate of the pump at design conditions. For the baseline, this is derived from the heating and cooling loads, the appropriate oversizing factors, and the design supply and return temperatures.
<i>Units</i>	gpm or gpm/ton for condenser and primary chilled water pumps
<i>Input Restrictions</i>	Not a user input
<i>Baseline Building</i>	<p>The temperature change on the evaporator side of the chillers is 12°F (56°F less 44°F) and this equates to a flow of 2 gpm/ton.</p> <p>The temperature change on the condenser side of the chillers is 10°F, which equates to a flow of 2.4 gpm/ cooling ton. The flow for secondary chilled water varies with cooling demand, since there are two-way valves at the coils. The flow for primary only heating varies with demand down to the minimum required for flow through the boiler. For hot water pumps servicing boilers, the flow rate in gpm shall be the boiler capacity in Btu/h / 25,000, which corresponds to a loop temperature drop of 50°F.</p>

## ***Pump Control Type***

<i>Applicability</i>	All pumps
<i>Definition</i>	<p>The type of control for the pump. Choices are:</p> <ul style="list-style-type: none"><li>• Fixed speed, fixed flow</li><li>• Fixed speed, variable flow (the default, with flow control via a valve)</li><li>• Two-speed</li><li>• Variable speed, variable flow</li></ul>
<i>Units</i>	None
<i>Input Restrictions</i>	As designed. The default is “Fixed Speed, Variable Flow,” which models the action of a constant speed pump riding the curve against two-way control valves.
<i>Baseline Building</i>	<p>Hot water loops are primary loops only.</p> <ul style="list-style-type: none"><li>• For systems serving less than 120,000 ft<sup>2</sup>, the HW pump is modeled as variable flow with a constant speed pump riding the pump curve. For systems serving more than 120,000 ft<sup>2</sup>, the HW pump is modeled as a variable flow with a variable speed pump controlled with a variable speed drive.</li></ul> <p>Condenser water pumps:</p> <ul style="list-style-type: none"><li>• Condenser water loops are primary only. CW pumps are required to be modeled as fixed speed and fixed flow.</li></ul> <p>Chilled water pumps:</p> <ul style="list-style-type: none"><li>• The CHW pumping for systems 7 and 8 are primary/secondary with variable flow. The chilled water pumps used for the primary loop are fixed speed and fixed flow.<ul style="list-style-type: none"><li>– For systems with a capacity of less than 300 tons, the secondary system pumps shall ride the pump curve.</li><li>– For systems with a capacity greater than 300 tons, the secondary pumps will be modeled as variable speed.</li></ul></li></ul> <p>District chilled water pump shall follow the same rules for secondary chilled water pumps.</p>

## ***Pump Operation***

<i>Applicability</i>	All pumps
<i>Definition</i>	<p>The type of pump operation can be either on-demand, standby, or scheduled. On-demand operation means the pumps are only pumping when their associated equipment is cycling, so chiller and condenser pumps are on when the chiller is on and the heating hot water pump operates when its associated boiler is cycling. Standby operation allows hot or chilled water to circulate through the primary loop of a primary/secondary loop system or through a reduced portion of a primary-only system, assuming the system has appropriate three-way valves. Scheduled operation means that the pumps and their associated equipment are turned completely off according to occupancy schedules, time of year, or outside conditions. Under scheduled operation, when the systems are on they are assumed to be in On-Demand mode.</p>

<i>Units</i>	List: On Demand, Standby, Scheduled
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	The baseline system pumps are assumed to operate in on-demand mode. The chilled water and condenser pumps are tied to the chiller operation, cycling on and off with the chiller, and the heating hot water pumps are tied to the boiler operation.

### **Pump Part Load Curve**

<i>Applicability</i>	All pumps
<i>Definition</i>	A part-load power curve for the pump:

$$CIRC - PUMP - FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3 \quad (56)$$

$$P_{pump} = P_{design} \times CIRC - PUMP - FPLR \quad (57)$$

Where:

*PLR* = Part load ratio (the ratio of operating flow rate in gpm to design flow rate in gpm)

*P<sub>pump</sub>* = Pump power draw at part-load conditions (W)

*P<sub>design</sub>* = Pump power draw at design conditions (W)

**Table 81.** Default Part-Load CIRC-PUMP-FPLR Coefficients<sup>9</sup>

Coefficient	Constant Speed, no VSD (Pump rides pump curve)	Default (VSD, No Reset)	VSD, DP Reset
a	0	0	0
b	3.2485	0.5726	0.0205
c	-4.7443	-0.301	0.4101
d	2.5294	0.7347	0.5753

Source: Thornton et al. 2011

<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed. Default is curve above.
<i>Baseline Building</i>	Use the defaults described above based on pump type. The curve with differential pressure reset isn't used for the baseline building.

<sup>9</sup> [http://www.pnnl.gov/main/publications/external/technical\\_reports/PNNL-22043.pdf](http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22043.pdf)

### 3.7.6 Thermal Storage

There are multiple ways to model thermal storage in the proposed design. The baseline building does not have thermal storage.

#### ***Storage Type***

<i>Applicability</i>	All thermal storage systems
<i>Definition</i>	A type of thermal energy storage (TES) that indicates the storage medium
<i>Units</i>	List
<i>Input Restrictions</i>	Ice, chilled water
<i>Baseline Building</i>	No thermal storage systems

#### ***Configuration***

<i>Applicability</i>	All thermal storage systems
<i>Definition</i>	Indication of how the TES is configured and operated in relation to the chilled water cooling
<i>Units</i>	List
<i>Input Restrictions</i>	Series, chiller upstream Series, chiller downstream Parallel
<i>Baseline Building</i>	No thermal storage systems

#### ***Ice Storage Type***

<i>Applicability</i>	All thermal storage systems with storage type = ice
<i>Definition</i>	Indication of the storage type for ice storage
<i>Units</i>	List
<i>Input Restrictions</i>	IceOnCoilExternal IceOnCoilInternal
<i>Baseline Building</i>	No thermal storage systems

#### ***Storage Capacity***

<i>Applicability</i>	All thermal storage systems using ice storage
<i>Definition</i>	Nominal storage capacity of the tank
<i>Units</i>	Ton-hrs
<i>Input Restrictions</i>	None

*Baseline Building* No thermal storage systems

#### ***Tank Volume***

*Applicability* All thermal storage systems using ice storage

*Definition* Nominal storage capacity of the tank

*Units* ft<sup>3</sup>

*Input Restrictions* None

*Baseline Building* No thermal storage systems

#### ***CHW Setpoint Schedule***

*Applicability* All thermal storage systems using ice storage

*Definition* Nominal storage capacity of the tank

*Units* Series, °F

*Input Restrictions* None

*Baseline Building* No thermal storage systems

#### ***Deadband Temperature Difference***

*Applicability* All thermal storage systems using chilled water

*Definition* The deadband temperature difference between enabling and disabling use of the TES system for cooling

*Units* °F

*Input Restrictions* None

*Baseline Building* No thermal storage systems

#### ***Maximum Temperature Limit***

*Applicability* All thermal storage systems using chilled water

*Definition* The minimum allowed temperature of the tank, below which charging of the tank cannot occur

*Units* °F

*Input Restrictions* None

*Baseline Building* No thermal storage systems

### ***Storage Tank Location Indicator***

<i>Applicability</i>	All thermal storage systems using ice storage
<i>Definition</i>	Nominal storage capacity of the tank
<i>Units</i>	List
<i>Input Restrictions</i>	Schedule, zone, or exterior. If <i>schedule</i> , the ambient temperature schedule must be specified. If <i>zone</i> , the zone name must be specified.
<i>Baseline Building</i>	No thermal storage systems

### ***Storage Tank Heat Gain Coefficient***

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	The heat transfer coefficient between the tank and the ambient surroundings
<i>Units</i>	Btu/h-°F
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	No thermal storage systems

### ***Use Side Heat Transfer Effectiveness***

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	The heat transfer effectiveness between the use side water and the tank water
<i>Units</i>	None
<i>Input Restrictions</i>	Between 0 and 1
<i>Baseline Building</i>	No thermal storage systems

### ***Use Side Design Flow Rate***

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	Design flow rate through the use side of the storage tank
<i>Units</i>	gpm
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	No thermal storage systems

### ***Source Side Heat Transfer Effectiveness***

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	The heat transfer effectiveness between the source side water and the tank water
<i>Units</i>	None
<i>Input Restrictions</i>	Between 0 and 1
<i>Baseline Building</i>	No thermal storage systems

### ***Source Side Design Flow Rate***

<i>Applicability</i>	All thermal storage systems using chilled water
<i>Definition</i>	Design flow rate through the source side of the storage tank
<i>Units</i>	gpm
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	No thermal storage systems

### ***Tank Recovery Time***

<i>Applicability</i>	All thermal storage systems using ice storage
<i>Definition</i>	This is the time in hours for the tank to cool from 14.4°C to 9°C. This input is only used if the source side design flow rate is not specified.
<i>Units</i>	Hours
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	No thermal storage systems

## **3.7.7 Heat Recovery Equipment**

### ***Heat Recovery Name***

<i>Applicability</i>	All heat recovery systems
<i>Definition</i>	A name assigned to a heat recovery system. This would provide a link to the construction documents.
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed

## *Heat Recovery Device Type*

*Applicability* All heat recovery systems

*Definition* The type of heat recovery equipment. Choices include:

- Double-bundled chiller
- Single-bundle heat recovery chiller
- Generator
- Engine-driven chiller
- Air conditioning unit
- Refrigerated casework

*Units* List (see above)

*Input Restrictions* As designed

*Baseline Building* The baseline building is modeled with a condenser heat recovery system for service water heating, when all of the following conditions are true:

- The building operates 24 hours per day.
- The total installed heat rejection capacity of the water cooled system exceeds 6,000,000 Btu/h. The design service hot water load is greater than 1,000,000 Btu/h.

The required heat recovery system for the baseline building, shall have the capacity to provide the smaller of:

- 60% of the peak heat rejection load at design conditions, or
- Preheat of the peak service hot water draw to 85°F

If the simulation software is not capable of modeling the requirements described, the requirement for providing such a system in the proposed building shall be met as a prescriptive requirement and heat recovery shall not be modeled in the baseline or proposed building designs.



### ***Heat Recovery Loads***

<i>Applicability</i>	All heat recovery systems
<i>Definition</i>	The loads met by the heat recovery system. Choices include: <ul style="list-style-type: none"><li>• Service water heating</li><li>• Space heating</li><li>• Process heating</li></ul> More than one load may be selected.
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Service water heating when required as described above

### ***Condenser Heat Recovery Effectiveness***

<i>Applicability</i>	Systems that use recover heat from a condenser
<i>Definition</i>	The percentage of heat rejection at design conditions from a DX or heat pump unit in cooling mode that is available for space or water heating
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	As designed. The software must indicate that supporting documentation is required on the output forms if heat recovery is specified.
<i>Baseline Building</i>	Same as proposed

### ***Condenser Heat Recovery Use***

<i>Applicability</i>	Systems that use heat recovery
<i>Definition</i>	The end use of the heat recovered from a DX or heat pump unit. The choices are: <ul style="list-style-type: none"><li>• Reheat coils</li><li>• Water heating</li></ul>
<i>Units</i>	List (see above)
<i>Input Restrictions</i>	As designed. The software must indicate that supporting documentation is required on the output forms if heat recovery is specified.
<i>Baseline Building</i>	Not applicable for most conditions. The end use will be water heating if required for 24-hour facility operation.

## **3.7.8 Plant Management**

Plant management is a method of sequencing equipment. Separate plant management schemes may be entered for chilled water systems, hot water systems, etc. The following building descriptors are

specified for each load range, e.g., when the cooling load is below 300 tons, between 300 tons and 800 tons, and greater than 800 tons.

#### ***Equipment Type Managed***

<i>Applicability</i>	All plant systems
<i>Definition</i>	The type of equipment under a plant management control scheme. Choices include: <ul style="list-style-type: none"><li>• Chilled water cooling</li><li>• Hot water space heating</li><li>• Condenser water heat rejection</li><li>• Service water heating</li><li>• Electrical generation</li></ul>
<i>Units</i>	None
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as the proposed design

#### ***Equipment Schedule***

<i>Applicability</i>	All plant equipment
<i>Definition</i>	A schedule that identifies when the equipment is in service
<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Where multiple equipment is used, they shall be staged in operation

#### ***Equipment Operation***

<i>Applicability</i>	All plant equipment
<i>Definition</i>	Equipment operation can be either on-demand or always-on. On-demand operation means the equipment cycles on when it is scheduled to be in service and when it is needed to meet building loads, otherwise it is off. Always-on means that equipment runs continuously when scheduled to be in service.
<i>Units</i>	None
<i>Input Restrictions</i>	As designed. The default is on-demand.
<i>Baseline Building</i>	Assume on-demand operation

### *Equipment Staging Sequence*

<i>Applicability</i>	All plant equipment
<i>Definition</i>	The staging sequence for plant equipment (chillers and boilers) indicates how multiple equipment will be staged on and off when a single piece of equipment is unable to meet the load.
<i>Units</i>	Structure – this should include (a) the percent of capacity above which additional equipment is staged on and (b) the percent of capacity below which one plant equipment is staged off
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Software shall bring the first boiler to 100% capacity prior to the staging of the next boiler. When more than one chiller is required in the baseline design, each chiller shall run to full capacity prior to staging of the next chiller. When more than one chiller is operational, then the load shall be shared equally among all the chillers.

## **3.8 Miscellaneous Energy Uses**

Miscellaneous energy uses are defined as those that may be treated separately since they have little or no interaction with the conditioned thermal zones or the HVAC systems that serve them.

### **3.8.1 Water Heating**

Water heating systems shall always be modeled for both the proposed design and baseline building when the proposed building is expected to have a water heating load, even if no water heating is shown on the plans or specifications for the proposed design. In such instances, an electric resistance system shall be modeled for both the proposed design and baseline building, meeting the efficiency requirements of the baseline standard.

When the construction documents show a water heating system, the layout and configuration of the baseline building system shall be the same as the proposed design, e.g., the baseline building shall have the same number of water heaters and the same distribution system.

#### **3.8.1.1 System Loads and Configuration**

##### *Water Heating System Name*

<i>Applicability</i>	All water heating systems
<i>Definition</i>	A unique descriptor for each water heating system. A system consists of one or more water heaters, a distribution system, an estimate of hot water use, and a schedule for that use. Nonresidential buildings will typically have multiple systems, perhaps a separate electric water heater for each office break room, etc. Other building types such as hotels and hospitals may have a single system serving the entire building.
<i>Units</i>	Text, unique

<i>Input Restrictions</i>	Where applicable, this should match the tags that are used on the plans such that a plan reviewer can make a connection.
<i>Baseline Building</i>	The naming convention for the baseline building system shall be similar to the proposed design.

### ***Water Heating Peak Use***

<i>Applicability</i>	All water heating systems, required
<i>Definition</i>	<p>An indication of the peak hot water usage (e.g., service to sinks, showers, and kitchen appliances). When specified per occupant, this value is multiplied by design occupancy density values and modified by service water heating schedules to obtain hourly load values that are used in the simulation.</p> <p>Peak consumption is commonly specified as gallons per hour per occupant, dwelling unit, hotel room, patient room, or floor area. If consumption is specified in gallons per hour, then additional inputs would be needed such as supply temperature, cold water inlet temperature, etc.</p> <p>It is also common to specify peak use as a thermal load in Btu/h. In the latter case, there is an implied assumption for the cold water inlet temperature, supply temperature, distribution losses, and other factors. The thermal load does not include conversion efficiencies of water heating equipment.</p>
<i>Units</i>	Btu/h or gallons/h
<i>Input Restrictions</i>	As designed. If these values are not available, the hot water use specified in COMNET Appendix B (COMNET, 2011) may be used.
<i>Baseline Building</i>	<p>Hot water consumption or load in the baseline building shall be the same as the proposed design, except in cases where:</p> <ul style="list-style-type: none"> <li>• A specific measure is specified for the proposed design that will reduce water consumption. Examples of such measures include low-flow terminal devices or controls.</li> <li>• SHW energy consumption can be demonstrated to be reduced by increasing makeup water temperature or reducing SHW temperature (e.g., alternative sanitizing technologies for dishwashing and heat recovery to entering makeup water).</li> <li>• SHW energy consumption can be demonstrated to be reduced by reducing the hot fraction of mixed water. Examples include heat recovery laundry or showers drains.</li> </ul> <p><b>NOTE:</b> Calculations need to be provided to support the difference in service hot water loads between the proposed and baseline model.</p>

### ***Water Heating Schedule***

<i>Applicability</i>	All water heating systems
<i>Definition</i>	A fractional schedule reflecting the time pattern of water heating use. This input modifies the water heating peak use, described above.
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	If known, anticipated schedules shall be used. If not known, the schedules from COMNET Appendix C (COMNET, 2011) may be used.
<i>Baseline Building</i>	Hot water schedules for the baseline building shall be the same as the proposed design, except in cases where a specific measure is specified for the proposed design that will reduce water consumption and the impact of the measure can be best approximated through an adjustment to the schedule. In general, such measures would be addressed through an adjustment to the water heating, peak use (see above).

### ***Water Heating System Configuration***

<i>Applicability</i>	All water heating systems
<i>Definition</i>	The configuration and layout of the water heating system, including the number of water heaters; the size, location, length, and insulation of distribution pipes; recirculation systems and pumps; and any other details about the system that would affect the energy model.
<i>Units</i>	Data structure
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	The baseline building shall have the same configuration and layout as the proposed design

### ***Water Mains Temperature Schedule***

<i>Applicability</i>	All water heating systems
<i>Definition</i>	A monthly temperature schedule indicating the water mains temperature. This temperature and the setpoint temperature are used to convert the load into a water flow rate.
<i>Units</i>	Data structure: schedule, °F
<i>Input Restrictions</i>	Entering water temperature can be defaulted to the values in Table 82 or provided by the user

**Table 82.** Defaults for Water Mains Temperature Based on Climate Zone

Monthly Average																	
Water Main Supply Temp (°F)																	
	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
January	76.5	70.2	64.6	65.8	56.5	59.4	59.7	50.8	52.3	52.9	45.5	48	50.6	43.1	43.1	37.6	32
February	77.1	72.2	65	67.3	56.4	59.5	59.5	50	51.7	52.3	44.1	47	49.9	41.6	41.6	35.6	32
March	79	77.6	67.9	72.2	59.5	62.4	60.1	52.2	53.8	53.4	45.8	48.7	50.7	42.7	42.5	36.1	32
April	81.7	85.1	72.7	79.5	65	67.4	61.5	57	58.3	56.1	50.1	53.1	52.7	46.4	45.6	39	32
May	84.6	92.6	77.9	87.2	71.6	73.3	63.2	63.1	64	59.5	56	58.8	55.5	51.6	50.2	43.5	32.9
June	86.8	98.1	82.3	93.1	77.4	78.4	64.8	68.9	69.3	62.9	61.9	64.3	58.3	57	54.9	48.5	36.9
July	87.7	100.2	84.6	95.8	80.8	81.3	65.9	72.7	72.8	65.2	66.2	68.2	60.4	61.1	58.6	52.6	40.7
August	87.1	98.1	84.2	94.3	80.9	81.3	66.1	73.6	73.5	65.9	67.6	69.4	61.1	62.8	60.2	54.7	43.1
September	85.1	92.6	81.2	89.2	77.8	78.3	65.4	71.3	71.3	64.7	65.9	67.6	60.3	61.6	59.2	54.2	43.4
October	82.4	85.1	76.4	81.8	72.2	73.2	64	66.4	66.7	62	61.5	63.2	58.2	57.9	56	51.3	41.5
November	79.5	77.6	71.1	74.2	65.6	67.3	62.3	60.3	61	58.5	55.6	57.5	55.4	52.6	51.4	46.7	38
December	77.4	72.2	66.8	68.3	59.9	62.3	60.7	54.6	55.8	55.2	49.7	51.9	52.6	47.2	46.7	41.7	33.8

*Baseline Building* Same as proposed

### 3.8.1.2 Water Heaters

This section describes the building descriptors for water heaters. Typically, a building will have multiple water heating systems and each system can have multiple water heaters, so these building descriptors may need to be specified more than once.

#### **Water Heater Name**

<i>Applicability</i>	All water heaters
<i>Definition</i>	A unique descriptor for each water heater in the system. Some systems will have multiple pieces of equipment, for instance a series of water heaters plumbed in parallel or a boiler with a separate storage tank.
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	Where applicable, this should match the tags that are used on the plans such that a plan reviewer can make a connection
<i>Baseline Building</i>	The naming convention for the baseline building system shall be similar to the proposed design

#### **Water Heater Type and Size**

<i>Applicability</i>	All water heaters
<i>Definition</i>	This building descriptor includes information needed to determine the criteria from baseline standards. The choices are listed below. <ul style="list-style-type: none"> <li>• Electric water heaters (storage and instantaneous) <ul style="list-style-type: none"> <li>– Small (<math>\leq 12</math> kW)</li> <li>– Large (<math>&gt; 12</math> kW)</li> <li>– Heat pump</li> </ul> </li> <li>• Gas storage water heaters</li> </ul>

- Small ( $\leq 75,000$  Btu/h)
- Large ( $> 75,000$  Btu/h)
- Gas instantaneous water heaters
  - Small ( $> 50,000$  and  $< 200,000$  Btu/h)
  - Large ( $\geq 200,000$  Btu/h),  $< 10$  gal
  - Large ( $\geq 200,000$  Btu/h),  $\geq 10$  gal
- Oil storage water heaters
  - Small ( $\leq 105,000$  Btu/h)
  - Large ( $> 105,000$  Btu/h)
- Oil instantaneous water heaters
  - Small ( $\leq 210,000$  Btu/h)
  - Large ( $> 210,000$  Btu/h),  $< 10$  gal
  - Large ( $> 210,000$  Btu/h),  $\geq 10$  gal
- Gas hot water supply boiler
- Oil hot water supply boiler
- Heat exchanger from steam or district hot water

*Units* List (see above)

*Input Restrictions* The water heater type shall agree with equipment specified in the construction documents.

If no service hot water system exists or has been specified, but the building will have service hot water loads, a service water system using electric resistance heat shall be assumed.

For buildings that will have no service hot water load, no service water heating system shall be modeled.

*Baseline Building* Water heaters in the baseline system will be the same as those in the proposed design, using the actual component except when the proposed design has a heat pump water heater, in which case the baseline building system shall have an electric storage water heater.

For new service hot water systems, the system will be sized according to the provisions of Standard 90.1-2010, Section 7.4.1, and the equipment shall match the minimum efficiency requirements in Standard 90.1-2010, Section 7.4.2. Where the energy source is electricity, the heating method shall be electrical resistance.

If no service hot water system exists or has been specified, but the building will have service hot water loads, a service water system(s) using electrical- resistance heat and matching minimum efficiency requirements of Standard 90.1-2010, Section 7.4.2, shall be assumed and modeled identically in the proposed and baseline building designs.

### ***Rated Capacity***

<i>Applicability</i>	All water heaters
<i>Definition</i>	The heating capacity of a water heater at the rated conditions specified in DOE 10 CFR Part 430 or ANSI Z21.10
<i>Units</i>	Thousands of British thermal units per hour (MBH)
<i>Input Restrictions</i>	As designed. If the loads are not met, then the system needs to be autosized.
<i>Baseline Building</i>	Autosize

### ***Storage Volume***

<i>Applicability</i>	All water heaters
<i>Definition</i>	The storage volume of a gas-fired water heater. This is used in the standby loss calculations and baseline calculations of energy factor (EF).
<i>Units</i>	gallons
<i>Input Restrictions</i>	As designed. If the loads are not met, then the system needs to be autosized.
<i>Baseline Building</i>	Autosize

### ***Energy Factor***

<i>Applicability</i>	Equipment covered by the National Appliance Energy Conservation Act (NAECA), which includes small storage and instantaneous water heaters
<i>Definition</i>	The EF is the ratio of the energy delivered by the water heater divided by the energy used, in the same units. EF is calculated according to the DOE 10 CFR Part 430 test procedure, which specifies a 24-hour pattern of draws, a storage temperature, inlet water temperature, and other test conditions. These conditions result in the energy delivered for the test period. Energy inputs are measured for the same test period and the EF ratio is calculated.
<i>Units</i>	Unitless ratio (between 0 and 1)
<i>Input Restrictions</i>	Building descriptors for the proposed design should be consistent with equipment specified on the construction documents or observed in the candidate building.
<i>Baseline Building</i>	The EF for the baseline building system shall be determined from Table 7.8 of Standard 90.1-2010. The following baseline EF applies for water heaters:



**Table 83.** Standard 90.1-2010 Requirements for Baseline Water Heater Performance

	Size Category (Input)	Performance Required
Electric water heater	≤ 12 kW	EF= 0.97 - 0.00132 V
	> 12 kW	SL (Btu/h) = 20 + 35 √V
Heat pump	≤ 24 Amps and ≤ 250 Volts	EF= 0.93 - 0.00132 V
Gas storage water heaters	≤ 75,000 Btu/hr	EF = 0.67 - 0.00192V
	> 75,000 Btu/h	SL = Q/800 + 110 √V
Gas instantaneous water heater	>50,000 Btu/h and <200,000 Btu/h	EF=0.62 -0.0019V
	≥ 200,000 Btu/h	80% Et SL = Q/800 + 110 √V
Oil storage water heater	≤ 105,000 Btu/hr	EF= 0.59 - 0.0019V
	>105,000 Btu/h	SL = Q/800 + 110 √V
Oil instantaneous water heater	≤ 210,000 Btu/hr	EF= 0.59 - 0.0019V
	> 210,000 Btu/hr	SL = Q/800 + 110 √V

### ***Thermal Efficiency***

<i>Applicability</i>	Oil and gas-fired water heaters not covered by NAECA
<i>Definition</i>	The full load efficiency of a water heater at rated conditions expressed as a dimensionless ratio of output over input
<i>Units</i>	Unitless ratio (between 0 and 1)
<i>Input Restrictions</i>	Building descriptors for the proposed design should be consistent with equipment specified on the construction documents or observed in the candidate building
<i>Baseline Building</i>	From Table 7.8 of Standard 90.1-2010

### ***Tank Standby Loss***

<i>Applicability</i>	Water heaters not covered by NAECA
<i>Definition</i>	The tank standby loss for storage tanks, which includes the effect of recovery efficiency
<i>Units</i>	Btu/h for the entire tank
<i>Input Restrictions</i>	As specified in manufacturer data and documented on the construction documents
<i>Baseline Building</i>	As specified in Table 7.8 of Standard 90.1-2010

### ***Tank Off-Cycle Loss Coefficient***

<i>Applicability</i>	Water heaters
<i>Definition</i>	The tank standby loss coefficient (UA) for the water heater. For small water heaters covered by NAECA, the loss coefficient is a derived parameter, a function of the energy factor and recovery efficiency.
<i>Units</i>	Btu/h-°F

*Input Restrictions* For NAECA covered water heaters, the loss coefficient is calculated by the following:

$$UA = \frac{1/EF - 1/RE}{67.5 \times \left( \frac{24}{41094} - \frac{1}{RE \cdot Pon} \right)}$$

Where:

*EF* = The energy factor of the rated water heater (unitless)

*RE* = The recovery efficiency of the rated water heater. If this data is not available, the default shall be 0.78 for gas water heaters and 0.93 for electric water heaters.

*Pon* = The input power to the water heater, in Btu/h

*Baseline Building* The baseline loss coefficient for NAECA water heaters shall be:

10 Btu/h-°F for gas-fired water heaters

#### ***Off Cycle Parasitic Losses***

*Applicability* Water heater

*Definition* The rate of parasitic losses, such as a pilot light or controls, when the water heater is not heating. If modeled explicitly, pilot lights should contribute to off-cycle heating.

*Units* watts

*Input Restrictions* As designed

*Baseline Building* 0

#### ***Off Cycle Fuel Type***

*Applicability* Water heater

*Definition* The type of fuel that serves energy using parasitic equipment, such as a pilot light or controls, when the water heater is not heating

*Units* List: Electricity, Gas, Oil, Propane

*Input Restrictions* As designed

*Baseline Building* Not applicable

### ***On Cycle Parasitic Losses***

<i>Applicability</i>	Water heater
<i>Definition</i>	The rate of parasitic losses, such as a pilot light or draft fan controls, when the water heater is heating. This may be different than off cycle losses if the flue energy is considered.
<i>Units</i>	watts
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	0

### ***On Cycle Fuel Type***

<i>Applicability</i>	Water heater
<i>Definition</i>	The type of fuel that serves energy using parasitic equipment, such as a pilot light or controls, when the water heater is not heating
<i>Units</i>	List: Electricity, Gas, Oil, Propane
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Not applicable

### ***Water Heater Ambient Temperature Indicator***

<i>Applicability</i>	Water heater
<i>Definition</i>	The location of the water heater for determining losses and energy interaction with the surroundings
<i>Units</i>	List: Schedule, Zone, Outdoors
<i>Input Restrictions</i>	As designed. When “Schedule” is used, a time of day schedule needs to be specified with temperature schedule for each hour.
<i>Baseline Building</i>	Same as proposed

### ***Fuel Water Heater Part Load Efficiency Curve***

<i>Applicability</i>	Water heating equipment for which a thermal efficiency as opposed to an EF is specified
<i>Definition</i>	A set of factors that adjust the full-load thermal efficiency for part load conditions. The factor is set as a curve.
<i>Units</i>	Percent (%)
<i>Input Restrictions</i>	The following default curve shall be used unless detailed information is provided to justify alternative values. The default curve shall take the form of a quadratic equation as follows:

$$Fuel_{partload} = Fuel_{design} \times FHeatPLC$$

$$FHeatPLC = \left( a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left( \frac{Q_{partload}}{Q_{rated}} \right)^2 \right)$$
(58)

Where:

- $FHeatPLC$  = The fuel heating part load efficiency curve
- $Fuel_{partload}$  = The fuel consumption at part load conditions (Btu/h)
- $Fuel_{design}$  = The fuel consumption at design conditions (Btu/h)
- $Q_{partload}$  = The water heater capacity at part load conditions (Btu/h)
- $Q_{rated}$  = The water heater capacity at design conditions (Btu/h)
- $a$  = Constant, 0.021826
- $b$  = Constant, 0.977630
- $c$  = Constant, 0.000543

*Baseline Building* The baseline shall use the default curve.

### 3.8.1.3 Recirculation Systems

This section describes the building descriptors for hot water recirculation systems. The baseline building has a recirculation system when the proposed design does. This is one aspect of the *water heating system configuration* (see above).

#### ***Recirculation System Name***

<i>Applicability</i>	All recirculation systems
<i>Definition</i>	A unique descriptor for each water heating recirculation system
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	Where applicable, this should match the tags or descriptions that are used on plans such that a plan reviewer can make a connection
<i>Baseline Building</i>	The naming convention of the baseline building shall be similar to the proposed design

### ***Pumping Power***

<i>Applicability</i>	All recirculation systems
<i>Definition</i>	The electric demand of the pumps when the recirculation system is operating. This input is a function of the flow rate, the pumping head, the motor efficiency, and the pump efficiency. Some software may allow each of these factors to be separately entered.
<i>Units</i>	watts (W)
<i>Input Restrictions</i>	Pumping power shall be consistent with the piping configuration, flow rate, and equipment specified on the construction documents.
<i>Baseline Building</i>	Pumping power in the baseline building shall be the same as the proposed design unless specific measures are included in the proposed design to reduce the pumping power. Example measures could include reducing pumping head by oversizing distribution piping or specifying premium efficiency motors or pumps.

### ***Schedule***

<i>Applicability</i>	All recirculation systems
<i>Definition</i>	An on/off or fraction schedule that indicates when the recirculation system is expected to be operated
<i>Units</i>	Data structure: schedule, on/off or fraction
<i>Input Restrictions</i>	The schedule for operation of the recirculation system shall be consistent with the design intent of the system. Hotels, hospitals, and other 24x7 institutional buildings will typically have a system that runs continuously. The schedule should be consistent with the controls called for on the construction documents: no control (runs constantly), timer control, temperature control, timer/temperature control, or demand control.
<i>Baseline Building</i>	Recirculation schedules for the baseline building shall be the same as the proposed design

### ***Piping***

<i>Applicability</i>	All recirculation systems
<i>Definition</i>	The heat loss rate of piping for recirculating systems. This may be defined separately for pipe that is exposed to outdoor conditions, indoor or semi-heated conditions, or buried underground conditions. These losses may be modeled as additional loads on the water heater(s).
<i>Units</i>	Btu/h-°F specified separately for outdoor, indoor, or buried locations
<i>Input Restrictions</i>	In accordance with Standard 90.1-2010, Section G3.1.3.6, piping heat losses are not modeled for the proposed building
<i>Baseline Building</i>	Same as proposed

### 3.8.1.4 Water Heating Auxiliaries

#### **External Storage Tank Insulation**

<i>Applicability</i>	All water heating systems that have an external storage tank
<i>Definition</i>	Some water heating systems have a storage tank that is separate from the water heater(s) that provides additional storage capacity. This building descriptor addresses the heat loss related to the external tank, which is an additional load that must be satisfied by the water heater(s).
<i>Units</i>	R-value (h-ft <sup>2</sup> -°F/Btu)
<i>Input Restrictions</i>	As specified in manufacturer data and documented on the construction documents
<i>Baseline Building</i>	Heat loss associated with the storage tank in the baseline building shall meet the requirements for an unfired storage tank in the baseline standards, which is an insulation R-value of 12.5. The surface area and location of the storage tank shall be the same as the proposed design.

#### **External Storage Tank Area**

<i>Applicability</i>	All water heating systems that have an external storage tank
<i>Definition</i>	Some water heating systems have a storage tank that is separate from the water heater(s) that provides additional storage capacity. This documents the entire exterior surface area of the tank.
<i>Units</i>	ft <sup>2</sup>
<i>Input Restrictions</i>	As specified in manufacturer specifications
<i>Baseline Building</i>	Same as proposed

#### **External Storage Tank Location**

<i>Applicability</i>	All water heating systems that have an external storage tank
<i>Definition</i>	Location of the storage tank, used to determine the heat loss rate and energy exchange with the surroundings
<i>Units</i>	List: Schedule, Zone, Outdoors
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as proposed

#### **Heat Recovery**

<i>Applicability</i>	Water heating systems that are coupled to heat recovery equipment
<i>Definition</i>	Building equipment such as air conditioners, chillers, gas-fired generators, and others produce thermal energy that may be recovered and used to heat water. The heat-producing characteristics are generally defined for the equipment that is producing the heat, not the equipment that is receiving the heat (water heaters in this case). The building descriptors will vary depending on the equipment. The models for heat-producing equipment need to produce

output hourly so that the schedule of heat production and heating needs can be aligned and evaluated in the water heating model.

<i>Units</i>	Data structure: depends on the equipment producing the heat
<i>Input Restrictions</i>	There are no restrictions, other than agreement with the construction documents
<i>Baseline Building</i>	The baseline building requirements for condenser heat recovery are documented in Section 3.7.7 of this manual

### ***Solar Thermal***

<i>Applicability</i>	Water heating systems with a solar thermal system
<i>Definition</i>	<p>A solar thermal water heating system consists of one or more collectors. Water is passed through these collectors and is heated under the right conditions. There are two general types of solar water heaters: integrated collector storage (ICS) systems and active systems. Active systems include pumps to circulate the water, storage tanks, piping, and controls. ICS systems generally have no pumps and piping is minimal.</p> <p>Solar systems may be tested and rated as a complete system or the collectors may be separately tested and rated. SRCC OG-300 is the test procedure for whole systems and SRCC OG-100 is the test procedure for collectors. The building descriptors used to define the solar thermal system may vary with each software application and with the details of system design.</p> <p>The solar fraction shall be estimated by the f-chart procedure for solar water heating systems.</p>
<i>Units</i>	Data structure: will vary with the software and system details
<i>Input Restrictions</i>	As designed. The proposed design may have a combined space and water heating system.
<i>Baseline Building</i>	The baseline building shall be modeled with separate space heating and water heating systems, meeting the prescriptive requirements for each. The water heating system shall use the same fuel as the combined boiler.

### ***Combined Space Heating and Water Heating***

<i>Applicability</i>	Projects that use a boiler to provide both space heat and water heating
<i>Definition</i>	<p>A system that provides both space heating and water heating from the same equipment, generally the space heating boiler. Such systems are restricted by the baseline standards, but may be modeled in the candidate building. The restrictions are due to the misalignment of the space heating load and the water heating load. The first is highly intermittent and weather dependent, while the latter is more constant and not generally related to the weather.</p>
<i>Units</i>	Data structure
<i>Input Restrictions</i>	As designed. The proposed design may have a combined space and water heating system.
<i>Baseline Building</i>	The baseline building shall be modeled with separate space heating and water heating systems, meeting the prescriptive requirements for each. The water heating system shall use the same fuel as the combined boiler.

### 3.8.2 Swimming Pools

Swimming pools must meet applicable mandatory requirements mentioned in the sections below.

#### **Pool Name**

<i>Applicability</i>	All pools
<i>Definition</i>	A unique identifier that keys the pool to the construction documents
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	The name for the baseline building pool should be similar to the proposed design

#### **Volume**

<i>Applicability</i>	All pools
<i>Definition</i>	The volume of the pool
<i>Units</i>	Cubic feet (ft <sup>3</sup> )
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

#### **Surface Area**

<i>Applicability</i>	All pools
<i>Definition</i>	The surface area of the pool affects heat loss and evaporation
<i>Units</i>	Square feet (ft <sup>2</sup> )
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

#### **Cover**

<i>Applicability</i>	All pools
<i>Definition</i>	An indication
<i>Units</i>	Boolean (yes/no)
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	The baseline building shall have a pool cover per Section 7.4.5.2 of Standard 90.1-2010



### **Cover Schedule**

<i>Applicability</i>	All pools
<i>Definition</i>	A schedule indicating when the pool cover is in place
<i>Units</i>	Data structure: schedule, on/off or fractional
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### **Filtration Rate**

<i>Applicability</i>	All pools
<i>Definition</i>	The rate at which the pool water is passed through the filtering system when the filtration system is operating
<i>Units</i>	Hours per pool change
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### **Filtration Schedule**

<i>Applicability</i>	All pools
<i>Definition</i>	A schedule indicating when the pool filtration system is in operation
<i>Units</i>	Data structure: schedule, on/off or fractional
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### **Temperature**

<i>Applicability</i>	All pools
<i>Definition</i>	Temperature at which the pool is maintained
<i>Units</i>	Degrees Fahrenheit (°F)
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### ***Temperature Schedule***

<i>Applicability</i>	All pools
<i>Definition</i>	A schedule indicating variation in the pool temperature, either seasonally or monthly
<i>Units</i>	Data structure: schedule, temperature
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### ***Pumping and Filtration: Pumping Power***

<i>Applicability</i>	All pools
<i>Definition</i>	The power used by the pumping system. This is a function of the pumping head (which depends on pipe lengths, sizes, and filtration type), the pump efficiency, the motor efficiency, and the flow rate. Some software may allow these to be entered as separate building descriptors. This value should be consistent with the filtration rate noted above.
<i>Units</i>	watts (W)
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as the proposed design unless the proposed design uses special low head filters and premium efficiency motors

### ***Heating Equipment: Heater Type***

<i>Applicability</i>	All pools
<i>Definition</i>	The type of equipment that is used to maintain the pool temperature
<i>Units</i>	List: Solar, Heat Pump, Gas, Oil, or Electric Resistance
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	If there is gas or oil on the site, the baseline building shall be modeled with a natural gas or oil pool heater meeting the requirements of Table 7.8 of Standard 90.1-2010. If there is no gas or oil on the site, the baseline building shall be modeled with a heat pump pool heater meeting the requirements of Table 7.8 of Standard 90.1-2010.

### ***Heating Equipment: Heater Efficiency***

<i>Applicability</i>	All pools with heaters
<i>Definition</i>	The thermal efficiency of the pool heater
<i>Units</i>	Unitless, thermal efficiency
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	See the baseline rules for heater type

### Solar System Features

<i>Applicability</i>	All pools with solar pool heaters
<i>Definition</i>	The collector area, size, efficiency, and pumping characteristics of the solar pool system
<i>Units</i>	Data structure
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Not applicable

### 3.8.3 Exterior Lighting

All exterior lighting applications shall be included in the model. Exterior lighting applications not connected to the building electricity meter (e.g., street lighting or common area lighting) should not be included.

The building descriptors that are described in this section apply separately to each lighting application; input for each building descriptor is provided for parking lot lighting, façade lighting, entry lighting, and other exterior lighting applications. Each lighting application is modeled as a separate system. Exterior lighting applications affect the electric load of the building but do not produce heat that would need to be removed by the building’s cooling system.

Standard 90.1-2010 groups exterior lighting applications as tradable or non-tradable. Non-tradable lighting applications are “use-it-or-lose-it” categories such that the allowed power is the lesser of the power used for the proposed design or the allowed power.

- Tradable applications include uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs, and outdoor sales areas. Thus, the allowed LPD of these applications is multiplied by the associated area or length to yield the baseline power.
- Non-tradable applications can only be used for the specific application and cannot be traded between applications or with other non-tradable applications such as building façades, automated teller machines, guard houses, loading for law enforcement, drive-through windows, or parking near retail.

#### Calculation of Baseline Exterior Lighting Power Allowance

The baseline building exterior lighting power allowance (ELPA) is the sum of site allowance, allowance for the sum of all tradable surfaces, and allowance for all non-tradable surfaces.

- Site allowance: This is the base allowance that could be used for tradable or non-tradable surfaces and is dependent on the exterior lighting zone.

**Table 84.** Site Allowance for Exterior Lighting

Zone 0	Zone 1	Zone 2	Zone 3	Zone 4
No Base Site in Zone 0	500 W	600 W	750 W	1300 W

- Tradable applications: Allowance for tradable surfaces is calculated in accordance to Standard 90.1-2010 Table 9.4.3B.

- Non-tradable applications: Allowance for non-tradable applications is calculated in accordance with Standard 90.1-2010 Table 9.4.3B or is equal to the proposed design, whichever is less.

Trade-offs are allowed for tradable surfaces only. Each non-tradable lighting application is required to comply on its own. No trade-offs are permitted with other tradable lighting applications or non-tradable lighting applications. Credit is offered for power reductions for tradable lighting applications, but not for non-tradable lighting applications. The allotment for non-tradable applications is in a use-it-or-lose-it format. Thus, the baseline power for these applications is the lesser of the wattage input for these applications or the product of the LPD for these applications and the area/length of these applications.

#### ***Exterior Lighting Name***

<i>Applicability</i>	All exterior lighting systems
<i>Definition</i>	A name for the lighting system
<i>Units</i>	Text, unique
<i>Input Restrictions</i>	The name should be descriptive and provide a link to the construction documents
<i>Baseline Building</i>	The baseline building should have a corresponding exterior lighting system that maps to the one in the proposed design. The name should be similar.

#### ***Exterior Lighting Zones***

<i>Applicability</i>	All projects with exterior lighting
<i>Definition</i>	Standard 90.1-2010 identifies five lighting zones for determining exterior lighting power allowance: <ul style="list-style-type: none"> <li>a. Zone 0 - Undeveloped areas within national parks, state parks, forest land, rural areas</li> <li>b. Zone 1 - Developed areas of national parks, state parks, forest land, and rural areas</li> <li>c. Zone 2 - Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use, and residential mixed use areas</li> <li>d. Zone 3 - All other areas</li> <li>e. Zone 4 - High activity commercial districts in major metropolitan areas as designated by the local jurisdiction</li> </ul>
<i>Units</i>	List: Zone 0, Zone 1, Zone 2, Zone 3, Zone 4
<i>Input Restrictions</i>	As designed and approved by the building official
<i>Baseline Building</i>	Same as proposed

#### ***Exterior Lighting Area or Length***

<i>Applicability</i>	All exterior lighting systems
<i>Definition</i>	All exterior lighting applications have an associated area or length. This area or length is a

factor in determining the Baseline Building lighting power. The following rules should be taken into account when calculating length or area:

- Façade illuminated area: Only areas of façade that are illuminated without obstruction are included in the illuminated area.
- If the lighted façade area exceeds exterior wall area or if the door linear footage exceeds 25% of building perimeter, the software shall produce a warning.
- Uncovered parking: Uncovered parking shall be calculated according to the rules for the parking portion of “Illuminated hardscape” from Title 24-2013. This definition accounts for the paved area that is within 3 times the luminaire mounting height of parking luminaires: “Illuminated area is defined as any area within a square pattern around each luminaire or pole that is six times the mounting height with the luminaire in the middle of the pattern less any area that is within a building, under a canopy, beyond property lines or obstructed by a sign or structure.”<sup>10</sup>

*Units* ft<sup>2</sup> or lft

*Input Restrictions* The area of the exterior lighting application should be determined using the rules in the baseline standard and the associated user’s manual

*Baseline Building* Same as proposed

### ***Exterior Lighting Power***

*Applicability* All projects with exterior lighting. All exterior lighting connected to the building’s electricity meter should be included.

*Definition* The calculated exterior lighting power. For the proposed building, this is referred to as the exterior installed lighting power (EILP), for the baseline building, this is referred to as the exterior lighting power allowance (ELPA).

*Units* List: Base Allowance (W), Tradable Surfaces, Non-Tradable Surfaces (Refer to Standard 90.1-2010, Table 9.4.3B for a list of surfaces and allowances.)

*Input Restrictions* As designed. The EILP for the proposed design is determined by totaling the installed exterior lighting power for all proposed exterior luminaires that are not exempt from the exterior lighting requirements. (Refer to the section below for a list of exempt exterior lighting applications.)

*Baseline Building* The total exterior lighting power allowance for all exterior building applications is the sum of the base site allowance plus the individual allowances for areas that are designed to be illuminated and are permitted in Standard 90.1-2010 Table 9.4.3B for the applicable lighting zone.

**NOTE:** A warning would be displayed if the baseline exterior lighting power allowance is more than twice the EILP. This variation should be reported in the output reports.

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<sup>10</sup> 2005 T-24 Section 147(c)1A

### ***Non-Regulated Exterior Lighting Power Allowance***

<i>Applicability</i>	All projects with exterior lighting
<i>Definition</i>	<p>Lighting used for the following exterior applications is exempt when equipped with a control device that complies with the requirements for exterior lighting control and is independent of the control of the nonexempt lighting. These are not required to be included in the total calculated exterior lighting power allowance.</p> <ol style="list-style-type: none"><li>Specialized signal, directional, and marker lighting associated with transportation</li><li>Advertising signage or directional signage</li><li>Lighting integral to equipment or instrumentation and installed by its manufacturer</li><li>Lighting for theatrical purposes, including performance, stage, film production, and video production</li><li>Lighting for athletic playing areas</li><li>Temporary lighting</li><li>Lighting for industrial production, material handling, transportation sites, and associated storage areas</li><li>Theme elements in theme/amusement parks</li><li>Lighting used to highlight features of public monuments and registered historic landmark structures or buildings</li><li>Lighting for hazardous locations</li><li>Lighting for swimming pools and water features</li><li>Searchlights</li></ol>
<i>Units</i>	W/ft <sup>2</sup> or watts
<i>Input Restrictions</i>	As designed. The exceptions to exterior lighting power allowance should be cross-referenced to the type of exception and to the construction documents.
<i>Baseline Building</i>	Same as proposed

### ***Exterior Lighting Schedule***

<i>Applicability</i>	All exterior lighting systems
<i>Definition</i>	<p>The exterior lighting schedule describes the fraction of installed connected lighting power that is operating for any given hour. The lighting schedule is a matrix of fractional values for each hour of the day and by day of week.</p>
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	<p>The default exterior lighting schedule shall be from dusk until 1 hour after the indoor lighting schedule drops below emergency lighting level (i.e., below 15%). Custom schedules may be created for atypical operating hours for exterior lighting systems. Each lighting system may operate on its own schedule. The default schedule shall be used when detailed information is unavailable.</p> <p>The schedule may be modified when qualifying lighting controls are installed (see Exterior</p>

Lighting Control below).

*Baseline Building* The schedule for the baseline building shall be the same as the proposed design. However, with approval of the rating authority, variations of the power requirements, schedules, or control sequences of the exterior lighting modeled in the baseline building from those in the proposed design shall be allowed by the rating authority based upon documentation that the exterior lighting installed in the proposed design represents a significant verifiable departure from documented conventional practice.

The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building exterior lighting different from that installed in the proposed design. If the baseline building's exterior lighting differs from the proposed building, this input must be flagged and instructions given to provide the proper documentation.

**NOTE:** If exterior lighting loads/schedule for the baseline building differs from the proposed design, this needs to be flagged and reported in the compliance reports.

### ***Exterior Lighting Control***

*Applicability* All projects with exterior lighting

*Definition* These are mandatory requirements for Standard 90.1-2010. Lighting for exterior applications shall meet the following requirements:

- a. Photocell or other device that shuts off lighting during daylight hours
- b. Automatic shut-off for building façade and landscape lighting between midnight or business closing, whichever is later, and 6 am or business opening, whichever comes first
- c. All other lighting shall be controlled by time switches that automatically reduce the connected lighting power by at least 30% for at least one of the following conditions
  - a. From 12 midnight or within 1 hour of the end of business operations, whichever is later, until 6 am or business opening, whichever is earlier
  - b. During any period when no activity has been detected for a time of no longer than 15 minutes

**Exception:** Lighting required for safety, security, or eye adaptation

*Units* List: Photocell, Automatic Shut-Off, Time Switches

*Input Restrictions* As designed, at a minimum meeting the above mandatory requirements

*Baseline Building* Same as proposed

However, with approval of the rating authority, variations of the power requirements, schedules, or control sequences of the exterior lighting modeled in the baseline building from those in the proposed design shall be allowed based upon documentation that the exterior lighting installed in the proposed design represents a significant verifiable departure from documented conventional practice. The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building exterior lighting different from that installed in the proposed design. If baseline building's exterior lighting differs from the proposed building, this input must be flagged and instructions given to provide the proper documentation.

**NOTE:** If exterior lighting loads or schedules for the baseline building differ from the proposed design, this needs to be flagged and reported in the compliance reports.

### 3.8.4 Other Electricity Use

This set of building descriptors should be used to include any miscellaneous electricity use that would add to the electric load of the building and would be on the building meter. These energy uses are assumed to be outside the building envelope and do not contribute heat gain to any thermal zone.

Snow-melt systems prevent ice buildup at building entrances and other critical areas. Systems consist of a heating element, which is embedded in the slab; sensors to detect OATs and moisture; a heating source; and controls to tie the heating element, sensors, and heating source together. The energy modeler should make a reasonable estimate of the energy consumption of the snow-melt system and this estimate shall be used for both the Baseline Building and the proposed design, e.g., no credit.

#### *Miscellaneous Electric Power*

<i>Applicability</i>	All buildings with miscellaneous electric equipment located on the building site
<i>Definition</i>	The power for miscellaneous equipment
<i>Units</i>	watts (W)
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as the proposed

#### *Miscellaneous Electric Schedule*

<i>Applicability</i>	All buildings with miscellaneous electric equipment located on the building site
<i>Definition</i>	The schedule of operation for miscellaneous electric equipment
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	The schedule specified for the building should match the operation patterns of the system
<i>Baseline Building</i>	Same as proposed

### 3.8.5 Other Gas Use

This set of building descriptors should be used to include any miscellaneous gas use that would add to the load of the building and would be on the building meter. These energy uses are assumed to be outside the building envelope and do not contribute heat gain to any thermal zone.



### ***Other Gas Power***

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	Gas power is the peak power, which is modified by the schedule (see below)
<i>Units</i>	Btu/h-ft <sup>2</sup>
<i>Input Restrictions</i>	As designed
<i>Baseline Building</i>	Same as the proposed

### ***Other Gas Schedule***

<i>Applicability</i>	All buildings that have commercial gas equipment
<i>Definition</i>	The schedule of operation for commercial gas equipment
<i>Units</i>	Data structure: schedule, fractional
<i>Input Restrictions</i>	Continuous operation is prescribed
<i>Baseline Building</i>	Same as the proposed

## **3.9 On-Site Power Generation**

Building projects may incorporate other on-site electricity generation equipment, such as cogeneration plants or fuel cells that make electricity and produce heat. Projects may also include wind turbines. These systems may be modeled in various ways and the building descriptors below should be considered an example of one set. In all cases, the baseline building will be modeled without on-site generation equipment. If there is no thermal link between the power generation equipment and building equipment (such as heat recovery from combined heat and power [CHP]), on-site power generation can be modeled in a separate process; otherwise, it needs to be linked to the building simulation.

RESERVED FOR FUTURE USE – onsite power generation systems are not currently modeled.

## **3.10 Common Data Structures**

This section describes common data structures referenced in this chapter. The data structures presented here define objects and example parameters needed to define them. The parameters described are the most common for energy simulation engines. Other parameters or data constructs are acceptable; however, the fields used by the simulation program must be mapped to the fields used by the building descriptor.

### **3.10.1 Schedule**

This data structure provides information on how equipment, people, lights, or other items are operated hourly. The ultimate construct of a schedule is an hourly time series for the simulation period, typically 8,760 hours (365 days, 24 hours per day). However, software has often built up the hourly schedule from 24-hour schedules for different day types: weekdays, Saturdays, Sundays, holidays, etc.

There are several types of schedules:

- a. **Temperature** schedules specify a temperature to be maintained in a space, a temperature to be delivered from an air handler, or the leaving temperature from a chiller or other equipment.
- b. **Fraction** schedules specify the fraction of lights that are on, the fraction of people that are in the space, the fraction of maximum infiltration, or other factors.
- c. **On/off** schedules specify when equipment is operating or when infiltration is occurring.
- d. **Time period** schedules define periods of time for equipment sequencing, utility tariffs, etc. A time period schedule typically breaks the year in to two or more seasons. For each season, day types are identified such as weekday, Saturday, Sunday, and holidays. Each day type in each season is then divided into time periods.

### 3.10.2 Holidays

A series of dates defining holidays for the simulation period. Dates identified are operated for the schedule specified for holidays.

### 3.10.3 Surface Geometry

This data structure represents the location, size, and position of a surface. Surfaces include roofs, walls, floors, and partitions. Surfaces are typically planar and can be represented in various manners, including the following:

- Rectangular surfaces may be represented by a height and width along with the X, Y, and Z of surface origin and the tilt and azimuth
- Surfaces may also be represented by a series of vertices (X, Y, and Z coordinates defining the perimeter of a surface). More complex polygons may be represented in this manner.

### 3.10.4 Opening Geometry

This data structure represents the location and size of an opening within a surface. The most common method of specifying the geometry of an opening is to identify the parent surface, the height and width of the opening, and the horizontal and vertical offset (X and Y coordinates relative to the origin of the parent surface). An opening can also include a recess into the parent surface, which provides shading. However, other geometric constructs are acceptable.

### 3.10.5 Opening Shade

This data structure describes the dimensions and position of external shading devices such as overhangs, side fins, or louvers that shade the opening. Overhangs are specified in terms of the projection distance, height above the opening, and extension distance on each side of the opening.

### **3.10.6 Construction Assembly**

This data structure describes the layers that make up the construction of a wall, roof, floor, or partition. Typically, a construction consists of a sequence of materials, described from the outside surface to the inside surface.

### **3.10.7 Fenestration Construction**

This data structure describes the frame, glass, and other features of a window or skylight. Information may be defined in multiple ways, but the criteria themselves are published as a combination of U-factor, solar heat gain coefficient (SHGC), and visible light transmission (VT). Some simulation programs use more detailed methods of describing the performance of fenestration that take into account the angle of incidence of sun striking the fenestration and other factors, such as the properties of each pane and the fill. The software only uses whole window performance properties (U-factor, SHGC, VT).

### **3.10.8 Material**

This data structure describes a material that is used to build up a construction assembly. Typical material properties include specific heat, density, conductivity, and thickness. Materials can also be described in terms of their thermal resistance. The latter approach is sometimes used to approximate construction layers that are not homogeneous, such as framing members in combination with cavity insulation.

### **3.10.9 Slab Construction**

This data structure describes the composition of a slab-on-grade. The model has building descriptors for the perimeter length and the F-factor, which represents the heat loss per lineal foot.

### **3.10.10 Exterior Surface Properties**

This data structure describes the characteristics of exterior surfaces. Exterior surface properties may include emissivity, reflectivity, and roughness. The first two govern radiation exchange from the surface, while the latter governs the magnitude of the exterior air film resistance.

### **3.10.11 Occupant Heat Rate**

This data structure represents the rate of heat and moisture generated by building occupants. This is typically specified in terms of a sensible heat rate and a latent heat rate. Both are specified in Btu/h.

### **3.10.12 Furniture and Contents**

This data structure represents the thermal mass effect of furniture and other building contents. This is expressed in terms of lb/ft<sup>2</sup> for the space in question.

### **3.10.13 Reference Position in a Space**

This data structure locates a reference point in a space, typically for the purposes of daylighting control. The typical construct for the reference point is a set of coordinates (X, Y, and Z) relative to the space coordinate system.

### **3.10.14 Two Dimensional Curve**

This data structure explains one parameter in terms of another. An example is a curve that modifies the efficiency of an air conditioner relative to the fraction of time that the equipment operates within the period of an hour, for example. The relationship can be expressed in terms of the X and Y coordinates of points on the curve or it can be expressed as an equation.

### **3.10.15 Three Dimensional Curve**

This data structure explains one parameter in terms of two others. An example is a curve that modifies the efficiency of an air conditioner relative to the outside air dry-bulb temperature and the wet-bulb temperature of air returning to the coil. The relationship is a three-dimensional surface and can be expressed in terms of the X and Y coordinates of points on the curve or it can be expressed as an equation.

### **3.10.16 Temperature Reset Schedule**

This data structure describes the relationship between one temperature and another. For example, the independent variable might be outside air temperature and the dependent variable might be SAT. In this case, a common schedule would be to set the SAT at 55°F when the outside air temperature is 80°F or warmer and at 62°F when the outside air temperature is 58°F or cooler with the SAT scaling between 55°F and 62°F when the outside air temperature is between 80°F and 58°F.

## 4.0 Energy Price Data

Annual energy costs shall be determined using either actual rates of purchased energy or the state average energy prices published by the Energy Information Administration (EIA). Rates from different sources cannot be mixed for the same project.

### *Currency*

<i>Applicability</i>	All projects
<i>Definition</i>	The currency used to compare the proposed design and the baseline building
<i>Units</i>	List: Custom Energy Costs, Default State Average Energy Costs
<i>Input Restrictions</i>	The default is state average energy costs as published by the EIA.
<i>Baseline Building</i>	Same as the proposed design

### 4.1 State Average Energy Costs

The building descriptors specified below are used when the currency type is Default State Average Energy Costs.

#### *State Average Electric Utility Rates*

<i>Applicability</i>	When Currency (see above) is “state average energy costs”
<i>Definition</i>	The state average electricity prices are published by DOE’s Energy Information Administration (EIA) for commercial building customers
<i>Units</i>	\$/kWh
<i>Input Restrictions</i>	The energy prices are prescribed and cannot be overwritten
<i>Baseline Building</i>	The baseline building shall use the same utility rate as the proposed design

#### *State Average Gas Utility Rates*

<i>Applicability</i>	When Currency (see above) is “state average energy costs”
<i>Definition</i>	The utility rates for natural gas delivered to the building. The state average gas prices are published by EIA for commercial building customers.
<i>Units</i>	\$/therm
<i>Input Restrictions</i>	The energy prices are prescribed and cannot be overwritten
<i>Baseline Building</i>	The baseline building shall use the same utility rate as the proposed design

### ***State Average Oil Utility Rates***

<i>Applicability</i>	When Currency (see above) is “state average energy costs”
<i>Definition</i>	The utility rates for oil delivered to the building. The state average gas prices are published by EIA for commercial building customers.
<i>Units</i>	Data structure
<i>Input Restrictions</i>	The energy prices are prescribed and cannot be overwritten
<i>Baseline Building</i>	The baseline building shall use the same utility rate as the proposed design

## **4.2 Custom Energy Costs**

For more detailed analysis of utility rates, the sections below may be used. This section defines the approach for using tariffs, specifying energy and demand charges, ratchets, etc.

### **4.2.1 Utility Costs: Tariffs**

This object can be used to define the name of the tariff, the type of tariff, and other details about the overall tariff.

#### ***Tariff Name***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	A unique identifier for the tariff being calculated. The name is used in identifying the output results and in associating all of the charges and other objects that make up a tariff.
<i>Units</i>	Text
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

#### ***Tariff Meter***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	Specifies the type of meter the tariff will accept to calculate energy used or demand: <ul style="list-style-type: none"><li>• Electricity: Specifies that the meter (s) will be electric.</li><li>• Gas: Specifies that the meter(s) will be natural gas.</li><li>• Gasoline: Specifies that the meter(s) will be gasoline.</li><li>• Diesel: Specifies that the meter(s) will be diesel.</li><li>• Coal: Specifies that the meter(s) will be coal.</li><li>• FUEL-OIL#1: Specifies that the meter(s) will be fuel oil #1.</li></ul>

- FUEL-OIL#2: Specifies that the meter(s) will be fuel oil #2.
- Propane: Specifies that the meter(s) will be propane.
- Steam: Specifies that the meter(s) will be steam.
- District Heating: Specifies that the meter(s) will be purchased hot water.
- District Cooling: Specifies that the meter(s) will be purchased chilled water.
- Electricity Purchased: Specifies that the meter(s) will be purchased electricity. This meter is quantity of electricity purchased from the utility and is always positive.
- Electricity Surplus Sold: Specifies that the meter(s) will be the surplus electricity sold to the grid. This meter is the excess electricity produced and sent out to the electrical grid. This value is always positive and indicates the surplus electricity from generation that exceeds whole building demand and fed into the grid.
- Electricity Net Purchased: This meter is the net electricity purchased from the utility. This value can be either positive or negative. Positive values are defined as electricity purchased from the utility. Negative values are defined as surplus electricity fed back into the grid.

*Units* List of all the output meters mentioned above

*Input Restrictions* None

*Baseline Building* Same as proposed

### ***Net Metering Option***

*Applicability* All projects using custom utility rates

*Definition* This input sets whether the specified tariff is used for buying, selling or both to the utility. The choices are:

- Buy From Utility: The values from the metered variable are used and are shown as being purchases from the utility. The corresponding meter for this option should be specified as “Electricity Purchased.”
- Sell To Utility: The values from the metered variable are used for a “sell back” rate to the utility. The charges in the rate should be expressed as negative values. The corresponding meter for this option should be specified as “Electricity Surplus Sold.”
- Net Metering: Negative values are used to reduce any positive values during the specific period on the tariff when negative values occur. The corresponding meter for this option should be specified as “Electricity Net Purchased.”

*Units* List: Buy From Utility, Sell To Utility, Net Metering

*Input Restrictions* None. The default selection for this input is Buy From Utility.

*Baseline Building* Same as proposed

## Conversion Factors

*Applicability* All projects using custom utility rates

*Definition* A choice that allows several different predefined conversion factors to be used. These multipliers are used to convert energy and/or demand into the units specified by the utility in their tariff.

- kWh
- Therm
- MMBtu
- Megajoule (MJ)
- KBtu
- Mil cubic feet (MCF)
- Centum cubic feet (CCF)

The following table shows the conversion factors for each of the units. The simulation results for energy use are in joules (J) and energy demand are in watts (W). The conversion factors specified below are used to convert energy and demand to the corresponding unit.

Choice	Energy Conversion Factor	Demand Conversion Factor
kWh	2.778E-07	0.001
Therm	9.48E-09	0.00003412
MMBtu	9.48E-10	0.000003412
MJ	0.000001	0.0036
KBtu	9.48E-07	0.003412
MCF	9.48E-10	0.000003412
CCF	9.48E-09	0.00003412

*Units* List of the unit choice or user defined

*Input Restrictions* One of the units defined in the list. If “User Defined” is selected, the corresponding energy and demand conversion factor needs to be provided.

*Baseline Building* Same as proposed

### 4.2.2 Utility Costs: Charges

Utility charges can be energy charges or demand charges. Energy or demand charges can be either a fixed flat rate based on consumption, or vary based on time of use (TOU) or season of use. Some utilities also follow real-time pricing where tariffs can change frequently. Also with charges based on consumption, a utility may also charge a fixed monthly fee irrespective of energy use or energy demand. The descriptors in the section below describe each of these charges.



## ***Tariff Variability***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	<p>Tariffs can be defined as a flat rate, or vary by the TOU, season or a real-time pricing. The variance in tariff can be defined through one or more of the variables below.</p> <ul style="list-style-type: none"><li>• <b>Monthly</b> This would be a flat monthly rate charged by the utility per customer. This is irrespective of energy use or energy demand.</li><li>• <b>Time of Use Period Schedule</b> This schedule defines the time-of-use periods that occur each day. The different variables that can occur in a day are<ul style="list-style-type: none"><li>– Peak</li><li>– Shoulder</li><li>– Off-peak</li><li>– Mid-peak</li></ul>Both energy and demand charges can be defined for each TOU period.</li><li>• <b>Seasonal Schedules</b> Utilities can also vary tariffs based on season. Tariffs can be defined for the following seasons<ul style="list-style-type: none"><li>– Winter</li><li>– Spring</li><li>– Summer</li><li>– Autumn</li></ul></li></ul>
<i>Units</i>	List: Monthly Charge, TOU Period Schedule, Seasonal Schedule
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

## ***Time of Use Period Schedule***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	<p>Unique name of a yearly schedule that specifies the TOU type for the entire year. The schedule specifies months and times in a year billed as peak, shoulder, off-peak, or mid-peak. This schedule is used for all TOU energy billing. TOU demand charges are calculated using the block-charges input.</p>
<i>Units</i>	Schedule name with TOU variables defined
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### ***Seasonal Schedule***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	Unique name of a yearly schedule that specifies the season type for the entire year. The schedule specifies months in a year billed using winter, summer, autumn, or spring tariffs. This schedule is used for the billing of all seasonal energy and demand charges using the block charges input.
<i>Units</i>	Schedule name with seasonal variables defined
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### ***Demand Window***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	<p>The determination of demand can vary by utility. Some utilities use the peak instantaneous demand measured, but most use a 15-minute average demand or a 1-hour average demand. Some gas utilities measure demand as the use during the peak day or peak week.</p> <p>The choices for demand window are:</p> <ul style="list-style-type: none"><li>• Quarter hour</li><li>• Half hour</li><li>• Full hour</li><li>• Day</li><li>• Week</li></ul> <p>The value for demand window must coincide with the value for number of timesteps. This is explained in Section 3.1.8 of this manual.</p>
<i>Units</i>	List: Quarter Hour, Half Hour, Full Hour, Day, Week
<i>Input Restrictions</i>	None. If no value is entered, Quarter Hour is assumed.
<i>Baseline Building</i>	Same as proposed

### **Monthly Charge**

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	Many utilities refer to this as a customer charge. This input accepts a list of 12 numeric values that add a fixed monthly charge to each billing cycle. If a single value is entered, the value will be used for all 12 billing periods.
<i>Units</i>	\$/month
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### **Energy Charge: Simple**

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	Energy charges are the charges associated with the energy use during a billing period. This input accepts a numeric value that allows specification of an energy charge that is constant with time and quantity, or a list of 12 values that allows the specification of an energy charge that is constant with quantity but may vary by billing period. Energy charges that vary with quantity are defined in the descriptor Block Charges.
<i>Units</i>	\$/unit
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### **Demand Charge: Simple**

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	Demand charges are the charges associated with the energy demand for the billing period. This input accepts either a single value that specifies a demand charge that is constant with time and quantity, or a list of 12 values that allows the specification a demand charge that is constant with quantity but may vary by billing period. The units are \$/peak-unit. As few as one value may be entered in the list, which will be used for all months within the billing period. Demand charges that vary with the quantity of demand, are defined in the descriptor Block Charges.
<i>Units</i>	\$/peak-unit
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### **Energy Charge: Block**

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	Block charges define the energy charges that vary according to the amount of energy used. The time period over which a block energy charge is to be used needs to be defined.

- For TOU energy charges, the time period can be off-peak, peak, shoulder, mid-peak. If no TOU rates apply, then the time period should be annual.
- For seasonal energy charges, the time period can be summer, winter, autumn, or spring. If no seasonal rates apply, then the time period should be annual.

*Units* List:  
 For TOU energy charges, the options should be Annual, Off Peak, Peak, Mid-Peak, Shoulder.  
 For seasonal energy changes, the options should be Annual, Summer, Winter, Autumn, Spring.

*Input Restrictions* None

*Baseline Building* Same as proposed

***Demand Charge: Block***

*Applicability* All projects using custom utility rates

*Definition* Block charges defines the demand charges that vary according to the energy demand.  
 The time period over which a block demand charge is to be used needs to be defined.

- For TOU demand charges, the time period can be off-peak, peak, shoulder, or mid-peak. If no TOU rates apply, then the time period should be annual.
- For Seasonal demand charges, the time period can be summer, winter, autumn, or spring. If no seasonal rates apply, then the time period should be annual.

*Units* List:  
 For TOU demand charges, the options should be Annual, Off Peak, Peak, Mid-Peak, Shoulder.  
 For seasonal demand changes, the options should be Annual, Summer, Winter, Autumn, Spring.

*Input Restrictions* None

*Baseline Building* Same as proposed

***Block Charges: Limits***

*Applicability* All projects using custom utility rates

*Definition* Block charges define the energy or demand charges that vary according to the amount used. The limits for the blocks need to be defined either in kW for demand charges or kWh for energy charges, along with the energy cost for each block.

*Units* For demand charges: kW and \$/kW for each of the block  
 For energy charges: kWh and \$/kW for each of the blocks  
 Up to 15 blocks may be specified for each group.

*Input Restrictions* None

*Baseline Building* Same as proposed

### 4.2.3 Utility Costs: Ratchets

Ratchets allow the modeling of tariffs that include some type of seasonal ratcheting. Ratchets are most common when used with electric demand charges. A ratchet is when a utility requires that the demand charge for a month with a low demand may be increased to be more consistent with a month that set a higher demand charge.

The time period over which the ratchet is calculated is defined by inputs for “Season From” and “Season To.” Ratchets take the hourly metered values as calculated in the parent tariff and determine a peak quantity for each billing period. If a season is specified, the ratchet may compute the demand for a specific season, such as summer. In addition, the ratcheted demand may be adjusted by an offset or multiplied by a fraction. A value is calculated for each billing period for use in associated tariff and block-charge.

#### ***Ratchet Name***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	A unique identifier for the ratchet being defined calculated. The name is used in identifying the output results and in associating all of the charges and other objects that are affected by the ratchet. Along with the name of the ratchet, the associated tariff also needs to be specified.
<i>Units</i>	Text
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

#### ***Season From***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	This input is the name of the season that is being examined. The maximum value for all of the months in the named season is what is used with the ratchet multiplier fraction and ratchet offset value. This is most commonly summer or annual.
<i>Units</i>	List: Summer, Winter, Spring, Autumn, Annual, Monthly  This input also requires a descriptor for Seasonal Schedule that defines the months for each season.
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### ***Season To***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	This input is the name of the season that the ratchet applies to. This is most commonly winter or annual. The ratchet only applies to the months in the names season.
<i>Units</i>	List: Summer, Winter, Spring, Autumn, Annual, Monthly  This input also requires a descriptor for Seasonal Schedule that defines the months for each season.
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

### ***Ratchet Multiplier Fraction***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	This is the value by which the peak demand in the months defined under Season From are multiplied to calculate the minimum demand applicable to months defined under Season To. The higher of the actual month demand or this calculated value is used to specify the demand for the applicable month. If both ratchet multiplier and ratchet offset are defined, the multiplier is applied to the offset demand or energy value, which then determines the minimum demand or energy for a month.
<i>Units</i>	Text
<i>Input Restrictions</i>	None. Default is 1.
<i>Baseline Building</i>	Same as proposed

### ***Ratchet Offset Value***

<i>Applicability</i>	All projects using custom utility rates
<i>Definition</i>	An offset may be defined that can either be added (in case of a positive offset) or subtracted (in case of a negative offset) from the calculated demand. The demand offset value (in kW) needs to be defined, which would be applied to the peak demand. If both ratchet multiplier and ratchet offset are defined, the multiplier is applied to the offset demand or energy value, which then determines the minimum demand or energy for a month.
<i>Units</i>	Number
<i>Input Restrictions</i>	None
<i>Baseline Building</i>	Same as proposed

## 5.0 Reporting

This chapter summarizes the requisite content and format of the PRM-RM standard reports. The establishment of these reports will standardize the way energy modeling output data is presented to various rating authorities. By standardizing the reports, all rating authorities will be able to view the same building information and evaluate the project for certification, labeling, or tax credit.

Simulated performance shall be documented, and documentation shall be submitted to the rating authority. The information shall be submitted in a report and shall include the following.

### 5.1 Content

The reporting requirements are organized into four standard reports. The first four reports are generated from the energy modeling tool. The fifth report includes additional documentation that needs to be provided by the user and isn't generated by the software tool.

#### Standard Reports Generated by Software Tool

- a. Building Summary  
The Building Summary contains basic building information such as project title, location, and size. This brief report provides essential building data at a glance.
- b. Performance Outputs  
This report summarizes energy use by fuel types and end uses. It also reports simulation advisory messages including errors, warnings, and UMLH.
- c. Model Inputs  
The Model Inputs report is required to have documentation of all energy features that are different between the proposed and baseline model, and includes a checklist to verify that the mandatory code requirements and documentation of inputs that use the exceptional calculation method or are flagged as being different between the baseline and proposed.
- d. Representations  
The Representations report includes all relevant building titles and claims.

#### Reports Provided by User

- a. Supporting Documentation  
Supporting documentation needs to include detailed architectural and mechanical drawings to support the inputs entered into the energy modeling software as well as calculations supporting the exceptional calculation methods used and inputs flagged by the tool as different between the baseline and proposed.

#### 5.1.1 Building Summary

This section will include a brief description of the project, the simulation program used, the version of the simulation program, the project location, and information on building owner, architect, engineer, etc. The reporting requirements for this section are listed below:

1. Building Information
  - a. Project name

- b. Project address (including city and state)
  - c. Analysis date and time
  - d. Climate zone
  - e. Project type (new construction, alterations, additions)
  - f. Number of floors (above grade and below grade)
  - g. Floor Area
    - i. Conditioned floor area
    - ii. Unconditioned floor area
    - iii. Total area
    - iv. Typical floor size
  - h. Window-to-wall ratio
  - i. Building use types
    - i. Area of each use type
    - ii. Space conditioning category for each use type
  - j. Applicable energy code building is permitted under
  - k. Weather file used
  - l. Simulation program used
  - m. Version of simulation program
  - n. Units of measure
2. Stakeholder Information

This information needs to be provided for the building owner, engineer, architect, and energy modeler.

- a. Role
- b. Last name
- c. First name
- d. Address (including city and state)
- e. Contact information (phone number or email address)

### 5.1.2 Performance Outputs

The performance outputs need to include documentation on the various energy sources used in the building, along with the utility rate structure used for the energy source. Table 85 provides an example for reporting the utility rate structure for the different fuel types used in the analysis.

**Table 85.** Utility Rates Reporting

Energy Type	Energy Consumption Units	Demand Units	Utility Rate Name	Utility Rate Structure
Electricity	kWh	kW		
Natural Gas	therm	Btuh x 10 <sup>6</sup>		

The performance outputs report shall also include the calculated values for the baseline building performance and the proposed building performance. It shall include an output from the simulation program or software with a detailed breakdown of energy use, demand, and cost for the following



components: lights, internal equipment loads, service water heating equipment, space heating equipment, space cooling and heat rejection equipment, fans, and other HVAC equipment (such as pumps). Table 86 provides an example format for reporting the energy use by end-use for the baseline building, for each of the four runs. Table 87 provides an example format for reporting the energy use by end-use for the proposed building as well as energy savings by end-use, as compared to the baseline building.

**Table 86.** Baseline Energy Summary by End-Use for Each Run

End Use	Unregulated?	Fuel Type	Units of Annual Energy and Peak Demand	Baseline 0° rotation	Baseline 90° rotation	Baseline 180° rotation	Baseline 270° rotation	Baseline Design Total (Average of 4 rotations)
Interior lighting		Electricity	Consumption (kWh)					
			Demand (kW)					
Exterior lighting		Electricity	Consumption (kWh)					
			Demand (kW)					
Space heating		Electricity/ Natural Gas	Consumption (kWh/therm)					
			Demand (kW/Btuh x 10 <sup>6</sup> )					
Space cooling		Electricity/ Natural Gas	Consumption (kWh/therm)					
			Demand (kW/Btuh x 10 <sup>6</sup> )					
Pumps		Electricity	Consumption (kWh)					
			Demand (kW)					
Heat rejection		Electricity	Consumption (kWh)					
			Demand (kW)					
Fans - interior ventilation		Electricity	Consumption (kWh)					
			Demand (kW)					
Fans - parking garage	x	Electricity	Consumption (kWh)					
			Demand (kW)					
Service water heating		Electricity/ Natural Gas	Consumption (kWh/therm)					
			Demand (kW/Btuh x 10 <sup>6</sup> )					
Receptacle equipment	x	Electricity	Consumption (kWh)					
			Demand (kW)					
IT equipment	x	Natural Gas	Consumption (therm)					
			Demand (Btuh x 10 <sup>6</sup> )					
Interior lighting - process	x	Electricity	Consumption (kWh)					
			Demand (kW)					
Refrigeration equipment	x	Electricity	Consumption (kWh)					
			Demand (kW)					
Fans - kitchen	x	Electricity	Consumption (kWh)					

End Use	Unregulated?	Fuel Type	Units of Annual Energy and Peak Demand	Baseline 0° rotation	Baseline 90° rotation	Baseline 180° rotation	Baseline 270° rotation	Baseline Design Total (Average of 4 rotations)
ventilation			Demand (kW)					
Cooking	x	Electricity/ Natural Gas	Consumption (kWh/therm)					
			Demand (kW/Btuh x 10 <sup>6</sup> )					
Industrial process	x	Electricity	Consumption (kWh)					
			Demand (kW)					
Elevators and escalators	x	Electricity	Consumption (kWh)					
			Demand (kW)					
Heat pump supplementary		Electricity	Consumption (kWh)					
			Demand (kW)					
Total Site Energy Use			Btu x 10 <sup>6</sup>					
Total Source Energy Use			Btu x 10 <sup>6</sup>					
Total Energy Use by Fuel Type		Electricity	kWh					
		Gas	therm					
Total Energy Cost by Fuel Type		Electricity	\$					
		Gas	\$					
Baseline Annual Energy Cost			\$					

**Table 87.** Baseline and Proposed Energy Summary by End-Use

End Use	Unregulated?	Energy Type	Units of Annual Energy and Peak Demand	Baseline	Proposed	Energy Use / Demand Savings per End-Use
Interior lighting		Electricity	Consumption (kWh)			
			Demand (kW)			
Exterior lighting		Electricity	Consumption (kWh)			
			Demand (kW)			
Space heating		Electricity/ Natural Gas	Consumption (kWh/therm)			
			Demand (kW/Btuh x 10 <sup>6</sup> )			
Space cooling		Electricity/ Natural Gas	Consumption (kWh/therm)			
			Demand (kW/Btuh x 10 <sup>6</sup> )			
Pumps		Electricity	Consumption (kWh)			
			Demand (kW)			
Heat rejection		Electricity	Consumption (kWh)			
			Demand (kW)			
Fans - interior		Electricity	Consumption (kWh)			

End Use	Unregulated?	Energy Type	Units of Annual Energy and Peak Demand	Baseline	Proposed	Energy Use / Demand Savings per End-Use
ventilation			Demand (kW)			
Fans - parking garage	x	Electricity	Consumption (kWh)			
			Demand (kW)			
Service water heating		Electricity/ Natural Gas	Consumption (kWh/therm)			
			Demand (kW/Btuh x 10 <sup>6</sup> )			
Receptacle equipment	x	Electricity	Consumption (kWh)			
			Demand (kW)			
IT equipment	x	Natural Gas	Consumption (therm)			
			Demand (Btuh x 10 <sup>6</sup> )			
Interior lighting - process	x	Electricity	Consumption (kWh)			
			Demand (kW)			
Refrigeration equipment	x	Electricity	Consumption (kWh)			
			Demand (kW)			
Fans - kitchen ventilation	x	Electricity	Consumption (kWh)			
			Demand (kW)			
Cooking	x	Electricity/ Natural Gas	Consumption (kWh/therm)			
			Demand (kW/Btuh x 10 <sup>6</sup> )			
Industrial process	x	Electricity	Consumption (kWh)			
			Demand (kW)			
Elevators and escalators	x	Electricity	Consumption (kWh)			
			Demand (kW)			
Heat pump supplementary		Electricity	Consumption (kWh)			
			Demand (kW)			

**Table 88.** Baseline and Proposed Energy Consumption and Cost by Fuel Type

Fuel Type	Baseline				Proposed			Percent Savings	
	Site Energy Use	Source Energy Use (Btu x 10 <sup>6</sup> )	Cost		Site Energy Use	Source Energy Use (Btu x 10 <sup>6</sup> )	Cost	Site Energy Use	Cost
Electricity	0.0	kWh	0.0		0.0	kWh	0.0		
Natural gas	0.0	therm	0.0		0.0	therm	0.0		
Energy model subtotal (Btu x 10 <sup>6</sup> )	0.0		0.0	\$ -	0.0		0.0	\$ -	

The output reports shall show the amount of UMLH for both the proposed design and baseline building design, and document any errors or warnings reported from the simulation software.

**Table 89.** Advisory Messages

	Baseline	Proposed	Difference (Proposed – Baseline)
Total unmet load hours (heating)			
Total unmet load hours (cooling)			
Total unmet load hours			
Number of error messages			
Number of warning messages			

### 5.1.3 Model Input Documentation

This section documents detailed building inputs for the baseline and proposed building including the wall, roof, floor, and window assembly inputs showing U-factors and window SHGC. It has space level details including lighting, plug loads, and occupant density for a few representative spaces, system level details, and utility costs.

#### 5.1.3.1 Model Summary

The simulation tool is required to produce reports summarizing building inputs, including wall area by orientation, WWR by orientation, and number of spaces for each space conditioning category. Table 90 provides an example of the reporting format and requirements.

**Table 90.** Building Envelope Summary

Model Input Parameter	Baseline			Proposed		
Above-grade wall and vertical glazing area by orientation						
Orientation	Above-Grade Wall Area (ft <sup>2</sup> )	Vertical Glazing Area		Above-Grade Wall Area (ft <sup>2</sup> )	Vertical Glazing Area	
		(ft <sup>2</sup> )	(%)		(ft <sup>2</sup> )	(%)
North				Identical to baseline		
East				Identical to baseline		
South				Identical to baseline		
West				Identical to baseline		
Total	0	0	0.0%	0	0	0.0%
Roof and skylight area	Roof Area (ft <sup>2</sup> )	Skylight Area		Roof Area (ft <sup>2</sup> )	Skylight Area	
		(ft <sup>2</sup> )	(%)		(ft <sup>2</sup> )	(%)
			0.0%	Identical to baseline		0.0%
Number of thermal blocks	Conditioned	Semi-heated	Unconditioned	Conditioned	Semi-heated	Unconditioned

### 5.1.3.2 Schedules of Operation

The equivalent full load hours (EFLH) of operation per year need to be reported for all unique space types for all internal loads as well as HVAC operation. Table 91 provides an example of the expected documentation for the report.

**Table 91.** EFLH Reporting Requirements for Internal Loads and HVAC Operation

Building ID	Areas Served	EFLH of Operation Per Year (maximum of 8,760). Leave blank or enter N/A if not applicable.									
		Interior Lighting	Service Water Heating	Receptacle Equipment and Appliances	Refrigeration	Server Equipment	Cooking Equipment	Elevators / Escalators	Exterior Lighting	Other Loads (Indicate Loads)	
Project Name	Dwelling Units	854	2,446	2,117							
Project Name	Main Building Schedules										

Building ID	Areas Served	HVAC: hours per year fans running continuously	Occupied Mode Setpoint		Setback Mode Setpoint	
			Cooling (°F)	Heating (°F)	Cooling (°F)	Heating (°F)
Project Name	Dwelling Units	8,760	78.0	72.0	80.0	70.0
Project Name	Main Building Schedules					

### 5.1.3.3 Energy Features for Baseline and Proposed

This section reports inputs that are different between the baseline and the proposed buildings. It highlights the requirements that are reported under each category and provides example table formats for the required reporting.

#### 1. Envelope

##### a. Opaque Envelope

Each envelope component is required to have a description for the baseline and proposed construction, with the assembly U-value or insulation R-value, where applicable. The reporting should address all envelope components modeled, including:

- i. Roof construction
- ii. Above-grade exterior wall construction
- iii. Below-grade exterior wall construction
- iv. Exposed floor construction
- v. Slab-on-grade floor construction
- vi. Opaque doors

##### b. Fenestration

Each unique fenestration assembly (vertical fenestration and skylights) needs to be described and documented for both baseline and proposed model. The assembly U-factor, SHGC, and VT need to be documented.

2. Natural Ventilation

If natural ventilation is modeled for the proposed building, documentation needs to that show minimum ventilation rates are provided for all occupied hours, for both baseline and proposed building.

3. Interior Lighting

The reporting requirements for interior lighting should include documentation of the baseline lighting power allowance. If the building area method is used for defining the LPD, the report outputs should include the baseline LPD allowance for the applicable building area type, the proposed design LPD as well as credit taken for lighting controls in addition to the mandatory minimum. Table 92 and Table 93 provide example formats for reporting lighting inputs using the building area method.

**Table 92.** Lighting Power Density Reporting for Building Area Method

General Information			Baseline	Proposed			
	90.1-2010 Table 9.5.1 Building Area Type	Total Building Type Area (ft <sup>2</sup> )	Modeled LPD (W/ft <sup>2</sup> )	Design LPD (W/ft <sup>2</sup> )	Additional Automatic Lighting Controls and Space Types	90.1-2010 Table G3.2 Power Adjustment	Modelled LPD (W/ft <sup>2</sup> )
1	Residential Dwelling Units		1.10				
2							
3							
Total		0	0.00	0.00			0.00

**Table 93.** LPD and Power Reporting for Building Area Method

Building ID	Average LPD			Total Power	
	Baseline Maximum Allowance (W/sq ft)	Design Maximum Allowance (W/sq ft)		Baseline Maximum Allowance (kW)	Design Maximum Allowance (kW)
Project Name	0.00	0.00		0.00	0.00

If the space-by-space approach is used for defining the lighting loads, the reporting for the proposed building should include the design LPD by space type as well as any adjustments for lighting controls in addition to the mandatory lighting controls. Table 94 and Table 95 provide an example of the reporting format for interior LPD requirements. Along with the ILPA, the report should describe spaces where additional lighting power is installed as well as description of the allowance.

**Table 94. Lighting Power Density for Baseline Building for Space-by-Space Approach**

General Information			Baseline					
Building ID:	90.1-2010 Table 9.6.1 Space Type	Total Space Type Area (ft <sup>2</sup> )	Maximum Allowance (W/ft <sup>2</sup> )	90.1-2010 Section 9.6.3 Room Geometry Adjustment <i>(Only complete for spaces where credit is taken for room geometry)</i>				Total Baseline LPD Allowance (W/ft <sup>2</sup> )
				Luminaire Mounting Height (ft)	Work-plane (ft)	Room Perimeter Length (ft)	Room Cavity Ratio	
Space Type 1	Residential Dwelling Units		0.90		0.90		0.90	
Space Type 2								
Space Type 3								
Space Type 4								
Space Type 5								
Total		0	0.00			0.00	0.00	

**Table 95. Lighting Power Density Reporting for Proposed Building for Space-by-Space Approach**

General Information			Proposed				
Building ID	90.1-2010 Table 9.6.1 Space Type	Total Space Type Area (ft <sup>2</sup> )	Design LPD (W/ft <sup>2</sup> )	Describe Automatic Lighting Controls	Section 9.6.2(c) Control Factor Adjustment		Modeled Design LPD (W/ft <sup>2</sup> )
					Lighting Power Under Control (W)	Table 9.6.2 adjustment	
Space Type 1	Residential Dwelling Units						
Space Type 2							
Space Type 3							
Space Type 4							
Space Type 5							
Total		0	0.00				0.00

4. Exterior Lighting

The exterior lighting zone for the proposed building needs to be reported along with the exterior lighting allowance and design lighting, for both tradable and nontradable surfaces. Table 96 and Table 97 provide examples of the format for reporting these requirements.

**Table 96. Exterior Lighting Power for Tradable Surfaces**

General Information			Baseline		Proposed
90.1-2010, Table 9.4.5, Tradable Exterior Lighting Application	Required Input (Area or Length)	Total Area (ft <sup>2</sup> ) or Length (ft)	Allowed LPD	Lighting Power Allowance (W)	Design Lighting Power (W)
Total tradable surface lighting allowance				0	0

**Table 97. Exterior Lighting Power for Nontradable Surfaces**

General Information			Baseline		Proposed
90.1-2010, Table 9.4.5, Nontradable Exterior Lighting Application	Required Input	Quantity of Required Input for Project	Allowed LPD	Lighting Power Allowance (W)	Design Lighting Power (W)
Building facades	Area		0.15	0.00	
ATMs and night depositories	Number of ATMs		270 W + 90 W per additional		
Parking near 24-hour retail entrances	Main Entries		800	0.00	
Total nontradable surface lighting allowance				0.00	0

5. Process Loads

The equipment power density needs to be reported for both baseline and proposed cases. Depending on the modeling approach used for the proposed building, this reporting is required to be at space-by-space level or a building average.

Any credit for improved EPD or process equipment needs to be supported through backup calculations, requirements for that are documented in Section 5.1.3.6 of this document.

**Table 98. Reporting for Space-by-Space Equipment Power Densities**

Building ID	Building Type	Total Space Type Area (ft <sup>2</sup> )	Equipment Power Density (W/ft <sup>2</sup> )	Equipment Included in Power Density	Baseline Modeled Identically
Space Type 1	Hotel guest rooms		0.50	-	
Space Type 2					
Space Type 3					
Totals		0	0.00	Total power modeled using space by space method (kW) 0.0	

**Table 99. Reporting for Non-Receptacle Process Equipment**

Building ID	Equipment Type	Energy Source	Energy Demand (kW for electricity) (Btuh for non-electricity)	Baseline Modeled Identically
Project Name	Refrigeration equipment			
Project Name	Kitchen equipment			
Project Name	Data center equipment			
Project Name	Process exhaust fans			
Project Name	Escalators			

6. HVAC

All HVAC systems included in the energy model are required to be documented through the output reports. A summary table is required, to list each system modeled for the baseline and proposed building as well as the spaces served by each system. Table 100 and Table 101 provide example summary tables for all systems included in the baseline and proposed building



**Table 100.** Proposed HVAC System Type Summary

Proposed System Name	Proposed System Description	Spaces Modeled

**Table 101.** Baseline HVAC System Type Summary

Proposed System Name	Proposed System Description	Spaces Modeled

In addition to this, the output reports need to include information for both baseline and proposed buildings, including heating and cooling system capacities, efficiency, fan control, supply airflow, outdoor air intake, and other relevant information. Table 102 provides an example format for reporting modeling parameters for air-side systems.

Water-side HVAC systems are also required to include information on number of pieces of equipment, equipment capacities, and efficiencies. In addition to this, part load efficiencies water supply and return temperatures, pump power, control and head, and loop configuration need to be reported. Table 103 to Table 107 provide example formats for reporting all parameters for water-side HVAC systems for baseline and proposed.

**Table 102.** Air-Side System Output Reporting Requirements

	Model Input Parameter		Units	Baseline	Proposed
				System Type: System Name: Number of Systems:	System Type System Name: Number of Systems:
1	Total cooling capacity		tons	0	0
2	90.1-2010, Table 6.8.1, Unitary Cooling (Systems 1 through 6)	Table 6.8.1 unitary cooling capacity range	tons		
		Unitary cooling efficiency			
		Unitary cooling part-load efficiency (if applicable)			
3	Total heating capacity		kBtu/h	0	0
4	90.1-2010, Table 6.8.1, Unitary Heating (Systems 2, 3, 4, and 9)	Table 6.8.1 unitary heating capacity range	kBtu/h		
		Unitary heating efficiency			
5	Fan control				
6	Supply airflow		cfm	0	0
7	Outdoor airflow		cfm	0	0
8	Demand control ventilation		n/a		
9	Economizer high-limit shutoff				
10	Supply air temperature reset		n/a		
11	Energy Recovery per 90.1-2010, Section 6.5.6.1	For Baseline, any individual systems where supply airflow rate exceeds value in Table 6.5.6.1 based on climate zone and percent outdoor air? For proposed,	n/a		

	Model Input Parameter		Units	Baseline	Proposed
				System Type:	System Type
				System Name:	System Name:
				Number of Systems:	Number of Systems:
		indicate if energy recovery is modeled.			
		Exhaust air energy recovery effectiveness or 6.5.6.1 exception claimed	% energy recovery effectiveness		
12	Fan Power	Supply fan power	kW		
		Return or relief fan power	kW		
		Exhaust fan power	kW		
		System fan power	kW	0	0
		Allowed fan power	kW		
13	Pressure Drop Adjustments (Systems 3 through 8)	Each pressure drop adjustment claimed needs to be documented along with the input design airflow rate through each applicable device.	Design cfm		
			Adjustment: in. w.c.		
		Total 90.1-2010, Table 6.5.3.1.1b, pressure drop adjustment (A)	bhp		
14	Fan power adjustments (Systems 9 through 10)	Non-mechanical cooling fan-additional fan power allowance	cfm		
			fan power per cfm (kW)		

**Table 103.** Water Side Equipment Output Reporting Requirements: Chiller

Model Input Parameter	Units	Baseline	Proposed
		System Type:	System Type
		System Name:	System Name:
		Number of Systems:	Number of Systems:
Number and type of chillers (and capacity per chiller if more than one type or size of chiller)	n/a		
Purchased chilled water rate (cost per unit energy)	\$		
Total chiller capacity			
Chiller efficiency - full load			
Chiller efficiency - part load			
Chilled water (CHW) supply temp	°F		
CHW ΔT	°F		
CHW supply temp reset parameters	n/a		
CHW loop configuration	n/a		
Number of primary or District plant CHW pumps	#		
Primary or District plant CHW pump power			
Primary or District plant CHW pump flow	gpm		
Primary or District plant CHW pump control	n/a		
Number of secondary or building booster CHW pumps	#		
Secondary or building booster CHW pump power			
Secondary or building booster CHW pump flow	gpm		

Model Input Parameter	Units	Baseline	Proposed
		System Type:	System Type
		System Name:	System Name:
		Number of Systems:	Number of Systems:
Secondary or building booster CHW pump control	n/a		
Water-side economizer	n/a		
Water-side energy recovery	n/a		

**Table 104.** Water Side Systems Output Reporting Requirements: Condensers

Model Input Parameter	Units	Baseline	Proposed
		System Type:	System Type
		System Name:	System Name:
		Number of Systems:	Number of Systems:
Number of cooling towers or fluid coolers	#		
Cooling tower fan power			
Cooling tower fan control	n/a		
Condenser water (CW) leaving temp	°F		
CW $\Delta T$	°F		
CW loop temp reset parameters	n/a		
Number of CW pumps	#		
CW pump power			
CW pump flow	gpm		
CW pump control	n/a		

**Table 105.** Water Side Equipment Output Reporting Requirements: Boilers

Model Input Parameter	Units	Baseline	Proposed
		System Type:	System Type
		System Name:	System Name:
		Number of Systems:	Number of Systems:
Number and type of boilers	n/a		
Purchased heating rate (cost per unit energy)	\$		
Total boiler capacity			
Boiler efficiency			
Hot water or steam (HW) supply temp	°F		
HW $\Delta T$	°F		
HW temp reset parameters	n/a		
HW loop configuration	n/a		
Number of primary or district plant HW pumps	#		
Primary or district plant HW pump power			
Primary or district plant HW pump flow	gpm		
Primary or district plant HW pump control	n/a		
Number of secondary HW pumps	#		
Secondary HW pump power	n/a		
Secondary HW pump flow	n/a		
Secondary HW pump control	n/a		

**Table 106. Water Side Equipment Output Reporting Requirements: Geothermal Systems**

Model Input Parameter	Units	Proposed
		System Type:
		System Name:
		Number of Systems:
Type of geothermal system	n/a	
Soil conductivity (if applicable)	n/a	
Geothermal source design temperature - summer	°F	
Geothermal source design temperature - winter	°F	
Geoexchange loop design fluid supply temperature - cooling	°F	
Geoexchange loop design fluid supply temperature -heating	°F	
Geoexchange loop - operating temperature	°F	
Geothermal energy transfer effect	n/a	
Geothermal loop pumping configuration	n/a	
Number of geothermal loop pumps	#	
Geothermal loop pump control	n/a	
Geothermal pump power	n/a	
Geothermal loop flow	n/a	
Geothermal air-side efficiency curves	n/a	

**Table 107. Water Side Equipment Output Reporting Requirements: Combined Heat and Power Systems**

Model Input Parameter	Units	Proposed
		System Type:
		System Name:
		Number of Systems:
Type of generator	n/a	
Quantity of CHP generators	n/a	
Total capacity of CHP generators (kW) at design conditions	n/a	
Thermal efficiency (%) at design conditions	n/a	
Electrical efficiency (%) at design conditions	n/a	
Controls or schedule	n/a	
Fuel Source	n/a	
Where is the recovered heat used? (e.g. gas absorption chillers, hot water distribution loop, etc.)	n/a	
Backup heat source when waste heat from CHP is unavailable? (e.g. fossil fuel boilers)	n/a	
Parasitic losses (e.g. AHU to cool the intake air)	n/a	

7. Service Hot Water

The service water heater table needs to be provided in the report for each unique type of system in the building. If the project includes low-flow fixtures, Table 109 also needs to be completed when service hot water loads are defined to be different between baseline and proposed model and credit is taken for the use of low-flow faucets. Backup calculations, in accordance with Section 5.1.5.3 of this manual need to be provided to support the variation of hot water loads between the baseline and proposed model.

**Table 108.** Reporting for Service Hot Water Systems

Model Input Parameter	Baseline	Proposed
Building ID		
System type and fuel		
Input rating (kW, MBH, etc.)		
Efficiency (EF, SL, %, etc.)		
Storage volume (gal)		
Storage temperature (°F)		
Peak hot water demand (gpm)		
Condenser heat recovery		
Number of pumps		
Total pump power (kW)		
Type of pump		

**Table 109.** Reporting for Service Hot Water Loads

General Information				Baseline			Proposed		
Building ID	Fixture Type	Fixture Outlet Temperature (°F)	Percent Hot Water (%)	Flow Rate (gpm)	Annual Total Water Consumption of Fixture (gallons/year)	Annual Fixture Hot Water Consumption (gallons/year)	Flow Rate (gpm)	Annual Total Water Consumption (gallons/year)	Annual Fixture Hot Water Consumption (gallons/year)
Space Name									
Space Name									
Space Name									

**5.1.3.4 Code Requirements**

1. Mandatory Requirements

Checklist showing compliance with all mandatory requirements of Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 of Standard 90.1-2010.

2. Prescriptive Requirements

A list that identifies all aspects of the proposed design that are less stringent than the requirements of Section 5.5, 6.5, 7.5, 9.5, and 9.6 of Standard 90.1-2010.

**5.1.3.5 Exceptional Calculation Methods**

When the simulation program does not model a design, material, or device of the proposed design, an exceptional calculation method shall be used if approved by the rating authority. Any calculation approach using the exceptional calculation method needs to be reported in the compliance report. Refer to Section 5.1.5 on supporting documentation required for designs using the exceptional calculation methods.

**5.1.3.6 Backup Calculations**

Backup calculations are required when the baseline value is identified to be different from the proposed or when calculations are performed outside of the simulation software. Inputs that require

backup calculations are flagged by the energy modeling tool and included in the compliance report. Examples of inputs that may require submittal of backup calculations include the following:

a. Infiltration

In accordance to Section 3.2.6 of this manual, the air leakage rate needs to be reported if specified by the user. Documentation (such as blower door test results) needs to be provided by the user to support the infiltration rates used by the simulation software.

b. Natural Ventilation

Section 3.2.7 of this manual specifies requirements for documentation if backup calculations are used to determine the airflow rate for natural ventilation.

c. Interior Lighting

Section 3.3.3 of this manual specifies interior lighting controls required for parking garages. If parking garage interior lighting controls for the baseline building differ from the proposed design, the input needs to be flagged and reported in this section. The user is required to provide supporting documentation to support the variation in baseline and proposed interior lighting controls for parking garage space.

d. Exterior Lighting

If exterior lighting schedule for the baseline building differs from the proposed design, the input needs to be reported in the compliance reports. Section 3.3.3 of this manual specifies baseline and proposed building requirements for exterior lighting schedule.

e. Daylighting Control Illumination Setpoint

If the user input for illumination setpoint is above or below the IESNA specification, the input should be flagged and included in the compliance reports. The user is required to provide documentation supporting the specification of illumination setpoint for the proposed design.

f. Commercial Refrigeration

Any variation between proposed and baseline refrigeration power, schedules, or control sequences of the refrigeration equipment should be reported for rating authority approval and inspection. Section 3.3.6 of the document specifies requirements for commercial refrigeration equipment.

g. Elevators, Escalators, and Moving Walkways

Variations of the power requirements, schedules, or control sequences of elevators, escalators, and moving walkways modeled in the baseline building from those in the proposed design need to be included in the compliance reports. The user is required to provide documentation supporting these variations. Section 3.3.7 of this manual specifies requirements for elevators, escalators, and moving walkways.

h. Process and Gas Equipment

Variations of the power requirements, schedules, or control sequences of the gas equipment modeled in the baseline building from those in the proposed design need to be reported in the compliance reports. Section 3.3.8 of this document specifies requirements for process and gas equipment.

i. Building Orientation

In accordance with Section 3.4.1 of this manual, the baseline building is not required to be simulated for all four orientations, if the orientation of the proposed design is dictated by site considerations. This exception needs to be reported in the output reports and documentation needs to be provided by the user to support this selection.

j. Service Hot Water

Section 3.8.1 of this manual specifies the requirements for service hot water loads. The service hot water loads are required to be the same between the baseline and proposed models, unless credit is taken for a design strategy that reduces the hot water loads in the proposed design. Such an input needs to be flagged and documented in the reports. Backup calculations need to be provided to support the difference in service hot water loads between the baseline and proposed models.

#### **5.1.4 Representations**

The representations report will have all relevant building titles and claims. The representations report is generated by the software tool and needs to be certified by the mechanical engineer, energy consultant, architect, and/or owner.

#### **5.1.5 Supporting Documentation**

This section of the report is provided by the user and will include drawings and details supporting the following.

##### **5.1.5.1 Drawings**

The report will include detailed architectural and mechanical drawings to support the inputs entered into the energy modeling software, including:

- a. A floor plan showing building orientation
- b. A site plan showing all adjacent buildings and topography that may shade the proposed building (with estimated height or number of stories)
- c. Building elevations and floor plans (schematic is acceptable)
- d. A diagram showing the thermal blocks used in the computer simulation

##### **5.1.5.2 Exceptional Calculation Methods**

The Model Input Documentations section reports inputs that claim to use exceptional calculation methods. The user needs to provide a narrative explaining the exceptional calculation method performed, and theoretical or empirical information supporting the accuracy of the method. The calculations shall be performed on a time step basis consistent with the simulation program used. All applications for approval of an exceptional method shall include:

- a. Step-by-step documentation of the exceptional calculation method performed that is 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 performance rating results calculated with and without the exceptional calculation method
- e. Backup calculations

### **5.1.5.3 Backup Calculations**

Where calculations or tests are used to support data inputs in the energy simulation, backup calculations should be submitted to the rating authority. Inputs that require backup calculations are flagged by the energy modeling tool and reported in the compliance report. The user is required to attach documentation supporting the flagged inputs. Examples of inputs that may require submittal of backup calculations include the following:

- a. Infiltration
- b. Natural ventilation
- c. Interior lighting
- d. Exterior lighting
- e. Commercial refrigeration
- f. Elevators, escalators, and moving walkways
- g. Process and gas equipment
- h. Building orientation
- i. Service hot water

## **5.2 Format of Report**

The energy modeling software will produce an XML file and PDF reports. Spreadsheets can be used to support the exceptional calculation method or the backup calculations.



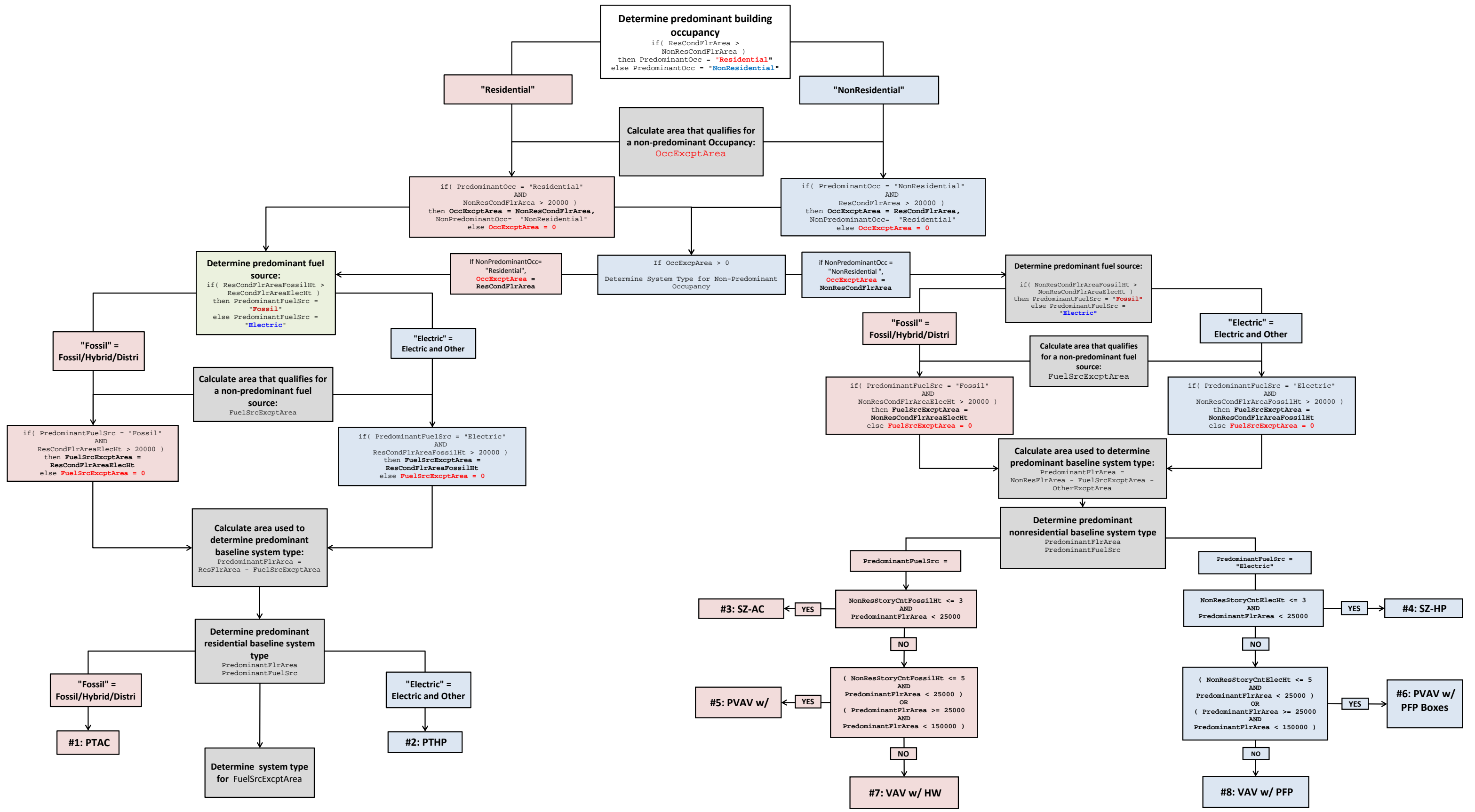
## 6.0 References

- ANSI/ASHRAE. (2004). *ANSI/ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.
- ANSI/ASHRAE. (2007). *ANSI/ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.
- ANSI/ASHRAE/IES. (2010). *ANSI/ASHRAE/IESNA 90.1-2010, Energy Standard for Buildings Except Low-Rise Residential Buildings*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.
- ANSI/ASHRAE/IES. (2013). *ANSI/ASHRAE/IESNA 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.
- ASHRAE. (2009). *Handbook of Fundamentals*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia.
- ASTM. (2001). *ASTM E1980 (2001), Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces*, American Society for Testing and Materials West Conshohocken, Pennsylvania.
- Briggs, R. S., Lucas, R. G., & Taylor, T. (2002). *Climate Classification for Building Energy Codes and Standards: Part 2- Zone Definitions, Maps, and Comparisons*. Atlanta, Georgia: ASHRAE Transactions, Vol 109, Part 1.
- California Energy Commission. (2014, August 14). *CBECC-Com NonResidential Compliance Software*. Retrieved December 19, 2014, from bees.archenergy.com: <http://bees.archenergy.com/referencemethod.html>
- California Energy Commission. (2013, May 7). *2013 Nonres ACM Reference Listing*. Retrieved October 8, 2015, from ca.gov: [http://www.energy.ca.gov/title24/2013standards/implementation/documents/2013\\_nonres\\_ACM\\_reference](http://www.energy.ca.gov/title24/2013standards/implementation/documents/2013_nonres_ACM_reference)
- COMNET (2011). Retrieved from Commercial Buildings Energy Modeling Guidelines & Procedures: <http://www.comnet.org/download-pdfs-mgp-manual>
- Gowri, K., Winiarski, D., & Jarnagin, R. (2009). *Infiltration Modeling Guidelines for Commercial Building Energy Analysis*. Richland, WA: Pacific Northwest National Laboratory.
- Hathaway, J. E., Pulsipher, T., Rounds, J., & Dirks, J. (2014). Statistical Quantification of Climate Similarity and the Monte Carlo Sifting Methods for. *Journal of Applied Meteorology and Climatology*.

PNNL. (2004). *Technical Support Document: Energy Efficiency Program for Commercial and Industrial Equipment: Advanced Notice of Proposed Rulemaking for Commercial Unitary Air Conditioners and Heat Pumps*. U.S. Department of Energy.

USDOE. 2015. EnergyPlus. <http://energyplus.net>. Content Last Updated: February 4, 2015

**Appendix A**  
**Baseline HVAC System Map**





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