COMNET

Commercial Buildings Energy Modeling Guidelines and Procedures

RESNET Publication 2010-001

August 16, 2010

www.comnet.org

P.O Box 4561
Oceanside, CA 92052
www.resnet.us

Cover image courtesy of DOE/NREL

Table of Contents

1 Overview **1-1**
  1.1 Purposes 1-1
  1.2 Scope 1-3
  1.3 Audience 1-3
  1.4 Organization 1-4

2 General Modeling Procedures **2-1**
  2.1 General Requirements for Data from the User 2-1
  2.2 Thermal Blocks, HVAC Zones and Space Functions 2-2
  2.3 Unmet Load Hours 2-5
  2.4 Calculation Procedures 2-6
  2.5 HVAC Capacity Requirements and Sizing 2-9
  2.6 Ventilation Requirements 2-11

3 Software Requirements **3-1**
  3.1 General Requirements 3-1
  3.2 ASHRAE Standard 140-2007 Tests 3-8
  3.3 Modeling Assumptions and Baseline Building Tests 3-9

4 Content and Format of Standard Reports **4-1**
  4.1 Overview 4-1
  4.2 Electronic Format: XML 4-1
  4.3 Hard Copy Format: PDF 4-6

5 Energy Costs and Currency Specification **5-1**
  5.1 Overview 5-1
  5.2 Geographic Regions 5-1
  5.3 Calculating the Zero Energy Performance Index (zEPI) 19

6 Building Descriptors Reference **6-1**
  6.1 Overview 6-1
  6.2 Project Data 6-4
  6.3 Thermal Blocks 6-12
  6.4 Space Uses 6-17
  6.5 Building Envelope Data 6-40
  6.6 HVAC Zone Level Systems 6-65
  6.7 HVAC Secondary Systems 6-73
  6.8 HVAC Primary Systems 6-125
  6.9 Miscellaneous Energy Uses 6-155
  6.10 On-Site Power Generation 6-169
  6.11 Common Data Structures 6-175

7 Advanced Modeling Tips **7-1**
  7.1 Challenging Building Types 7-1
  7.2 Design Features 7-7

List of Figures

Figure 1 – Hierarchy of Space Functions, HVAC Zones and Thermal Blocks 2-3
Figure 2 – Calculation Process for Tax Deductions and Green Building Ratings 2-7
Figure 3 – Procedure for Adjusting Equipment HVAC Sizes in the Baseline Building 2-10
Figure 4 – Prototype Buildings for Modeling Assumptions and Baseline Building Tests 3-10
Figure 5 – Prototypes A1, A3 and A20 3-13
Figure 6 – Prototypes B1 and C1..........3-14
Figure 7 – Prototype D Floor Plans..........3-14

Figure 8 – Prototype D Exterior View....3-15
Figure 9 – Information Flow....4-2
Figure 10 – XML Data Structures....4-3
Figure 11 – Sample of First Building Summary Page, Generated by Software....4-7
Figure 12 – Sample of Second Building Summary Page, Generated by Software....4-8
Figure 13 – Sample of First Energy Measures Page, Generated by Software....4-9
Figure 14 – Sample First Page, Energy Results, Generated by Software....4-10
Figure 15 – Sample of Second Page, Energy Results, Generated by Software....4-11
Figure 16 – United States Climate Zones....5-2
Figure 17 – Information Flow....6-1
Figure 18 – HVAC Mapping....6-2
Figure 19 – Example Stepped Daylighting Control....6-28
Figure 20 – Example Dimming Daylight Control....6-28
Figure 21 –SAT Cooling Setpoint Reset based on Outdoor Air Temperature (OAT) for Dry (B) and Marine (C) Climates....6-82
Figure 22 –SAT cooling setpoint reset based on outdoor air temperature for humid “A” climates....6-83
Figure 23 – Example of SAT heating setpoint reset based on outdoor air temperature (OAT)....6-84
Figure 24 – Chilled Water Supply Temperature Reset Schedule....6-139

List of Tables

Table 1 – Differences in Calculation Procedures by Purpose....1-1
Table 2 – Input Types and Restrictions....3-6
Table 3 – Spreadsheets for Verifying Standard 140 Tests....3-9
Table 4 – Summary of Analyses for Modeling Assumptions and Baseline Building Tests....3-12
Table 5 – Prototype D Surface Areas....3-16
Table 6 – Prototype D Lighting and Equipment Power....3-16
Table 7 – Project Data....4-4
Table 8 – Stakeholders....4-4
Table 9 – Contact....4-4
Table 10 – Sub-Spaces....4-4
Table 11 – Energy Efficiency Measures....4-5
Table 12 – Annual Energy Results....4-5
Table 13 – Energy Results Breakdown....4-5
Table 14 – Representations....4-5
Table 15 – Representation Types....4-5
Table 16 – Advisory Messages....4-6
Table 17 – Explanations for Default Overrides....4-6
Table 18 – Energy Cost Specification by Season and TOU Period – Climate Zone 1A....5-3
Table 19 – Energy Cost Specification by Season and TOU Period – Climate Zone 2A....5-4
Table 20 – Energy Cost Specification by Season and TOU Period – Climate Zone 2B....5-5
Table 21 – Energy Cost Specification by Season and TOU Period – Climate Zone 3A....5-6
Table 22 – Energy Cost Specification by Season and TOU Period – Climate Zone 3B (LA)....5-7
Table 23 – Energy Cost Specification by Season and TOU Period – Climate Zone 3B....5-8
Table 24 – Energy Cost Specification by Season and TOU Period – Climate Zone 3C....5-9
Table 25 – Energy Cost Specification by Season and TOU Period – Climate Zone 4A....5-10
Table 26 – Energy Cost Specification by Season and TOU Period – Climate Zone 4B....5-11
Table 27 – Energy Cost Specification by Season and TOU Period – Climate Zone 4C....5-12
Table 28 – Energy Cost Specification by Season and TOU Period – Climate Zone 5A....5-13
Table 29 – Energy Cost Specification by Season and TOU Period – Climate Zone 5B....5-14
Table 30 – Energy Cost Specification by Season and TOU Period – Climate Zone 6A....5-15
Table 31 – Energy Cost Specification by Season and TOU Period – Climate Zone 6B....5-16
Table 32 – Energy Cost Specification by Season and TOU Period – Climate Zone 7....5-17
Table 33 – Energy Cost Specification by Season and TOU Period – Climate Zone 8....5-18
Table 34 – EPA Source Energy Conversion Factors ($/kBtu)....20

Table 35 – Lighting Power Allowances for Retail Display Lighting 6-21
Table 36 – Light Heat Gain Parameters for Typical Operating Conditions...6-23
Table 37 – Power Adjustment Factors...6-23
Table 38 – Nominal Mean Power for Surveyed Devices 6-32
Table 39 – Credits for Energy Efficient Equipment...6-32
Table 40 – Multipliers for Energy Efficient Equipment (1 – Credit)..6-32
Table 41 – USDOE Requirements for Refrigerated Casework (kWh/d)...6-34
Table 42 – Default Power for Walk-In Refrigerators and Freezers (W/ft²)...6-35
Table 43 – Unit Energy Consumption Data for Elevators, Escalators and Moving Walkways 6-38
Table 44 – Baseline Building R-value and U-factor Criteria for Roofs..6-45
Table 45 – Baseline Building Roof Construction Assemblies...6-45
Table 46 – Baseline Building R-value and U-factor Criteria for Walls 6-48
Table 47 – Baseline Building Wall Construction Assemblies..6-48
Table 48 – Baseline Building R-value and U-factor Criteria for Exposed Floors 6-52
Table 49 – Baseline Building Exposed Floor Construction Assemblies 6-52
Table 50 – Baseline Building U-factor Criteria for Doors 6-54
Table 51 – Baseline Building Criteria for Vertical Glazing for 90.1 2001..6-57
Table 52 – Baseline Building Criteria for Vertical Glazing for 90.1 2007..6-57
Table 53 – Baseline Building Criteria for Skylights 6-59
Table 54 – Baseline Building C-factor Criteria for Below-Grade Walls...6-62
Table 55 – Baseline Building Below-Grade Wall Construction Assemblies 6-62
Table 56 – Baseline Building F-factor Criteria for Slab-on-Grade Floors 6-64
Table 57 – HVAC Zone Building Descriptors for Baseline Systems...6-66
Table 58 – Baseline Building HVAC Terminal Devices 6-68
Table 59 – Baseline Building Terminal Heat Type..6-68
Table 60 – HVAC Systems Building Descriptors for Baseline Systems 6-75
Table 61 – Baseline Building System Type 6-78
Table 62 – Baseline Building Fan System – ASHRAE Standard 90.1-2007 6-86
Table 63 – Baseline Building Fan System – ASHRAE Standard 90.1-2001 6-86
Table 64 – Building Descriptor Applicability for Fan Systems 6-86
Table 65 – Baseline Building Fan Control Method 6-89
Table 66 – Fan Curve Default Values...6-91
Table 67 – Baseline Economizer Control Type...6-99
Table 68 – Cooling Source for Baseline Building System 6-100
Table 69 –Cooling Capacity Curve Coefficients 6-102
Table 70 – Default Coil Bypass Factors...6-103
Table 71 – Coil Bypass Factor Airflow Adjustment Factor..6-104
Table 72 – Coil Bypass Factor Temperature Adjustment Factor..6-104
Table 73 – Coil Bypass Factor Part Load Adjustment Factor...6-104
Table 74 – Cooling System Coefficients for EIR-FPLR 6-106
Table 75 – Cooling System Coefficients for EIR-FT 6-107
Table 76 – Baseline Building Condenser Type...6-108
Table 77 – Part Load Curve Coefficients – Evaporative Cooler Effectiveness.....................................6-110
Table 78 – Heating Source for Baseline Building 6-112
Table 79 – Furnace Efficiency Curve Coefficients..6-114
Table 80 – Heat Pump Capacity Adjustment Curves (CAP-FT) 6-117
Table 81 – Heat Pump Heating Efficiency Adjustment Curves...6-118
Table 82 – Liquid Desiccant Unit Performance Curves 6-123
Table 83 – Primary Systems Building Descriptors for Baseline Systems...6-125
Table 84 – Default Minimum Unloading Ratios...6-130
Table 85 – Type and Number of Chillers 6-132
Table 86 – Default Minimum Unloading Ratios...6-133
Table 87 – Default Capacity Coefficients – Electric Air-Cooled Chillers...6-135
Table 88 – Default Capacity Coefficients – Electric Water-Cooled Chillers 6-135
Table 89 – Default Capacity Coefficients – Fuel- & Steam-Source Water-Cooled Chillers 6-135
Table 90 – Default Efficiency EIR-FT Coefficients – Air-Cooled Chillers 6-136

Table 91 – Default Efficiency EIR-FT Coefficients – Water-Cooled Chillers 6-136
Table 92 – Default Efficiency EIR-FPLR Coefficients – Air-Cooled Chillers..6-136
Table 93 – Default Efficiency EIR-FPLR Coefficients – Water-Cooled Chillers 6-136
Table 94 – Default FIR-FPLR coefficients – Fuel- & Steam-Source Water-Cooled Absorption Chillers.....6-138
Table 95 – Default FIR-FPLR coefficients – Engine Driven Chillers 6-138
Table 96 – Default FIR-FT coefficients – Fuel- & Steam-Source Water-Cooled Absorption Chillers....6-138
Table 97 – Default FIR-FT coefficients – Engine Driven Chillers 6-138
Table 98 – Default Capacity Coefficients – Cooling Towers..6-143
Table 99 – Default Efficiency TWR-FAN-FPLR Coefficients – VSD on Cooling Tower Fan 6-145
Table 100 – Default Part-Load CIRC-PUMP-FPLR Coefficients – VSD on Circulation Pump 6-152

Acknowledgments

Architectural Energy Corporation (AEC) prepared this manual under contract to the New Buildings Institute (NBI). Charles Eley served as the primary author and technical editor. Kimberly Goodrich wrote Chapter 4 and provided copy editing, formatting, and document production. John Arent, Kristen Salinas, Lisa Gartland, and Deborah Stanescu provided technical content in Chapter 6. AEC had four subcontractors. Energy and Environmental Economics (Snuller Price and his team) developed the default time-of-use energy tariffs and was primarily responsible for Chapter 5. Mangesh Basarkar of Florida Solar Energy Center (FSEC) developed the acceptance criteria for Standard 140-2007 and was primarily responsible for Chapter 3. Martyn Dodd of EnergySoft developed the advanced modeling recommendations and was primarily responsible for Chapter 7. Jon McHugh of McHugh Engineering contributed to Chapter 6 on lighting, daylighting, and refrigeration.

Mark Cherniack was the project manager for New Buildings Institute and managed the review process. Valuable input was received from Cliff Majersik and Sonal Kemkar of the Institute of Market Transformation; Martha Brook of the California Energy Commission; David Goldstein and Nick Zigelbaum of the Natural Resources Defense Council; Harry Misuriello of ACEEE; Jean Lupinacci of US EPA; Dan Macumber and Luigi Polese of the National Renewable Energy Laboratory; Krishnan Gowri, Ron Jarnigan, and Mike Rosenberg, of the Pacific Northwest National Laboratory; Tianzhen Hong and Philip Haves of Lawrence Berkeley National Laboratory; Kevin Madison of Madison Engineering; Fred Porter and Michael Holtz of AEC; Dan Nall of Flack+Kurtz; Joel Neymark of J. Neymark and Associates; Philip Fairey of FSEC; Jason Glazer of GARD Analytics; and several other members of the ASHRAE 90.1 Energy Cost Budget (ECB) Subcommittee.

New Buildings Institute, Architectural Energy Corporation, and other team members are grateful to John Wilson and the Energy Foundation, which provided funding to enable this work.

This publication benefited from considerable previous research which is documented in footnotes. However, the following documents were especially important resources:

- ASHRAE Standard 90.1-2001 and 90.1-2007, Energy Standards for Buildings Except Low-Rise Residential Buildings (especially the Performance Rating Method in Appendix G)
- California 2005 Nonresidential ACM manual, California Energy Commission
- ECB Compliance Supplement, Version 1.2, March 1996, Prepared by the 90.1 ECB Panel, but unpublished
- B. Griffith, et. al., Methodology for Modeling Building Energy Performance across the Commercial Sector, Technical Report NREL/TP-550-41956, March 2008

1 Overview

1.1 Purposes

The COMNET energy efficiency calculation process serves three distinct purposes:

- Establishing eligibility for federal tax deductions per §179D of the Internal Revenue Service (IRS) code;
- Calculating percent savings for point eligibility related to green building rating systems; and
- Estimating annual energy use for a building in the design phase for the purpose of energy labels.

COMNET approved software shall be capable of working for all three purposes, and this manual specifies the requirements and procedures for all three purposes. However, depending on the purpose, the process is somewhat different. Table 1 summarizes the major differences in calculation procedures for each purpose. These differences are described in more detail in the sections that follow.

Table 1 – Differences in Calculation Procedures by Purpose

	Tax Deductions	NB Green Building Ratings	Energy Labels
Baseline Standard	ASHRAE Standard 90.1-2001	ASHRAE Standard 90.1-2007	CBECS Median Energy Use
Operating Assumptions	Prescribed	Default	Default
Percent Savings Energy Use	Regulated Only	All Energy Use	Not applicable

1.1.1 Baseline Standards

Both tax deductions and green building rating systems are based on comparing the performance of the proposed design against a code-minimum baseline building; the baseline for federal tax deductions is ASHRAE Standard 90.1-2001 and the baseline for green building ratings is ASHRAE Standard 90.1-2007. The baseline for most energy labels is the median or average energy use for a similar building, in a similar climate, operated in a similar manner. The median is based on energy consumption as reported in the CBECS[1] database.

This manual is consistent with ASHRAE Standard 90.1-2007, but does not include addenda, approved or otherwise. ASHRAE Standard 90.1 is under continuous maintenance. This means that the committee regularly develops, approves and publishes addenda to the standard. At the time of this writing, a number of addenda to Standard 90.1 have been approved and an even greater number is pending. ASHRAE intends to gather these addenda and include them in the 2010 publication of the standard. The COMNET manual will be updated when the 2010 publication of Standard 90.1 is released.

The modeling rules and procedures in this manual are consistent with the Performance Rating Method (PRM) in Appendix G of ASHRAE Standard 90.1-2007, and with the prescriptive and mandatory requirements of ASHRAE Standard 90.1-2001 (for tax deductions) and ASHRAE Standard 90.1-2007 (for green building rating). When Standard 90.1 does not establish a baseline, the PRM often gives the rating authority the ability to establish a baseline. In some instances, this COMNET manual establishes a baseline where one does not exist in Standard 90.1, thereby assuming the responsibility of the rating authority. Examples include plug loads and commercial refrigeration. In other instances, the baseline building specification in the PRM was not specific enough and this manual expands on the definition to

---

[1] CBECS is Commercial Building Energy Utilization Survey, which is conducted by the federal Energy Information Agency (EIA) approximately every four years.

eliminate ambiguity.[2] The purpose of these elaborations and expansions is to reduce ambiguity and offer credits for energy efficiency measures not addressed by Standard 90.1. It is not the intent of this manual to change the baseline building defined by the PRM or the underlying standards. The COMNET manual is intended to work in series with, not in parallel with the PRM.

1.1.2 Modeling Assumptions

When calculating annual energy use, it is necessary to make assumptions about how the proposed building is operated. Operating assumptions include thermostat settings, number of occupants, receptacle loads, process loads, hot water loads as well as schedules of operation for HVAC systems, lighting systems and other systems. Sometimes these data are known with some certainty and other times (for instance for speculative buildings), it is necessary to make estimates. These inputs are *prescribed* (they are fixed for both the proposed design and for the baseline building and can't be changed) for tax deductions and they are *defaults* (use them unless better information is available) for green building ratings and energy labels.

1.1.3 Percent Savings

There are also differences in how percent savings are calculated, depending on the purpose. ASHRAE Standard 90.1-2001 and 2007 set a baseline for the energy used for heating, cooling, ventilation, interior lighting and hot water[3]. Since they are regulated by the baseline standard, these components of energy use are referred to in this manual as the *regulated energy*. There is a multitude of other equipment and systems in a building that use energy, including:

- All the things that are plugged into convenience outlets such as personal computers, printers, coffee machines, refrigerators and desk lamps;
- Commercial refrigeration equipment such as open or closed refrigerated casework, walk-in refrigerators, walk-in freezers, and other equipment common to restaurants, food stores, and convenience stores;
- Transportation systems such as elevators, escalators, and moving walkways;
- Special ventilation systems to remove carbon monoxide from parking garages or fumes from restaurants or laboratories;
- Grills, ovens, fryers, steam trays, and other cooking equipment in restaurants and cafeterias;
- Compressed air systems in manufacturing and warehouse facilities; and
- Other specialized equipment in laboratories, hospitals, and manufacturing plants.

These components of energy use are referred to in this manual as the *non-regulated energy*, because a baseline is not established by ASHRAE Standard 90.1-2001 or 2007. *Total energy* is the sum of the *regulated energy* and the *non-regulated energy*. When percent savings are calculated for tax deduction purposes, only the *regulated energy* is considered. When percent savings are calculated for green building rating systems, the *total energy* is considered. In both cases, energy cost is the metric for comparison, per the PRM.

---

[2] An example is the supply air temperature reset requirement for baseline building systems 5 through 8.

[3] Exterior lighting is also regulated by the Standard, but is typically not included in the performance calculations performed for code compliance purposes.

(1)

$$Percent\ Savings_{Tax\ Deductions} = \frac{Regulated\ Energy\ Cost_{Baseline} - Regulated\ Energy\ Cost_{Candidate\ Buidling}}{Regulated\ Energy\ Cost_{Baseline}}$$

(2)

$$Percent\ Savings_{Green\ Building\ Rating} = \frac{Total\ Energy\ Cost_{Baseline} - Total\ Energy\ Cost_{Candidate\ Buidling}}{Total\ Energy\ Cost_{Baseline}}$$

This difference in how percent savings is calculated can be quite significant for some building types such as supermarkets, restaurants or laboratories, especially when the *non-regulated energy* is held the same between the baseline and candidate, as is commonly the case.

1.2 Scope

This manual is intended to be used for buildings that are in the planning, design or construction phases. It is also intended to apply to buildings that are within the scope of ASHRAE Standard 90.1-2001 and ASHRAE Standard 90.1-2007.

The long-term goal of this manual is to define modeling rules and procedures for all conceivable design features that may be incorporated in buildings. The authors recognize, however, that this goal cannot be fully achieved due to limitations in the development energy simulation algorithms, and due to the natural lag time between the introduction of an advanced energy efficiency measure or device and the development of algorithms to simulate its performance.

The goal of the manual is to provide methods that are as flexible and accurate as possible. This goal can best be achieved if the manual is a 'living document,' changing and growing as increasing amounts of information and better modeling methods become available.

1.3 Audience

This document has been written with several different audiences in mind. These audiences are:

1.3.1 Software Developers

The majority of this document's content consists of rules which are intended to be implemented by software developers. These requirements include rules for automatically creating the baseline building and for producing standard reports with correct percent savings and energy use estimates.

1.3.2 Rating Authorities

The term 'rating authority' is used in this manual to represent the organization that is issuing a green building rating or energy label. The term is also extended to include government organizations that would review and approve claims for tax deductions.

1.3.3 Energy Analysts

When permitted by the rating authority, an energy analyst can manually apply the COMNET modeling rules and procedures to create the baseline buildings and the proposed design and to summarize information into a report for submission to the rating authority.

1.4 Organization

This document is organized in seven chapters and six appendices, as described below:

Chapter Des	cription
1. Overview	The purpose, organization, content, and intent of the manual (this chapter).
2. General Modeling Procedures	An overview of the COMNET modeling process, outlining the modeling rules and assumptions that are implemented in the same way for both the standard design and the proposed design, and procedures for determining system types and equipments sizes.
3. Software Requirements	Requirements for the simulation engines and software shells that are used to make calculations.
4. Content and Format of Standard Reports	The content and organization of the standard reports that need to be produced by qualifying software.
5. Energy Costs and Currency	Data on how energy savings are valued and compared.
6. Building Descriptors Reference	The acceptable range of inputs for the proposed design and a specification for the baseline building .
7. Modeling Tips for Advanced Design Features	Modeling rules and procedures for advanced design features.
Appendix A – Building Descriptors Table	Tabular summary and classification of building descriptors.
Appendix B – Modeling Data	Modeling data and assumptions by building type and space use.
Appendix C – Schedules	Default and prescribed schedules of operation.
Appendix D – Construction Materials	Default construction materials library.
Appendix E – Software Tests	Spreadsheets and specifications for software tests.
Appendix F – Energy Costs	Documentation of the methodology used to develop the Chapter 5 energy costs.

2 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 calculations. Users must provide valid data for all descriptors that are designated as *compulsory* or *required* in Appendix A and that apply to parts of the building that must be modeled.

2.1.2 Requirement for Complete Building Description

Complete descriptions of the building envelope, mechanical, service water heating, and electrical systems for the project are required.

2.1.3 Building Envelope Descriptions

The user shall provide accurate descriptions for all building envelope assemblies including exterior walls, windows, doors, roofs, underground walls and floors. The user shall provide data for all of the required descriptors listed in Appendix A that correspond with these assemblies. However, the following exceptions apply:

- Any envelope assembly that covers less than 1% of the total area of that assembly type (e.g., exterior walls) need not be separately described. If not separately described, the area of an envelope assembly must be added to the area of the next most similar assembly of that type.
- 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 Space Use Classification

The user must 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 determine the default or prescribed occupant density, receptacle power, service water heating, minimum outdoor ventilation air, operating schedule, and lighting assumptions used in the rating analysis.

The user must specify the space use classifications using either the *building area* or *space-by-space* categories but may not combine the two types of categories within a single analysis. The building area method assigns assumptions based on average values that occur within typical buildings of the designated type. The building area method is recommended for use 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 space-by-space categories in the baseline standard, which were developed for lighting requirements. The space-by-space method requires space-by-space 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.

2.1.5 Treatment of Descriptors Not Fully Addressed By This Document

The goal for 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 large number of features that must be covered and the continuous evolution of building materials and technologies. Where descriptors need to be used that are not addressed completely (or are not addressed at all) in this manual, users are expected to employ these inputs using their judgment consistent with accepted design and construction practice. Any uncertainty regarding appropriate modeling assumptions must be resolved so that the impact is conservatively assessed; for example, so as to make it less likely rather than more likely that percent savings will be higher.

2.2 Thermal Blocks, HVAC Zones and Space Functions

2.2.1 Definitions

A *thermal block* is a space or collection of spaces within a building having sufficiently similar space conditioning requirements so that those conditions could be maintained with a single thermal controlling device. A thermal block is a thermal and not a geometric concept: spaces need not be contiguous to be combined within a single thermal block.

An *HVAC zone* is a physical space within the building that has its own thermostat and zonal system for maintaining thermal comfort. HVAC zones are identified on the HVAC plans. HVAC zones should not be split between thermal blocks, but a thermal block may include more than one HVAC zone.

A *space function* is a sub-component of a thermal zone that has specific baseline lighting requirements and for which there are associated defaults for outside air ventilation, occupancy, receptacle loads, and hot water consumption. An *HVAC zone* may contain more than one *space function*. Appendix B has a list of the space functions that may be used with the COMNET rating method.

Figure 1 shows the hierarchy of *space functions, HVAC zones* and *thermal blocks*.

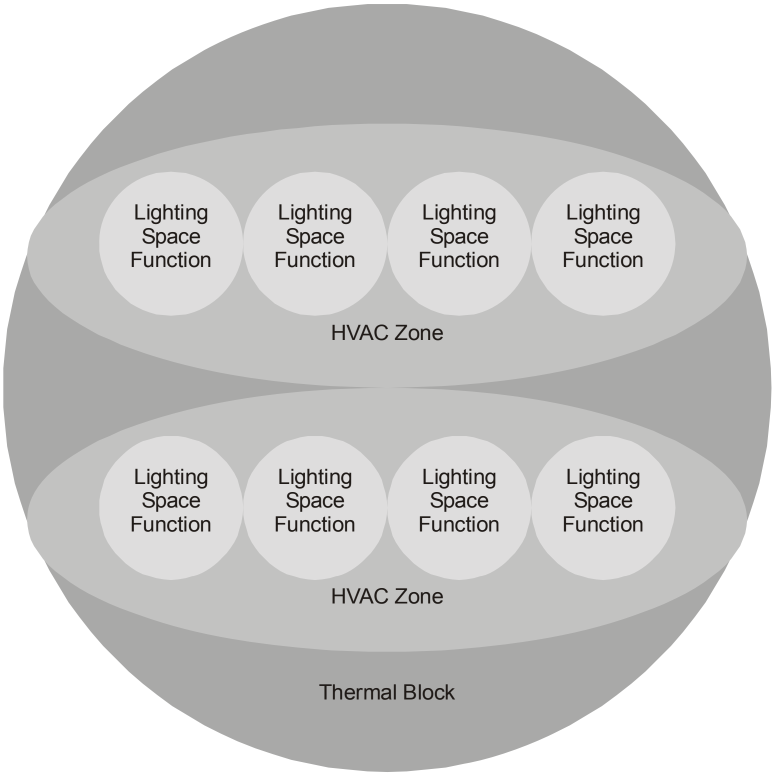


Figure 1 – Hierarchy of Space Functions, HVAC Zones and Thermal Blocks

2.2.2 General Guidance

Thermal blocks and the HVAC zones and space functions that they contain are user inputs; they are not automatically generated by the COMNET software. This section provides some general rules and guidance on how to effectively define the thermal blocks. Albert Einstein once said “everything should be made as simple as possible, but no simpler” and that is the challenge when creating thermal blocks[4]. The energy simulation model should include as few thermal blocks as possible, but as many as are needed. Breaking a building into thermal blocks is a step of the energy modeling process that requires considerable judgment.

Because of differences in the capabilities and limitations of various simulation tools and the extreme variety in size and complexity of buildings to which the *rating method* may be applied, a rigid set of rules for defining thermal blocks is not possible. Some exercise of user judgment will be required in most cases to determine the most appropriate way to subdivide and model a building.

Defining appropriate thermal blocks will save time for the user and will help to ensure accurate results. However, regardless of how the user chooses to subdivide the building, identical subdivisions will be used in modeling the proposed design and baseline building. It is difficult to predict what impact a faulty decision would have on percent savings, but there is little doubt that the impact on proposed design energy use could be significant.

---

[4] "On the Method of Theoretical Physics" The Herbert Spencer Lecture, delivered at Oxford (10 June 1933); also published in *Philosophy of Science*, Vol. 1, No. 2 (April 1934), pp. 163-169.

2.2.3 Number of Thermal Blocks

In general, the smaller the number of thermal blocks that are defined, the lower the user's effort will be to create the building description. However, if too few thermal blocks are defined, simulation results are likely to be less accurate. In order to simplify ratings, users should define as few thermal blocks as possible, consistent with the other guidance in this section. Normally, the number of thermal blocks in a building should not exceed the number of HVAC zones in the building.

2.2.4 Space Use Classification Considerations

Thermal blocks may contain up to ten different space use classifications, provided the spaces have similar space conditioning requirements. If the building area method is used, each thermal block must be assigned to one and only one building area category. For space classifications that are combined in a single thermal block, the spaces must meet all of the following conditions:

- Use the same operating schedule.
- Use the same space temperature schedule.
- Have similar internal load power densities. Combined lighting, receptacle, and process equipment power densities that differ by no more than 2.0 W/ft² or a factor of two may be considered similar.
- Have similar occupant densities. Occupant densities (i.e., densities represented in floor area per occupant [under peak design conditions]) that differ by no more than a factor of three may be considered similar.

2.2.5 Envelope Load Considerations

Thermal blocks shall consist of spaces having similar envelope loads; for example, thermal loads from solar heat gains and conductive heat losses from roofs. In general, spaces close to the perimeter of the building should be in separate thermal blocks from interior spaces. The following guidance shall be applied in combining HVAC zones into thermal blocks:

- Exterior and interior spaces shall not be combined in the same thermal block, except as permitted below.

  Exception: Exterior spaces without fenestration or doors may be combined with interior spaces in the same thermal block.
- Exterior spaces having different glazed orientations shall not be combined in the same thermal block, except as permitted below.

  Exception: Exterior spaces having different glazed orientations but small effective apertures for solar heat gain (i.e., solar heat gain coefficient times fenestration area divided by zone floor area less than 10%) may be combined in a single thermal block.

  Exception: Exterior spaces having different glazed orientations but whose orientations differ by 45° or less may be combined in a single thermal block. This is not intended to prevent or discourage modeling of actual or anticipated corner zones or other actual HVAC zones which include fenestration of varying orientations in a single contiguous space.
- Spaces with envelope loads from floors and/or roofs shall only be combined within a single thermal block with spaces having similar loads from floors and/or roofs.
- Separate thermal blocks shall be created when fenestration area varies greatly. For example, a long perimeter corridor with small windows at one end, but all glass at the other should be split into two thermal blocks.

2.2.6 Conformance with HVAC Zones

Thermal blocks shall conform with the actual HVAC zoning as documented on the construction documents or the as-built drawings. "Conform with" as used here means that thermal blocks shall accurately reflect the actual floor areas of the HVAC zones (i.e., to within 5% of actual square footage), and thermal blocks and HVAC zones should share the same bounding surfaces.

2.2.7 Combining HVAC Zones

Under specific conditions, different HVAC zones may be combined into a single thermal block to reduce user input and to simplify the computer description of the building. Zone multipliers may also be used to achieve similar simplification, when this is a feature of the software. Provided all of the following conditions are met, different HVAC zones may be combined to create a single thermal block (or identical thermal blocks to which multipliers are applied):

- No more than ten different space classifications are included in any one thermal block.
- All the space classifications have similar space conditioning requirements.
- All of the zones are served by the same HVAC system or by the same kind of HVAC system. Perimeter baseboards, unit heaters or fan powered boxes (vs. straight boxes) should not be considered the “same kind” of HVAC system as zones without these features.
- All zones have similar minimum airflows (cfm/ft²) and if any have separate exhaust, this is met generally by transfer air from the HVAC zones in the thermal block.

2.2.8 Thermal Blocks in Multifamily Residential Buildings

Multifamily residential buildings, including hotel and motel occupancies, should be modeled using one thermal block per unit. Where units are thermally similar, dwelling units or hotel rooms may be combined. Corner units and units with roof or floor loads shall only be combined with units sharing these features.

2.2.9 Plenums

Plenums are spaces above the ceiling and below the floor above where lighting fixtures, pipes, ducts and other building services are often located. Plenums may or may not be used as return air plenums. Because of the leakage through the ceiling (typically suspended), the temperature of the plenum tracks the temperature of the space, except that it is generally warmer because of heat stratification and heat produced by lighting fixtures located at the ceiling or in the plenum.

It is generally recommended that plenums be modeled as separate thermal blocks, but at the modeler’s discretion, they may be combined with conditioned space below for modeling simplicity. If plenums are modeled in the proposed design, they should also be modeled in the baseline building. See the building descriptor “Return Air Path” in Chapter 6 for input restrictions and rules for defining the baseline building.

2.3 Unmet Load Hours

The Performance Rating Method and this manual use the term “unmet load hours” as a criterion for sizing equipment, for qualifying natural ventilation systems, and for other purposes. The concept of unmet load hours applies to individual thermal blocks but is summed for the building as a whole. For a thermal block, it represents the number of hours during a year when the HVAC system serving the thermal block is unable to maintain the set point temperatures for heating and/or cooling. During periods of unmet loads, the space temperature drifts above the cooling setpoint or below the heating setpoint. An unmet load hour occurs only during periods when the HVAC system is scheduled to operate. One hour with un-met loads in one or more thermal block counts as a single un-met load hour for the building. If unmet load hours for more than one thermal block coincide (occur at the same hour), they count as only one unmet load hour for the building. Un-met load hours include periods when the space is either under cooled or under heated.

Unmet load hours can occur because fans, air flows, coils, furnaces, air conditioners or other equipment is undersized. Unmet load hours can also occur due to user errors including mismatches between the thermostat setpoint schedules and HVAC operating schedules or from other input errors, for instance, high internal gains or occupant loads. The term, as used in this manual, only addresses equipment undersizing. It is the responsibility of the user to address other causes of unmet load hours in the proposed design. There can be many reasons, but the following checklist is offered as a starting point:

- Make sure that thermostat schedules 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 ability of the HVAC system to meet loads in the thermal block.
- Check to make sure that inputs for internal gains, occupants, outside air ventilation are reasonable and are consistent with the intended operation of the building.
- Examine the simulated operation of controls to determine if primary or secondary heating or cooling equipment (pumps, coils, boilers, etc.) is activated. Verify that the controls are not resetting in a way that reduces modeled capacity.

2.4 Calculation Procedures

The process for tax deductions and green building ratings is illustrated in Figure 2. For both of these purposes, the *proposed design* is compared to a *baseline building* and the percent savings are calculated for the *proposed design* relative to the *baseline building*.

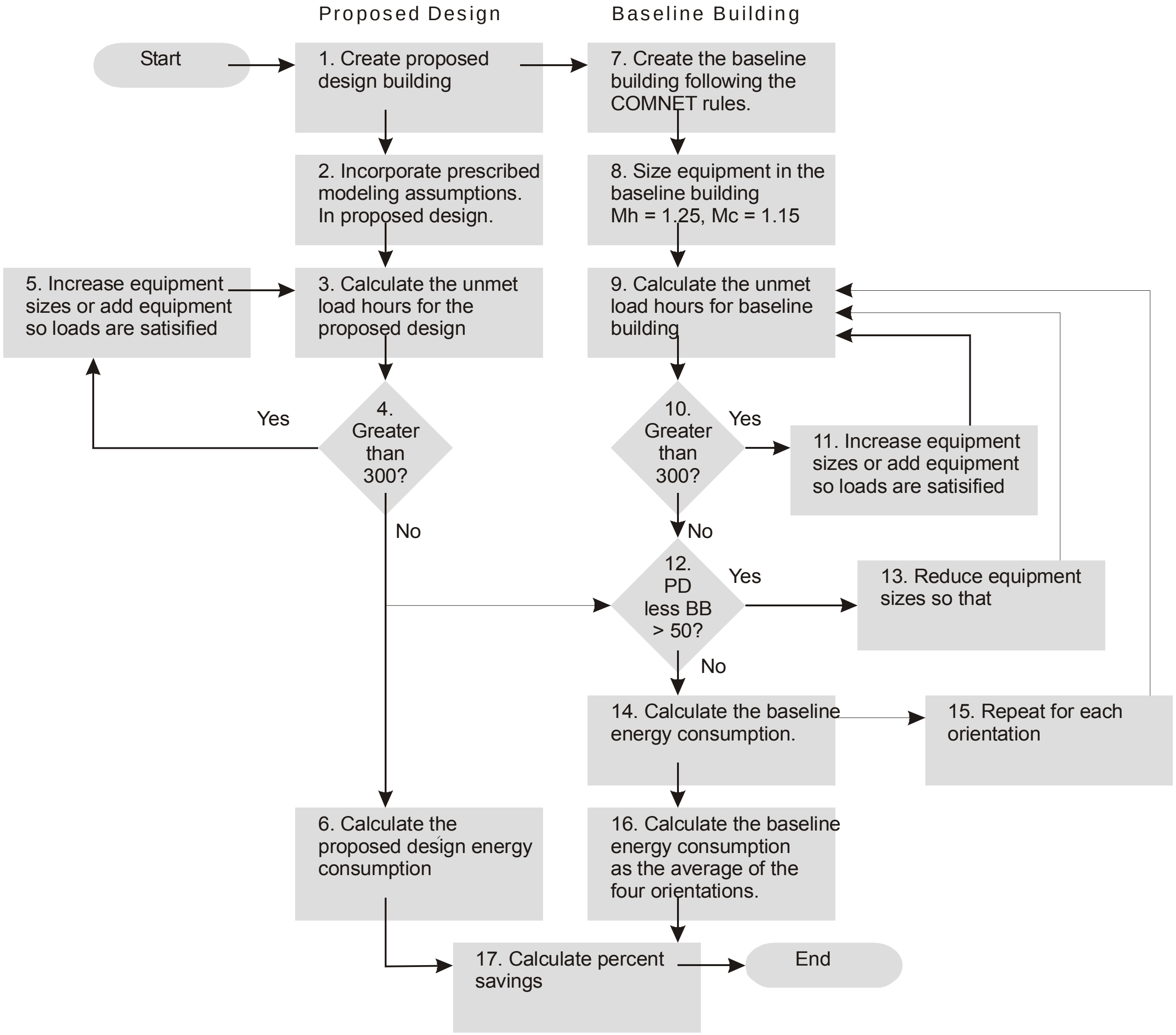


Figure 2 – Calculation Process for Tax Deductions and Green Building Ratings

1. The process begins with a detailed description of the proposed design. Information is 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*. A detailed presentation of the building descriptors are provided in Chapter 6.
2. Before the calculations are performed, some of the building descriptors are modified for the proposed design to incorporate *prescribed* modeling assumptions. Prescribed modeling assumptions are different depending on purpose. For tax deductions, they include schedules of operation and plug loads. For green building ratings, there are few prescribed modeling assumptions.
3. The next step is to make a simulation of the *proposed design* to determine how well the heating and cooling loads are being satisfied. The indicator is *unmet load hours*, the number of hours during the year when the space temperature is below the heating set point temperature or greater than the cooling set point temperature. A large number of hours indicate that the equipment is undersized.

4. Test the number of unmet load hours and proceed only if the hours are less than 300 for the year of the simulation.
5. If the unmet load hours for the thermal block being evaluated are greater than 300 for the year, then the baseline building simulation model is adjusted to reduce the unmet load hours to less than 300. If the problem is heating, then the size of the boiler or furnace may need to be increased. If the problem is cooling, then the size of the coils or chillers may need to be increased. See Figure 3.
6. If the unmet load hours are less than 300, then the final simulation is performed. If no changes are made in the model, this may be the same simulation in step 3. These calculations produce the results that are compared to the baseline building, which is calculated in steps 7 through 16.
7. Create the baseline building following the rules in this manual. The baseline building 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 the *baseline standard*. 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, the number of stories and the fuel used for heating. See Figure 18.
8. Sizing calculations are performed for the baseline building and heating equipment is oversized by 25% and cooling equipment by 15%.
9. The baseline building is simulated to determine the number of unmet load hours. This process is the same as performed for the proposed design in step 3.
10. The number of unmet load hours is then tested to see if they are greater than 300. This is not likely to occur since the heating and cooling equipment is oversized by 15% for cooling and 25% for heating in step 8.
11. If the unmet load hours are greater than 300, then equipment in the baseline building is increased so that the unmet hours are less than 300. See Figure 3.
12. Once both the baseline building and the proposed design have unmet load hours less than 300, they are compared to confirm that the unmet load hours for the proposed design are not greater than 50 more than the baseline building.
13. If the difference in unmet hours is greater than 50, then the equipment in the baseline building is reduced in size so that the difference is less than or equal to 50. See Figure 3.
14. Once the tests on unmet load hours are satisfied, then 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.
15. The baseline building is rotated 90 degrees and modeled again. This is repeated for four orientations. Each time the building is rotated the equipment is resized. The energy use of the proposed design is compared to the average of the baseline building for each of four orientations so that credit is offered for good orientation in the proposed design and a penalty is assessed for poor orientation.
16. The baseline energy use for the baseline building is calculated as the average of the energy use for the four orientations.
17. Finally, the percent savings are calculated. For tax deductions, only regulated energy is considered, but for green building ratings, total energy is considered.

The COMNET calculation process described above is consistent with the ASHRAE Standard 90.1-2007 Performance Rating Method (PRM) as contained in Appendix G of the Standard.

2.5 HVAC Capacity Requirements and Sizing

To ensure that the simulated space-conditioning loads are adequately met, adequate capacity must be available in each of the components of the HVAC system; e.g., supply-air flow rates, cooling coils, chillers, and cooling towers. If any component of the system is incapable of adequate performance, the simulation may understate the required energy inputs for space conditioning and report unmet load hours. Adequate capacities are required in the simulations of both the proposed design and baseline building. The subsections below describe the procedures that shall be followed to ensure that both versions of the design are simulated with adequate space-conditioning capacities.

2.5.1 Specifying HVAC Capacities for the Proposed Design

As shown in Figure 2, the proposed design shall have no more than 300 unmet load hours in any thermal block. If this requirement is violated, the software shall require the user to make changes to the proposed design building description to bring the unmet load hours below 300. This process is not automated by the software. There are two tests that must be met:

- Space loads must be satisfied: Space temperatures must be maintained within one half of the throttling range (e.g., 1°F with a 2°F throttling range) of the scheduled heating or cooling thermostat setpoints. This criterion may be exceeded for no more than 300 hours for a typical year for any thermal block.
- 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.

If either the space or system loads do not meet the above criteria, the equipment in the proposed design shall be resized by the user and appropriate changes shall be made to the construction documents such that the criteria are met. If the space conditioning criteria are not met because the HVAC equipment in the proposed design lacks the capability to provide either heating or cooling, equipment capable of providing the needed space conditioning must be modified by the user. The type of equipment added will depend on the type of HVAC system in the proposed design and the judgment of the energy analyst.

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 block(s), the user shall be prompted to make changes to equipment sizes and to make corresponding changes to the construction documents. This occurs when the unmet load hours in any thermal block exceed 300 for the year.

2.5.2 Sizing Equipment in the Baseline Building

Equipment in the baseline building is automatically oversized by the program (25% for heating and 15% for cooling). However, in cases when unmet load hours in the proposed design are greater than 50 hours compared to the baseline building, equipment in the baseline building may have to be downsized. The criterion is that the unmet load hours in the proposed design may be no greater than 50 hours more than the corresponding thermal block in the baseline building. Figure 3 shows the recommended procedure for downsizing equipment in the baseline building so that the 50 hour delta requirement is satisfied. Note that this procedure may result in the baseline building equipment not meeting the 25% oversizing requirement for heating and the 15% oversizing requirement for cooling. It is also possible that the downsizing will result in a reduction in the 20 F delta-T specified in § G3.1.2.8 of the PRM.

Un-met load hours are evaluated at the building level by looking at the un-met load hours for each of the thermal blocks being modeled. One hour with un-met loads in one or more thermal block counts as a single un-met load hour for the building. Therefore, the un-met load hours for the building will never be less than the worst thermal block.

Figure 3 shows the process of adjusting equipment sizes in the baseline building in order to meet the 50 hour delta requirement. Equipment in the baseline building is already oversized, so the process is to incrementally make adjustments to the thermal block with the most unmet load hours until the un-met load hours for the baseline building are within 50 of the proposed design. The process is explained in greater detail in the paragraphs that follow Figure 3.

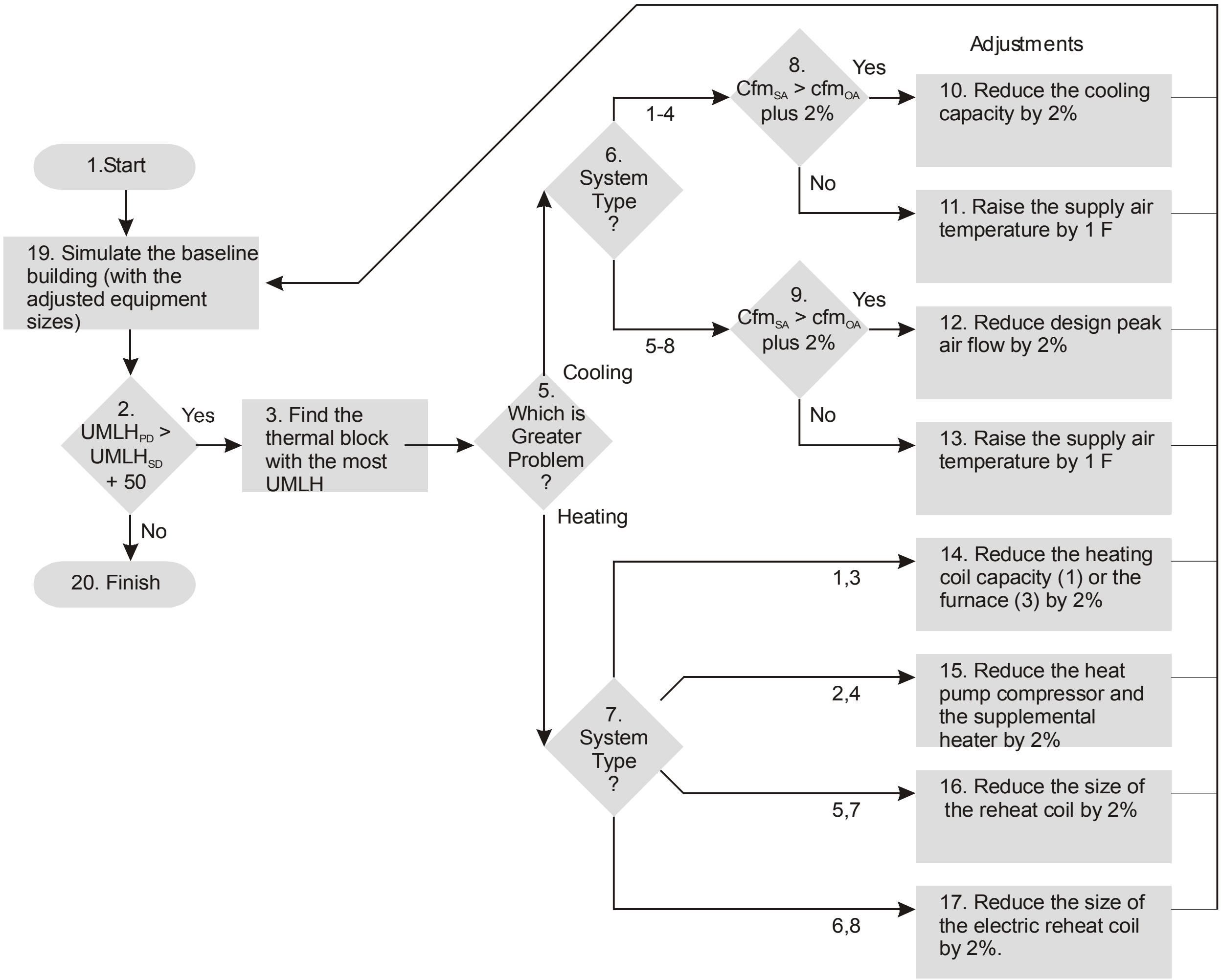


Figure 3 – Procedure for Adjusting Equipment HVAC Sizes in the Baseline Building

1. The process begins with simulation results for both the proposed design and the baseline building.
2. Simulate the baseline building and calculate the un-met load hours for the building (see definition above).
3. Compare the unmet load hours between the proposed design and the baseline building. If the proposed design is no more than 50 hours greater than the baseline building, then move no adjustments are necessary and the process is complete (step 18), otherwise move to 4.
4. When the difference between the proposed design and the baseline building is greater than 50 un-met load hours, then determine the thermal block with the greatest total un-met load hours for heating and/or cooling. Adjustments will be made to this thermal block.
5. Test to see which is greater: the difference in heating unmet load hours or cooling unmet load hours.

6. If the difference for the thermal block is mostly cooling, then look at the system type serving the thermal block. If the system is type 1 through 4 (single zone systems) then go to 8, otherwise go to 9.
    8. For system types 1 through 4, test to see if it is possible to reduce air flow to the thermal block and still maintain the minimum outside air ventilation level. If so, go to 10; otherwise, go to 11.
        10. Reduce the cooling capacity of the packaged equipment by 2% and let the air flow to the zone scale in order to meet a 20°F delta-T difference between the setpoint temperature in the space and the supply air. Maintain the same ratio of sensible to total cooling capacity.
        11. Raise the supply air temperature to the thermal block by 1°F. This reduces the 20°F delta-T, but is necessary to maintain air flow to the space at a volume adequate to meet the outside air ventilation requirement.
    9. For system types 5 through 8, test to see if it is possible to reduce air flow to the thermal block and still maintain the minimum outside air ventilation level. If so, go to 12; otherwise, go to 13.
        12. Reduce the design air flow rate to the thermal block by 2%. Allow the upstream coil and cooling equipment to be auto-sized so that their capacity is also reduced.
        13. Raise the supply air temperature to the thermal block by 1°F. This reduces the 20°F delta-T, but is necessary to maintain air flow to the space at a volume adequate to meet the outside air ventilation requirement.
7. If the difference for the thermal block is mostly heating, then look at the system type serving the thermal block. If the system type is 1 or 3, go to 14; if the system type is 2 or 4, go to 15; if the system type is 5 or 6, go to 16; or if the system type is 6 or 8, go to 17.
    14. For system types 1 or 3, reduce the heating coil capacity or the size of the furnace by 2%
    15. For system types 2 or 4, reduce the size of the heat pump compressor and the supplemental heater by 2%. Note that for modeling purposes the size of the heat pump compressor is changed without changing the size of the cooling capacity.
    16. For system types 5 or 6, reduce the size of the reheat coil by 2%. Autosize the boiler accordingly.
    17. For system types 6 or 8 reduce the size of the electric reheat coil by 2%.
3. Move back to step 2.
20. Finish.

2.6 Ventilation Requirements

Assumptions regarding outside air ventilation shall be based on applicable building codes or ASHRAE Standard 62.1-2007 if local codes do not apply. If information on ventilation rates is unavailable, recommended values from Appendix B shall be used. The same assumptions on outside air ventilation are used in the baseline building and the proposed design; therefore, no credit can be realized by reducing ventilation rates in the proposed design.

3 Software Requirements

This chapter contains the software requirements that must be implemented by approved COMNET software. The tests fall into the following categories:

- Tests to verify that the software is evaluating thermal loads and the response of the HVAC systems to these loads in a manner that is acceptable. These tests reference *ASHRAE Standard 140-2007, Standard Method of Test for Evaluation of Building Energy Analysis Computer Programs*.
- Tests to verify that the candidate building or the proposed design is modeled with the correct fixed and restricted inputs, including schedules of operation, receptacle loads, process loads and other components.
- Tests to verify that the baseline building is created correctly, e.g. that the baseline HVAC system is properly specified and that other components of the baseline are correctly defined.

3.1 General Requirements

3.1.1 Scope

The *Rating Software* must satisfy the requirements contained in this section.

The *Rating Software* shall be capable of modeling at least 50 *thermal blocks*.

The *Rating Software* shall be capable of modeling at least 15 separate HVAC systems.

3.1.2 Calculation Methods

The *Rating Software* shall calculate the annual consumption of all end uses in buildings, including fuel and electricity for:

- HVAC (heating, cooling, fans, and ventilation);
- Lighting (both interior and exterior);
- Receptacles and miscellaneous electric;
- Service water heating;
- Process energy uses;
- Commercial refrigeration systems; and
- All other energy end uses that typically pass through the building meter.

The *Rating Software* shall perform a simulation on an hourly time interval (at a minimum) over a one year period (8760 hours) with the ability to model changes in weather parameters, schedules, and other parameters for each hour of the year. This is typically achieved by specifying a 24-hour schedule for each day of the week plus holidays.

Calculating Design Loads

The software shall be capable of performing design load calculations for determining required HVAC equipment capacities and air and water flow rates using accepted industry calculation methods for both the proposed design and baseline building design.

Checking Simulation Output for Unmet Loads

The software shall be capable of checking the output of the energy analysis module for the proposed design to ensure that space conditions are maintained within the tolerances specified (maximum of 300 unmet load hours per year).

Adjusting Capacities

For the baseline building, the software shall be capable of modifying capacities, temperatures or flow rates for baseline building HVAC system components resulting in excessive unmet loads hours meeting the criteria, following the procedures in Chapter 2.

Error Handling

The software shall identify error conditions when unmet loads exceed 300 hours, prevent completion of the rating analysis, and provide information to the user describing the error that has occurred and what steps the user should take to remedy the situation.

3.1.3 Climate Data

The *Rating Software* shall perform simulations using hourly values of climate data, such as temperature and humidity, derived from WYEC (Weather Year for Energy Calculation), TMY (Typical Meteorological Year) or CWEC (Canadian Weather for Energy Calculations) climate data.

The *Rating Software* shall calculate solar radiation on exterior surfaces on an hourly basis from the values of direct normal irradiance and diffuse horizontal irradiance contained in the climate data, taking ground reflectance into account.

3.1.4 Utility Rates

The *Rating Software* shall be capable of simulating time-of-use rates and apply both demand and energy charges for each time period of the rate schedule.

3.1.5 Thermal Mass

The calculation procedures used in the *Rating Software* shall account for the effect of thermal mass on: loads due to occupants, lights, solar radiation, and transmission through building envelope; amount of heating and cooling required to maintain the specified space temperature schedules; and variation in space temperature.

3.1.6 Modeling Space Temperature

The *Rating Software* shall contain a dynamic simulation of space temperature which accounts for:

- Dynamics in change in heating and cooling setpoint temperatures;
- Deadband between heating and cooling thermostat settings;
- Temperature drift in transition to setback or setup thermostat schedules;
- Temperature drift in periods when heating or cooling capability are scheduled off;

- Temperature drift when heating or cooling capability of the system is limited by heating or cooling capacity, air flow rate, or scheduled supply air temperature; and
- Indirectly conditioned *thermal blocks*, where the temperature is determined by internal loads, heat transfer through building envelope, and heat transfer between *thermal blocks*.

3.1.7 Heat Transfer between Thermal Blocks

The *Rating Software* shall be capable of modeling heat transfer between a *thermal block* and adjacent *thermal blocks*.

The *Rating Software* shall account for the effect of this heat transfer on the space temperature, space conditioning loads, and resulting energy use in the *thermal block* and in the adjacent *thermal blocks*.

3.1.8 Control and Operating Schedules

The *Rating Software* shall be capable of modeling control and operating schedules which can vary by:

- The hour of the day;
- The day of the week; and
- Holidays treated as a special day of the week.

The *Rating Software* shall be capable of explicitly modeling all of the schedules specified in Appendix C of this manual.

3.1.9 Loads Calculation

The loads calculations described in this section relate to the simulation engine and not to the procedure used the design engineer to size and select equipment.

Internal Loads

The *Rating Software* shall be capable of calculating the hourly cooling loads due to occupants, lights, receptacles, and process loads.

The calculation of internal loads shall account for the dynamic effects of thermal mass.

The *Rating Software* shall be capable of simulating schedules for internal loads in the form given in Appendix C.

The simulation of cooling load due to lights shall account for:

- The effect of the proportion radiant and convective heat, which depends on the type of light, on the dynamic response characteristic; and
- A portion of heat from lights going directly to return air, the amount depending on the type and location of fixture.

Building Envelope Loads

The *Rating Software* shall calculate heat transfer through walls, roofs and floors for each *thermal block*, accounting for the dynamic response due to thermal characteristics of the particular construction as defined in the *Building Descriptors* in Chapter 6.

The calculation of heat transfer through walls and roofs shall account for the effect of solar radiation absorbed on the exterior surface, which depends on orientation and absorptance of the surface.

The *Rating Software* shall calculate heat transfer through windows and skylights, accounting for both temperature difference and transmission of solar radiation through the glazing.

Calculation of cooling load due to transmission of solar radiation through windows and skylights shall account for:

- The angular incidence of the direct beam sunlight and the angular and spectral dependence of the solar properties.
- The variation of thermal properties of the fenestration system with ambient temperature.
- Orientation (azimuth and tilt of surface).
- The effect of shading from overhangs side fins, louvers or neighboring buildings or terrain.

Infiltration

The *Rating Software* shall be capable of simulating infiltration that varies by the time of day and day of the week.

Natural Ventilation

The *Rating Software* shall be capable of simulating natural ventilation.

3.1.10 Systems Simulation

General

The *Rating Software* shall be capable of modeling:

- The baseline building systems defined in Chapter 6,
- The lighting, water heating, HVAC and miscellaneous equipment detailed in Chapter 6
- All compulsory and required features as listed in Appendix A and detailed in Chapter 6

The capability to model multiple zone systems shall allow at least 15 *thermal blocks* to be served by one multiple zone system.

The *Rating Software* shall be capable of modeling plenum air return.

Terminal Characteristics

The *Rating Software* shall be capable of simulating the effect on space temperature and energy use of:

- Limited capacity of terminal heating devices;
- Limited capacity of terminal cooling devices; and
- Limited rate of air flow to *thermal blocks*.

HVAC Systems and Equipment

The *Rating Software* shall be capable of simulating the effect on energy use and space temperature in *thermal blocks* served by the HVAC system of:

- Limited heating capacity of an HVAC system; and
- Limited cooling capacity of an HVAC system.

The simulation of HVAC systems shall account for:

- Temperature rise of supply air due to heat from supply fan, depending on the location of the fan;
- Temperature rise of return air due to heat from return fan;
- Temperature rise of return air due to heat from lights to return air stream; and
- Fan power as a function of supply air flow in variable air volume systems.

Central Plant Systems and Equipment

The *Rating Software* shall be capable of simulating the effect on energy use of limited heating or cooling capacity of the central plant system.

If the *Rating Software* is not capable of simulating the effect of limited heating or cooling capacity of the central plant system on space temperature in *thermal blocks* dependent on the central plant system for heating and cooling, then it shall issue a warning message when loads on the central plant system are not met.

Equipment Performance Curves

The *Rating Software* shall be capable of modeling the part load efficiency and variation in capacity of equipment as follows:

- Furnaces as a function of part load;
- Boilers as a function of part load, supply hot water temperature, and return hot water temperature;
- Water-cooled compressors including heat pumps and chillers as a function of part load, evaporator fluid, or air temperature and condensing fluid temperature;
- Air-cooled compressors including heat pumps, direct expansion cooling and chillers as a function of part load, ambient dry-bulb temperature, and wet-bulb temperature returning to the cooling coil;
- Evaporative cooling systems as a function of ambient wet-bulb temperature; and
- Cooling towers as a function of range, approach and ambient wet-bulb temperature.

Economizer Control

The *Rating Software* shall be capable of modeling integrated air- and water-side economizers.

The *Rating Software* shall be capable of modeling electronic enthalpy air-side economizer controls that vary the high limit as a function of both temperature and enthalpy.

Air Side Heat-Recovery

The Rating Software shall be capable of modeling heat recovery between the exhaust air stream and the outside air stream. The software shall account for auxiliary energy uses associated with heat recovery systems, including pumping energy, frost control, and system control,

Heat-Recovery Water Heating

The Rating Software shall be capable of modeling heat recovery water heating from the following sources:

- Double bundled chiller;
- Refrigerant desuperheater as part of a packaged HVAC unit;
- Heat exchanger on the condenser water loop; and
- Heat-recovery water-to-water heat pump operating off of the condenser or chilled water loop.

Heat-Pump Water Heaters

The Rating Software shall be capable of modeling heat-pump water heaters. The algorithm must allow the evaporator coil to be located in:

- Any thermal block;
- Any plenum; and
- Outside air.

3.1.11 Managing User Input

This section addresses the processes of data entry and the validation of user input data that can be performed prior to and independent of the energy simulation.

Building Descriptor Inputs and Restrictions

Building descriptors are discussed in Chapter 6 and listed in tabular form in Appendix A. There are four types of inputs as shown in Table 2: compulsory, required, optional, and unsanctioned. Compulsory inputs must always be specified by the user for any rating. Required inputs shall be supported by the rating software but they may not be applicable for all ratings. Optional inputs are addressed in this manual and restrictions may apply, but it is up to the software vendor as to whether the inputs are supported. Unsanctioned inputs are inputs that are not addressed in this manual; these are not listed in Appendix A or discussed in Chapter 6.

All inputs shall conform with the input conditions and restrictions specified in Appendix A and Chapter 6. Four levels of restriction are specified for building descriptors. The most limiting restriction is a prescribed value. This is an input that must be used in all instances, with no variation. A critical default may be overridden, but when it is, the user must provide special documentation. A default is provided for convenience and may be overridden by the user with no special documentation. For many inputs there is no restriction. The relationship between input types and restrictions is shown in Table 2.

Table 2 – Input Types and Restrictions

Input Type	Prescribed	Critical Default	Default	No Restriction
Compulsory	n.a.	n.a.	n.a.	✓
Required	✓	✓	✓	✓
Optional	✓	✓	✓	✓
Unsanctioned	n.a.	n.a.	n.a.	✓

Restrictions apply to all required inputs. If the software provides a means for the user to input building descriptors listed as optional in Appendix A, all input conditions and restrictions in Appendix A and Chapter 6 pertaining to those building descriptors shall be met. The software user interface shall: 1) clearly indicate when a building descriptor has an associated default, 2) indicate what the default value is, and 3) provide a convenient means for the user to over-ride the default. When critical default values are overridden, the software interface shall notify the user that documentation of the revised assumption is required.

The software is not required to provide a means for users to enter data for building descriptors designated as prescribed in Appendix A and Chapter 6. However, if the user is permitted to input values for prescribed inputs, the software must inform the user that a prescribed value and not the value input by the user will be used in the rating.

No restrictions are specified for unsanctioned inputs. If the software uses unsanctioned inputs, the software documentation or help system shall specify the applicability of the building descriptors, its definition, the units in which it is expressed, restrictions on input for the proposed design, and, if applicable, how the building descriptor is defined for the baseline building.

Rating Software may not provide default assumptions other than those specified in Appendix A and Chapter 6. However, the software may assist the user in describing the proposed design by displaying typical values for building descriptors, provided deliberate action by the user is necessary before a displayed value is used.

Data Validation

Compulsory Input Checks

The software shall check to ensure that valid entries have been made for all compulsory building descriptors before the user is permitted to proceed with the next step in the rating process. Appendix A and Chapter 6 specify the compulsory building descriptors. Examples of compulsory inputs are climate zone, floor area, and space-by-space classification.

Handling of Missing Inputs

If a required input is missing or invalid, the software shall: 1) notify the user that the input is missing or invalid, 2) identify the input field(s) with missing or invalid data, and 3) prevent the user from moving to the next step of the rating process. The software may provide additional information designed to help the user correct the deficiency.

Validity Checks

The software shall check all user inputs to ensure that the following conditions are met:

- *Simulation Tool Limits* Inputs do not exceed the minimums or maximums for the parameters permitted by the simulation engine.
- *Rating Rule Limits* Inputs do not exceed minimums or maximums for the descriptors specified in Chapter 6 of this document.
- *Simulation Tool Discrete Options* Inputs correspond with valid discrete or list options for parameters available in the simulation engine.
- *Rating Rule Discrete Options* Inputs correspond with valid discrete options provided for in Chapter 6.

Handling Invalid Input

When invalid data is entered, the software shall: 1) notify the user of the invalid input, 2) identify the nonconforming input field, and 3) prevent execution of the next step of the rating process; i.e., generating the input description for the proposed design. The software may provide additional information designed to help the user correct the deficiency.

Consistency Checks

The consistency checks described above are intended to identify errors and oversights in user input and thereby help ensure that the building description is complete and interpretable by the energy analysis program. Examples of consistency checks include that window should not exceed the areas of wall in which they are contained and that the necessary plant equipment has actually been connected to the secondary HVAC systems. The software may include additional consistency checks provided these additional consistency checks are clearly documented in the user documentation or on-line help.

Handling Inconsistent Input

If the proposed design fails a consistency check, the software shall: 1) notify the user that an inconsistency exists, 2) identify the specific consistency check that has been failed, 3) identify the inconsistent input fields, if feasible, and 4) prevent execution of the next step of the rating process; i.e., generating the input description for the proposed design. The software may provide additional information designed to help the user correct the deficiency.

3.2 ASHRAE Standard 140-2007 Tests

This method of testing is provided for analyzing and diagnosing building energy simulation software using software-to-software and software-to-quasi-analytical-solution comparisons. The methodology allows different building energy simulation programs, representing different degrees of modeling complexity, to be tested by comparing the predictions from other building energy programs to the simulation results provided by the Rating Software in question.

The specifications for determining input values, the weather data required and an overview for all the test cases containing information on those building parameters that change from case to case is provided in the Standard 140-2007 documentation. The cases are grouped as:

- Building Thermal Envelope and Fabric Load Base Case
- Building Thermal Envelope and Fabric Load Basic Tests
    - Low mass
    - High mass
    - Free float
- Building Thermal Envelope and Fabric Load In-Depth Tests
- Space-Cooling Equipment Performance Analytical Verification Base Case
- Space-Cooling Equipment Performance Parameter Variation Analytical Verification Tests
- Space-Cooling Equipment Performance Comparative Test Base Case
- Space-Cooling Equipment Performance Comparative Tests
- Space-Heating Equipment Performance Analytical Verification Base Case
- Space-Heating Equipment Performance Analytical Verification Tests
- Space-Heating Equipment Performance Comparative Tests

COMNET software is required to perform the ASHRAE Standard 140-2007 suite of software tests and the results of these tests shall conform to the COMNET acceptance requirements. All tests shall be completed in accord with the requirements of ASHRAE Standard 140-2007. The resulting estimates of energy consumption shall fall between the minimum and maximum values established by COMNET, unless a valid explanation is provided. The portfolio folder for Appendix E contains spreadsheets wherein the software vendor enters the results of the Standard 140 simulations for comparison against the criteria. When results from candidate software fall outside the COMNET acceptance range or when candidate software is unable to perform one of the tests, the vendor shall provide an explanation of the reason as per ASHRAE Standard 140-2007 requirements. The portfolio folder for Appendix E also contains a methodology paper that describes how the acceptance criteria were developed.

3.2.1 Using the Spreadsheets

Four spreadsheets are provided in Appendix E for documenting results from candidate software and comparing to the COMNET acceptance ranges. These parallel the spreadsheets provided with ASHRAE Standard 140-2007. For each of the spreadsheets, the fields where data is entered are shaded pale yellow. The tabs where data is entered and where results are reviewed are shown in Table 3.

Table 3 – Spreadsheets for Verifying Standard 140 Tests

Spreadsheet	Enter Data on Tab	Check Results on Tab
COMNET Acceptance Range Results 5-2.xls	A	A
COMNET Acceptance Range Results 5-3A.xls	YD	A
COMNET Acceptance Range Results 5-3B.xls	YD	Q
COMNET Acceptance Range Results 5-4.xls	YD	Q

3.3 Modeling Assumptions and Baseline Building Tests

The previous suite of tests, based on ASHRAE Standard 140-2007, verifies that the simulation engine produces results that are reasonable. Each test requires a simulation to be run. The tests in this section are intended to verify that the software correctly constructs the proposed design and baseline buildings and correctly applies the proposed design input restrictions specified in Chapter 6 and Appendix A. Each test described in this section requires a minimum of five simulations, plus the sizing calculations: one simulation of the proposed design and four simulations of the baseline building (one for each of four orientations).

The simulations described in this section represent a green building rating or a tax credit calculation and use five prototype buildings. Prototypes A1, A3 and A20 are all the same five-zone, 150 ft x 150 ft, floor plate, but with one, three and 20 stories. Prototypes B1 and C1 are five-zone, one-story, square prototype buildings measuring 200 ft x 200 ft and 400 ft x 400 ft respectively. Prototype D is a more complex, mixed use building with a below-grade garage, retail on the first level, office space on levels two and three, and four stories of multi-family housing over the office. Figure 4 is an image of all of the prototype buildings, positioned next to each other. Portfolio Appendix E has a Google Sketchup file with the detailed geometry for each of the prototypes. The portfolio folder also has a spreadsheet with tabular detail on each of the prototype buildings along with forms for the software vendor to complete.

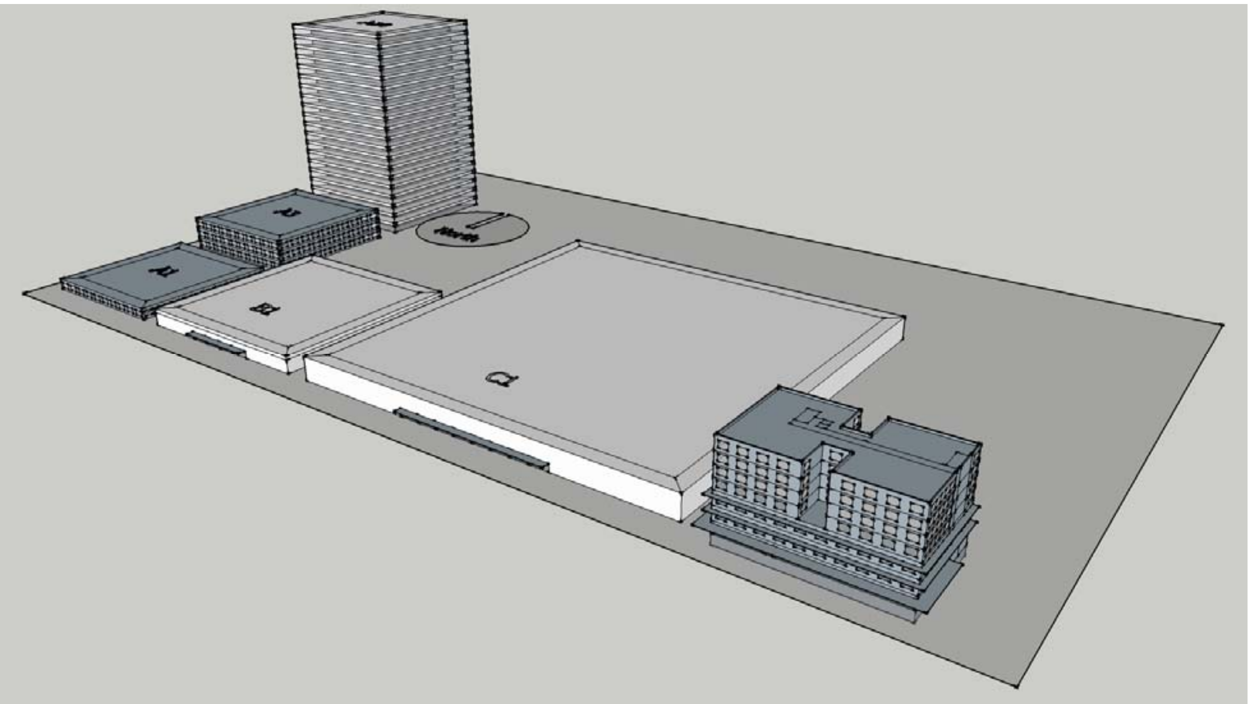


Figure 4 – Prototype Buildings for Modeling Assumptions and Baseline Building Tests

Evaluation of the modeling assumptions and baseline building tests is **qualitative**. The software developer shall use the candidate software and make the simulations described in this section for the proposed design and the baseline building. The input and output files for each of these cases shall then be evaluated by the software developer to verify that:

- Default schedules of operation are applied for both the baseline building and the proposed design.
- The baseline building use the correct system types as prescribed in Chapter 6
- An economizer (of the right type) is included in the baseline building if required.
- The primary and secondary baseline building systems are properly specified and sized.
- Fan brake horsepower is correctly specified for the baseline building.
- The baseline building is correctly rotated and the equipment is re-sized for each rotation.
- The baseline building envelope constructions are correctly substituted for exterior opaque surfaces, partitions and fenestration.
- Fenestration area in the baseline building is reduced, when the proposed design fenestration area is greater than 40% of the exterior wall.
- The baseline building lighting system is correctly specified and that exterior lighting is modeled.
- Receptacle loads, refrigeration equipment and other equipment is modeled according to the rules in this manual.
- Prescribed modeling assumptions are applied for both the baseline building and the proposed design.
- Elevators in Prototypes A20 and D are included.
- Overhangs are modeled in the proposed design for Prototype D but not the baseline building.
- The models make a reasonable estimate of unmet load hours.
- Unconditioned spaces are modeled.

- Other baseline building specifications and/or modeling assumptions are correctly applied.

As the software developer verifies the above and other conditions, the input and output files should be annotated with comments or other methods to demonstrate that the modeling rules specified in Chapter 6 and Appendix A are correctly applied. Software developers should use the output format spreadsheets, included in Portfolio Appendix E, to report the results of these tests. These annotated files are then submitted to COMNET for further evaluation. Any errors discovered shall be corrected by making modifications to the software; the simulations shall be repeated; and the new results shall be annotated for submittal to COMNET.

3.3.1 Summary of Required Simulations

A total of 29 rating analyses shall be performed as summarized in Table 4.

Table 4 – Summary of Analyses for Modeling Assumptions and Baseline Building Tests

Run	Purpose	Prototype	Climate	Occupancy Option	Lighting Power Density (W/ft²)	Equipment Power Density (W/ft²)	HVAC System	Default Schedules
1	Points	A1	Chicago	Office	1.00	1.00	PSZ-AC	Yes
2	Points	A1	Chicago	Office	1.20	1.50	PSZ-HP	No
3	Points	A1	Chicago	Office	1.40	2.00	PVAV	No
4	Points	A1	Denver	Office	1.00	1.00	PSZ-AC	Yes
5	Points	A1	Miami	Office	1.00	1.00	PSZ-AC	Yes
6	Points	A3	Chicago	Office	1.00	1.00	PVAV	Yes
7	Points	A3	Denver	Office	1.00	1.00	PVAV	Yes
8	Points	A3	Miami	Office	1.00	1.00	PVAV	Yes
9	Points	A20	Chicago	Office	1.00	1.00	VAV	Yes
10	Points	A20	Denver	Office	1.00	1.00	VAV	Yes
11	Points	A20	Miami	Office	1.00	1.00	VAV	Yes
12	Points	B1	Chicago	Supermarket	2.10	0.20	PSZ-AC	Yes
13	Points	B1	Denver	Retail	1.90	0.90	PSZ-AC	Yes
14	Points	B1	Miami	Manufacturing	1.30	1.00	PSZ-HP	Yes
15	Points	C1	Chicago	Retail	1.50	0.90	PSZ-AC	Yes
16	Points	C1	Denver	Warehouse	0.80	0.40	PSZ-AC	Yes
17	Points	C1	Miami	Manufacturing	1.30	1.00	PSZ-HP	Yes
18	Points	D	Chicago	See detail	See detail	See detail	See detail	Yes
19	Points	D	Denver	See detail	See detail	See detail	See detail	Yes
20	Points	D	Miami	See detail	See detail	See detail	See detail	Yes
21	Tax	A1	Chicago	Office	1.00	1.00	PSZ-AC	Yes
22	Tax	A1	Denver	Office	1.00	1.00	PSZ-AC	Yes
23	Tax	A1	Miami	Office	1.00	1.00	PSZ-AC	Yes
24	Tax	B1	Chicago	Supermarket	2.10	0.20	PSZ-AC	Yes
25	Tax	B1	Denver	Retail	1.90	0.90	PSZ-AC	Yes
26	Tax	B1	Miami	Manufacturing	1.30	1.00	PSZ-HP	Yes
27	Tax	D	Chicago	See detail	See detail	See detail	See detail	Yes
28	Tax	D	Denver	See detail	See detail	See detail	See detail	Yes
29	Tax	D	Miami	See detail	See detail	See detail	See detail	Yes

3.3.2 Prototypes A1, A3 and A20

Prototypes A1, A3 and A20 are all office buildings. They have the same 150 ft by 150 ft floor plate with a simple 15 ft perimeter zone. The main difference between the prototypes is the number of stores. A1 is a single story, A3 has three stories and A20 has twenty stories. These prototypes are modeled for the purpose of both tax deduction calculations and green building ratings. They are modeled in three locations: Chicago, Denver and Miami and with a variety of lighting power densities, equipment power densities, HVAC system types and schedules of operation. See Table 4 for the required variations.

All three prototypes have a 12 floor-to-floor height and a plenum with a height of 3 ft 6 in. Ceiling height is 8 ft 6 in. Prototypes A1 and A3 have a window wall ratio of 31%; fenestration consists of 10 ft by 5 ft 6 in. windows spaced around the perimeter at 15 ft. Prototype A20 has a window-wall-ratio of 71% with floor-to-ceiling glass on all sides. Figure 5 is a visual image of the three prototype buildings.

Prototype A1 is a wood framed building while prototypes A3 and A20 are steel framed. Except for test scenarios 2 and 3 with prototype A1, all other runs will use the COMNET specified default schedules.

Detailed specifications for each of the prototype building models are presented in spreadsheets included in Portfolio Appendix E.

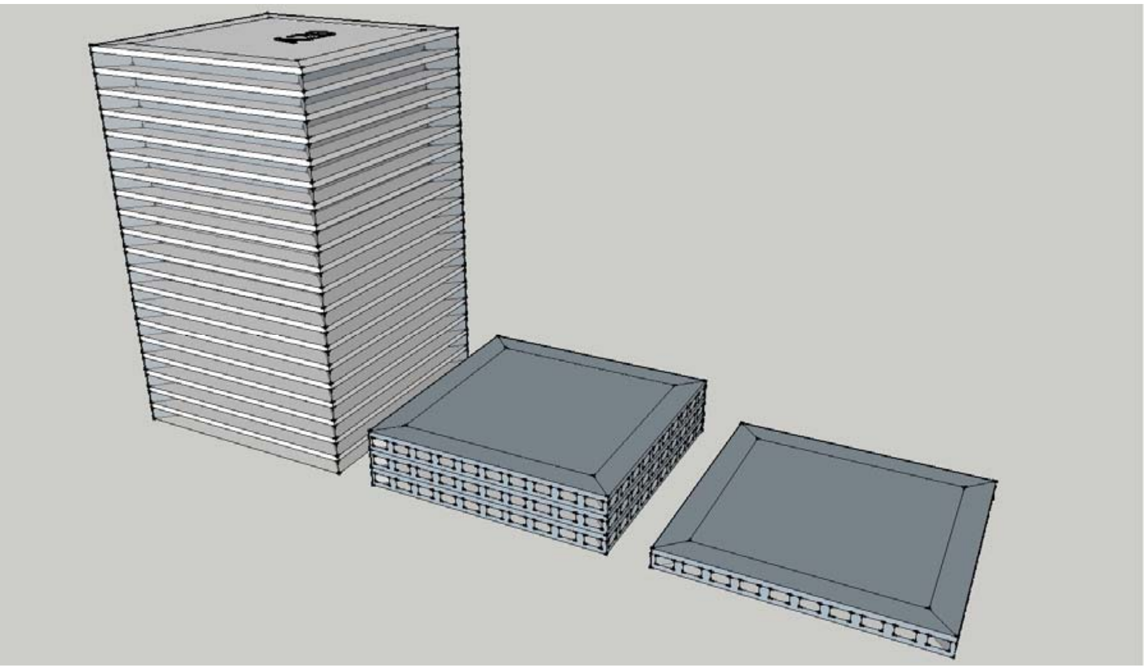


Figure 5 – Prototypes A1, A3 and A20

3.3.3 Prototypes B1 and C1

Prototypes B1 and C1 are both single story, large floor plate buildings. Prototype B1 measures 200 ft x 200 ft with an 18 ft height and a 4 ft plenum. Prototype C1 measures 400 ft x 400 ft with a 24 ft height and no plenum. These prototypes are modeled in three climates: Chicago, Denver and Miami. They are modeled as four primary occupancies: retail, manufacturing, warehouse, and grocery store. They are modeled with a variety of lighting and equipment power. See Table 4 for the required rating analyzes for these prototypes. Figure 6 is a visual image of the two prototypes. Prototypes B1 and C1 each have fenestration on just one side. Prototype B1 has a store front glazing system that is 8 ft high by 80 ft wide. Prototype C1 has a store front glazing system that is 8 ft high by 160 ft wide. Both curtain wall systems have an horizontal overhang located at the top of the glazing that extends a distance of 8 ft. Both prototypes have mass walls (8 inch solid grouted CMU blocks, interior insulation and gypsum board). Detailed specifications for each of the prototype building models are presented in spreadsheets included in Portfolio Appendix E.

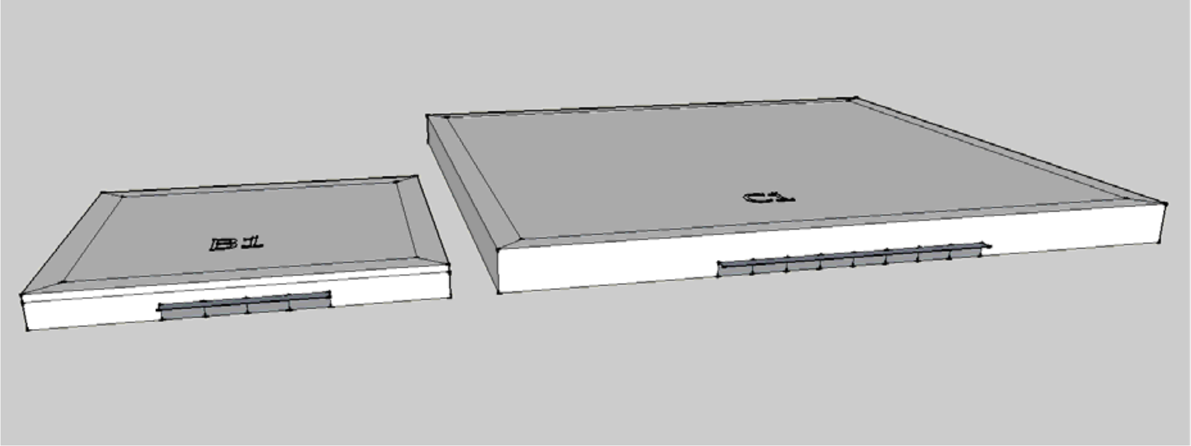


Figure 6 – Prototypes B1 and C1

3.3.4 Prototype D

Prototype D is a mixed use building with a clear specification. There are no variations other than the purpose (tax deductions and green building ratings) and climate location. Prototype D is the case study building used in the User's Manual for ASHRAE Standard 90.1-2007 to demonstrate the use of the Performance Rating Method (PRM). The building has seven above-ground stories and an underground garage. The building's footprint is 150 ft x 90 ft with the long axis oriented due east-west. The first floor contains retail spaces with large display windows that have overhangs projecting 10 ft on the south, east, and west exposures. The second and third floors contain offices that have similarly oriented overhangs, although the overhangs project only 5 ft. Above the offices are apartments on floors four through seven. To provide more daylight and fresh air, the four floors of apartments have two 20 ft x 30 ft notches taken out of the floor plan; therefore, these levels have 1,200 ft² less floor area than floors one, two, and three. The building also has an unconditioned stairwell.

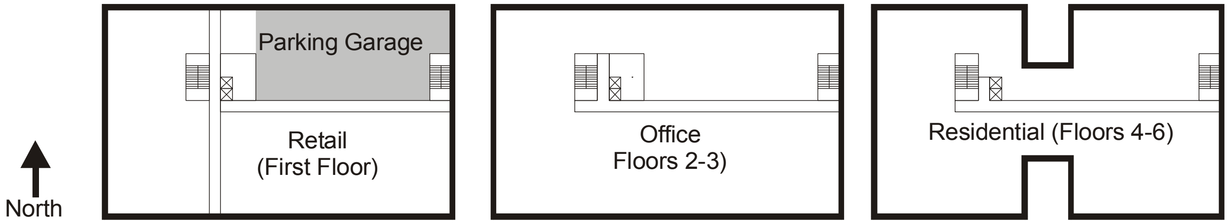


Figure 7 – Prototype D Floor Plans

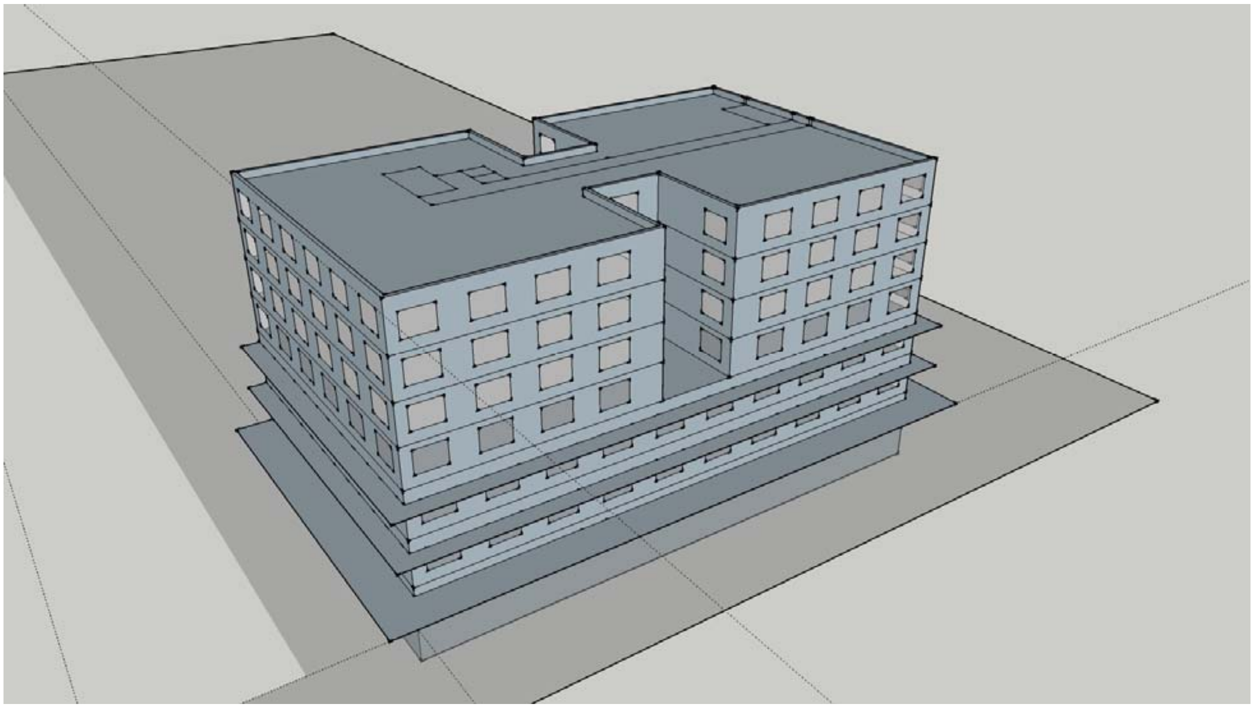


Figure 8 – Prototype D Exterior View

Prototype D is a steel-framed building with steel stud walls with R-7 insulation in the cavities and ⅝ in. sheetrock. The windows are single glazed with clear glass in all areas except the offices, which have single-pane windows with gray glass. All windows have thermally broken metal frames. Only the windows on the residential levels are operable.

A fluorescent electric lighting system is used throughout the commercial sections of the building. Lighting power density is 1.38 W/ft² in retail areas, 1.16 W/ft² in office areas, 0.25 W/ft² in the underground parking, and 0.5 W/ft² in stairwells. The perimeter zones of the office have automatic daylight dimming controls.

Retail spaces are served by a four-pipe fan coil system so that they can be independently shut down if the stores' operating hours differ significantly. A variable air volume (VAV) air-handling system served by the same centrifugal chiller and a boiler provides space conditioning in the office levels. The apartments are heated and cooled by four-pipe fan coil systems, which are also served by the chiller and boiler. The underground parking is ventilated during retail business hours.

A 160-ton, chiller with a rating of 0.6 kW/ton and a 2,250,000 Btu/h boiler serve all of the heating and cooling loads in the building.

Table 5 – Prototype D Surface Areas

Space Category	Orientation	Wall Area	Window Area	Window-Wall-Ratio	Proposed U-Value/SHGC
Residential	North	6,600	1,202		1.22/0.82
	Non-North	30,360	5,389		1.22/0.82
Residential total		36,960	6,591	18%	
Nonresidential					
Retail	North	1,600	534		1.22/0.82
Office	North	3,200	1,000		1.22/0.43
Retail	Non-North	4,293	2,920		1.22/0.82
Office	Non-North	8,587	2,054		1.22/0.43
Nonresidential total		17,680	6,508	37%	

Table 6 – Prototype D Lighting and Equipment Power

		Lighting Power		Equipment Power	
Area Description	Area	Watts	W/ft²	Watts	W/ft²
Parking	15,700	3,925	0.25	4,710	0.30
Retail	11,300	15,594	1.38	16,950	1.50
Office	27,000	31,320	1.16	27,000	1.00
Apartment units	43,600	71,940	1.65	71,940	1.65
Multi-family hallway	5,600	4,480	0.80	3,920	0.70
Totals	103,200	127,259	1.23	124,520	1.21

4 Content and Format of Standard Reports

4.1 Overview

This chapter provides a summary of the requisite content and format of the COMNET 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.

4.1.1 Content

Building information will be organized into four standard reports:

- Building Summary
- Energy Measures
- Energy Results
- Representations

The Building Summary contains basic building information such as project title, location, and size (see Table 7). This brief report provides essential building data at a glance. The Energy Measures report will list the design features that are different between the proposed design and the standard design (see Table 11). Credit is offered based on these measures. The Energy Results report will contain a summary of fuel types and end uses (see Table 12 and Table 13). The Representations report will have all relevant building titles and claims (see Table 14 and Table 15).

4.1.2 Format

There are two COMNET required formats for building information reports: electronic and hard copy. The electronic standard reports will be generated in XML (eXtensible Markup Language). The hard copy standard reports will be in PDF (Portable Document File). Both report formats will be automatically generated by COMNET approved software. Each page of the report will have a header with the project name and date.

4.2 Electronic Format: XML

4.2.1 Background

The electronic format of the COMNET standard reports will be XML. XML is a broadly used mechanism for describing, storing, and exchanging data. The primary function of XML is to effectively organize data and allow for it to be distributed in a platform independent format. Designating XML as the electronic format for COMNET is not intended to create more work for the user. Rather, XML supplies consistency as well as flexibility to the reporting process. XML facilitates straightforward data transfer from users to rating authorities.

The flow of information from the user (e.g. energy analyst) to the rating authority is summarized in Figure 9. First, the user inputs the necessary building data into the interface and runs the simulation engine as usual. When the user makes a successful simulation, the COMNET software will generate an XML file and produce the standard reports. This XML file will contain all of the data relevant to a building project for the purposes of rating and tax evaluation. Finally, the XML file can be sent to a rating authority and uploaded into their database for use in certification, labeling or determining tax deductions.

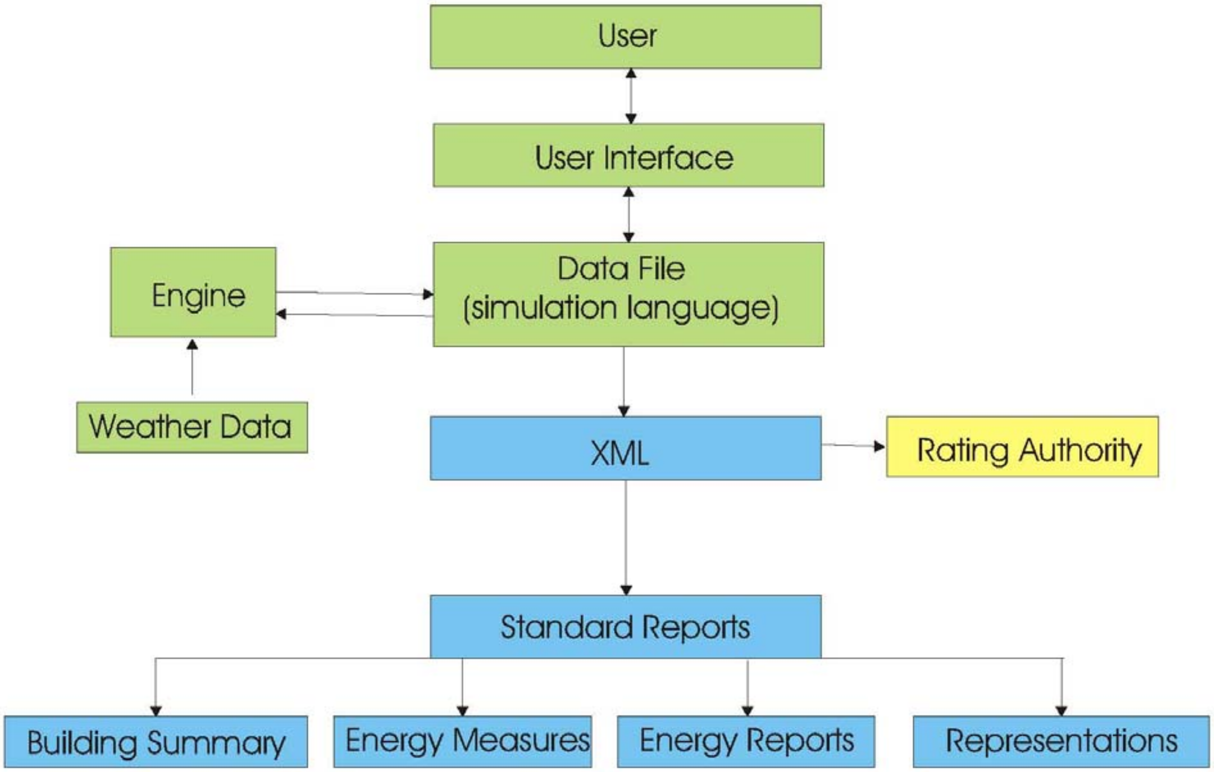


Figure 9 – Information Flow

4.2.2 XML File Structure Examples

The XML data structures will be simple, yet comprehensive enough for the user to ensure full transfer of all relevant building information. The four output reports (Building Summary, Energy Measures, Energy Results, and Representations) will be generated from the XML file.

The data structure is a 'many-to-one' relationship. The first structure (Project Data) is the primary or *parent* object. All successive structures will point back to this parent object. These successive structures have infinite input capability: the same structure can be used as many times as needed to represent the data. Figure 10 outlines the XML structures proposed for the COMNET standard. The XML format would allow for the addition of future structures to adapt to advances and innovation in energy modeling process. Table 7 through Table 16 provide more detailed outlines of the elements within the proposed XML data structures.

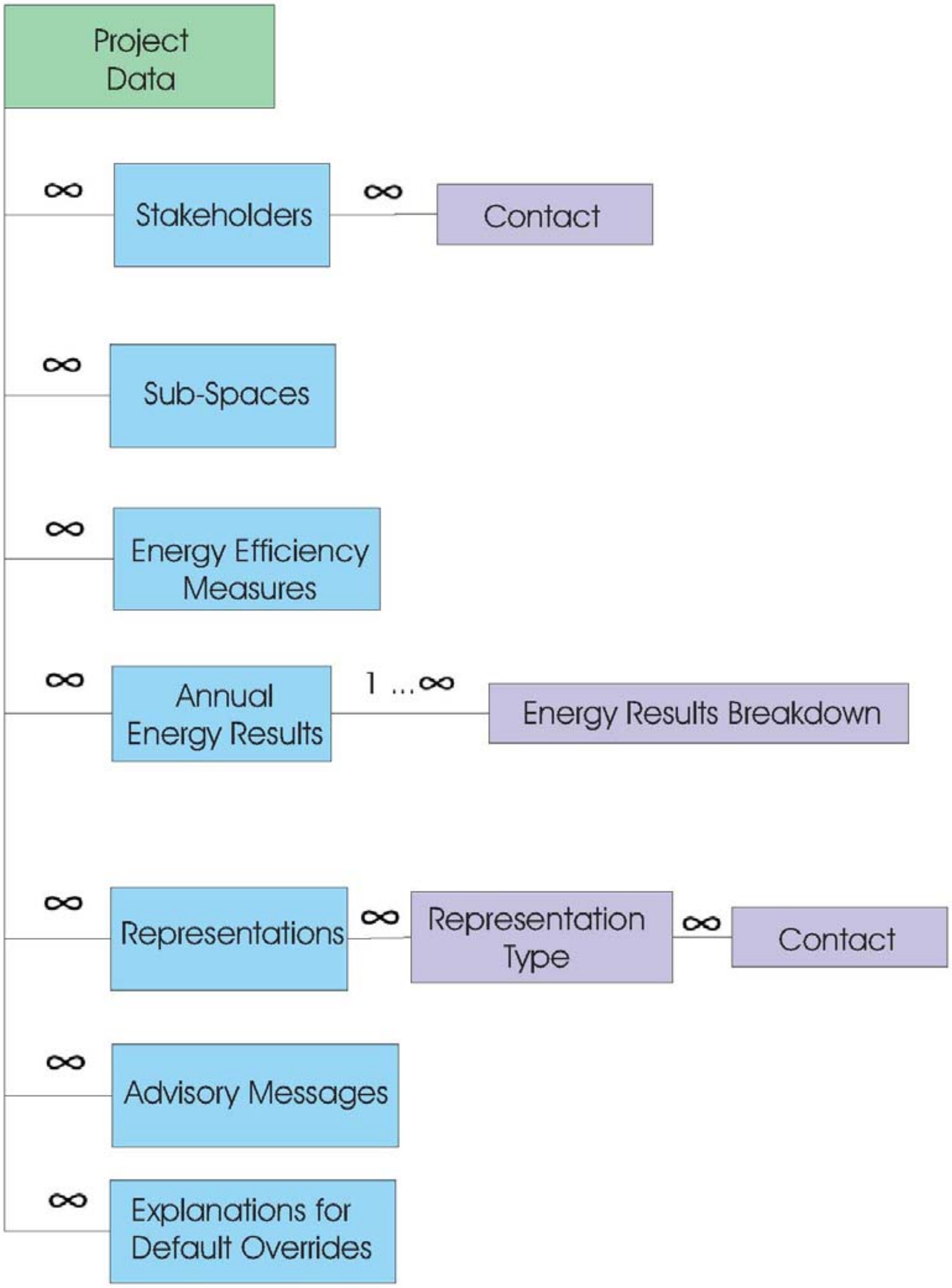


Figure 10 – XML Data Structures

Table 7 – Project Data

Field Name	Data Type	Notes
Project Name	Text	
Address	Structure	
Stories	Numeric	
Conditioned Area	Numeric	
Unconditioned Area	Numeric	
Total Area	Numeric	
Window to Wall Ratio	Numeric	
Skylight to Roof Ratio	Numeric	
Principal Building Activity	Text	
Simulation Program	Text	
Energy Code Used	Text	
Weather File	Text	
Currency	List	Source Energy, Site Energy, Cost, TDV
Utility Rate	Numeric	If Currency equals Cost
Proposed Design Name	Text	
Baseline Design Name	Text	

Table 8 – Stakeholders

Field Name	Data Type	Notes
Contact	Structure	
Role	List	Owner, Architect, HVAC Designer, Mechanical Engineer, Electrical Engineer, Lighting Designer, Energy Analyst, LEED Coordinator

Table 9 – Contact

Field Name	Data Type	Notes
Last Name	Text	
First Name	Text	
Address Line 1	Text	
Address Line 2	Text	
City	Text	
State	Text	
Zip	Numeric	
Company	Text	
Telephone	Numeric	

Table 10 – Sub-Spaces

Field Name	Data Type	Notes
Name	Text	
Description	Text	
Conditioned Area	Numeric	Square feet, square meters
Unconditioned Area	Numeric	Square feet, square meters
Total Area	Numeric	Square feet, square meters

Table 11 – Energy Efficiency Measures

(User Defined)

Field Name	Data Type	Notes
Name	Text	
Description	Text	
Type	List	Envelope, HVAC, Internal Gains, Plant
Baseline Building	Text	
Proposed Design	Text	
Modeling Technique	Text	How did you estimate the savings?

Table 12 – Annual Energy Results

Field Name	Data Type	Notes
Fuel	List	Electricity, Gas, Propane, Steam, Chilled Water
End-Use	List	Fans, Pumps, Cooling, Heating, Water Heating, Plug Loads, Heat Rejection (Towers)
Proposed Design	Numeric	
Baseline Building	Numeric	
Breakdown Type	Structure	Energy Results Breakdown

Table 13 – Energy Results Breakdown

Field Name	Data Type	Notes
Time Period	List	Month, Hour, Other (Specify)
Consumption	Numeric	
Baseline Building	Numeric	
Proposed Design	Numeric	

Table 14 – Representations

Field Name	Data Type	Notes
First Name	Text	
Last Name	Text	
Role	List	Owner, Architect, HVAC Designer, Mechanical Engineer, Electrical Engineer, Lighting Designer, Energy Analyst, LEED Coordinator
Contact	Structure	
Type	List	Representation Types

Table 15 – Representation Types

Field Name	Data Type	Notes
Title	List	
Claim	Text	
Other Information	Text	

Table 16 – Advisory Messages

Field Name	Data Type	Notes
Number of hours heating loads not met	Numeric	
Number of hours cooling loads not met	Numeric	
Number of warnings	Numeric	
Number of errors	Numeric	
Number of defaults overridden	Numeric	

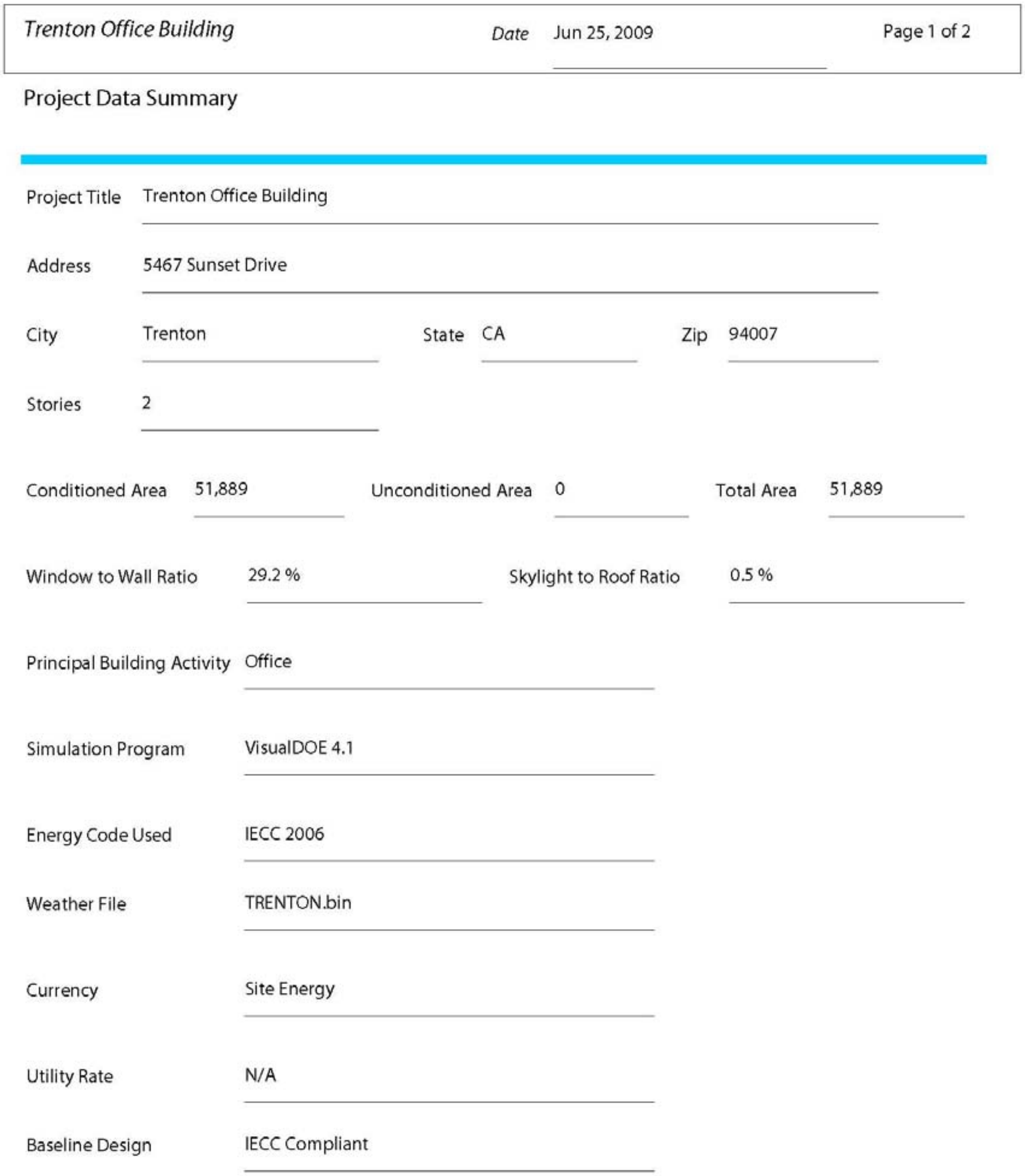
Table 17 – Explanations for Default Overrides

Field Name	Data Type	Notes
Building descriptor name	Text	
Data entered	Text	
Explanation for overriding default	Text	

4.3 Hard Copy Format: PDF

The COMNET approved software will produce an XML file and PDF reports. The following section provides examples of the automatically generated PDF standard reports: Building Summary, Energy Measures, Energy Results, and Representations. These examples are representative of a typical report output; however, they are not exhaustive.

4.3.1 Building Summary



Trenton Office Building *Date* Jun 25, 2009 Page 1 of 2

Project Data Summary

Project Title Trenton Office Building

Address 5467 Sunset Drive

City Trenton State CA Zip 94007

Stories 2

Conditioned Area 51,889 Unconditioned Area 0 Total Area 51,889

Window to Wall Ratio 29.2 % Skylight to Roof Ratio 0.5 %

Principal Building Activity Office

Simulation Program VisualDOE 4.1

Energy Code Used IECC 2006

Weather File TRENTON.bin

Currency Site Energy

Utility Rate N/A

Baseline Design IECC Compliant

Figure 11 – Sample of First Building Summary Page, Generated by Software

Trenton Office Building *Date* Jun 25, 2009 Page 2 of 2

Stakeholders

Role Owner

Last Name Pramtell

First Name Michelle

Address 897 Whirlwind Road

City Brackfield State CA Zip 93652

Role Architect

Last Name Havisham

First Name William

Address 4359 Creekside Avenue

City Fenton State CA Zip 91142

Role Mechanical Engineer

Last Name Evans

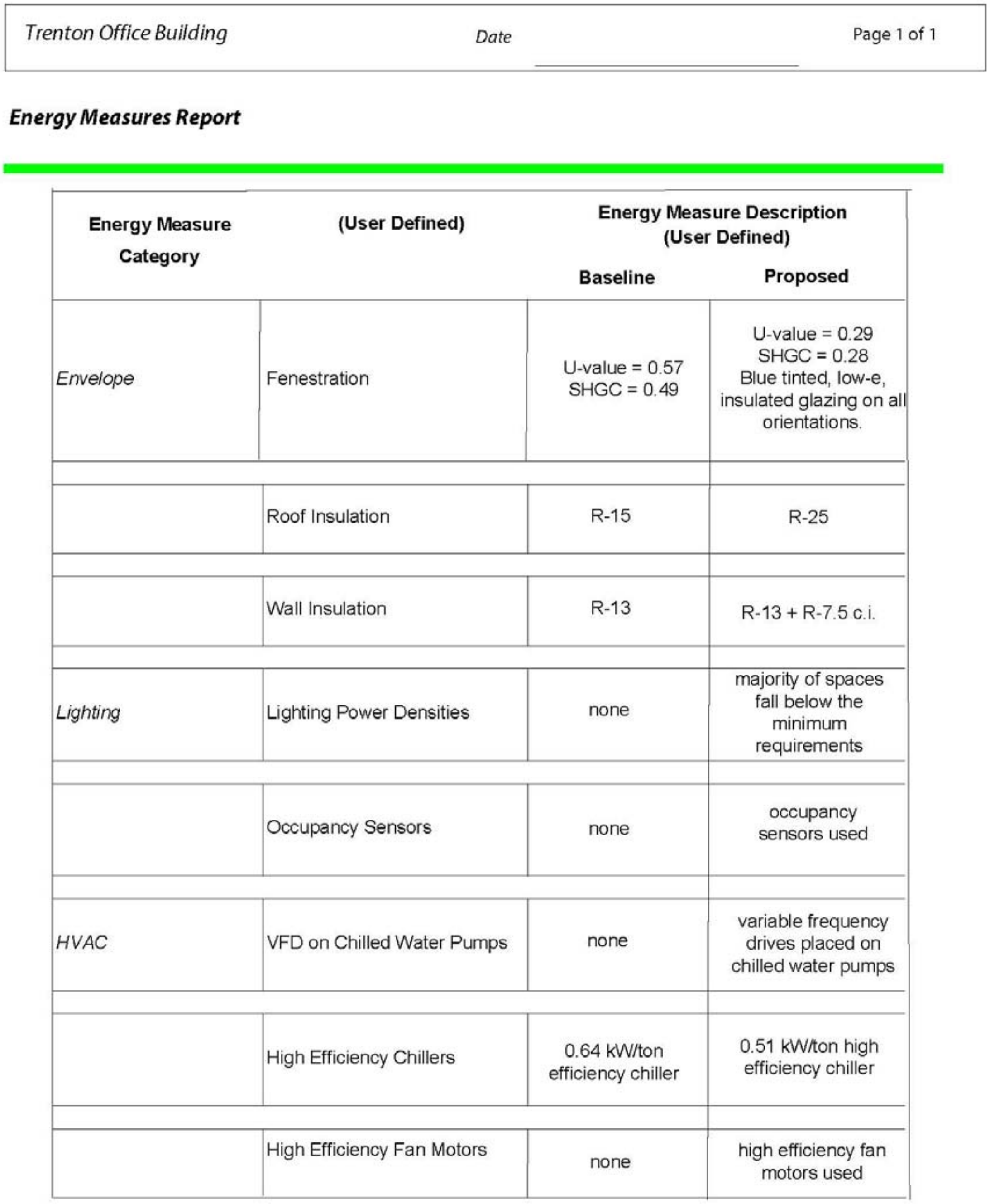
First Name Katherine

Address 228 Overland Trail

City Cicely State CA Zip 98865

Figure 12 – Sample of Second Building Summary Page, Generated by Software

4.3.2 Energy Measures Report



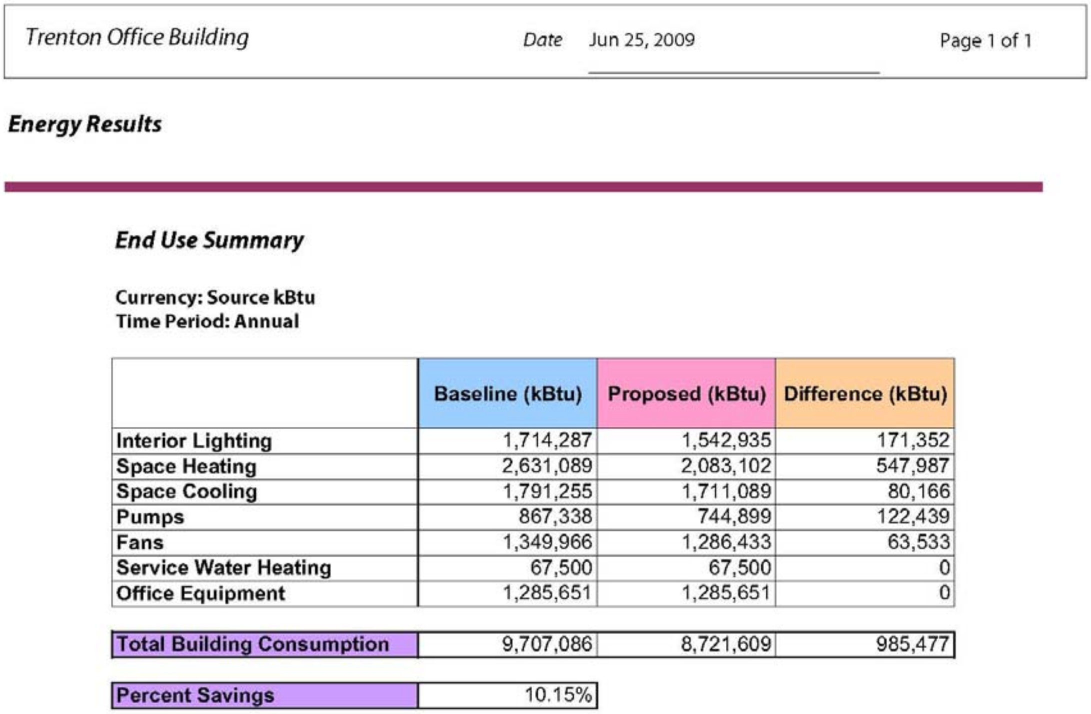
Trenton Office Building Date ________________ Page 1 of 1

Energy Measures Report

Energy Measure Category	(User Defined)	Energy Measure Description (User Defined)	
		Baseline	Proposed
Envelope	Fenestration	U-value = 0.57 SHGC = 0.49	U-value = 0.29 SHGC = 0.28 Blue tinted, low-e, insulated glazing on all orientations.
	Roof Insulation	R-15	R-25
	Wall Insulation	R-13	R-13 + R-7.5 c.i.
Lighting	Lighting Power Densities	none	majority of spaces fall below the minimum requirements
	Occupancy Sensors	none	occupancy sensors used
HVAC	VFD on Chilled Water Pumps	none	variable frequency drives placed on chilled water pumps
	High Efficiency Chillers	0.64 kW/ton efficiency chiller	0.51 kW/ton high efficiency chiller
	High Efficiency Fan Motors	none	high efficiency fan motors used

Figure 13 – Sample of First Energy Measures Page, Generated by Software

4.3.3 Energy Results Report



Trenton Office Building *Date* Jun 25, 2009 Page 1 of 1

Energy Results

End Use Summary

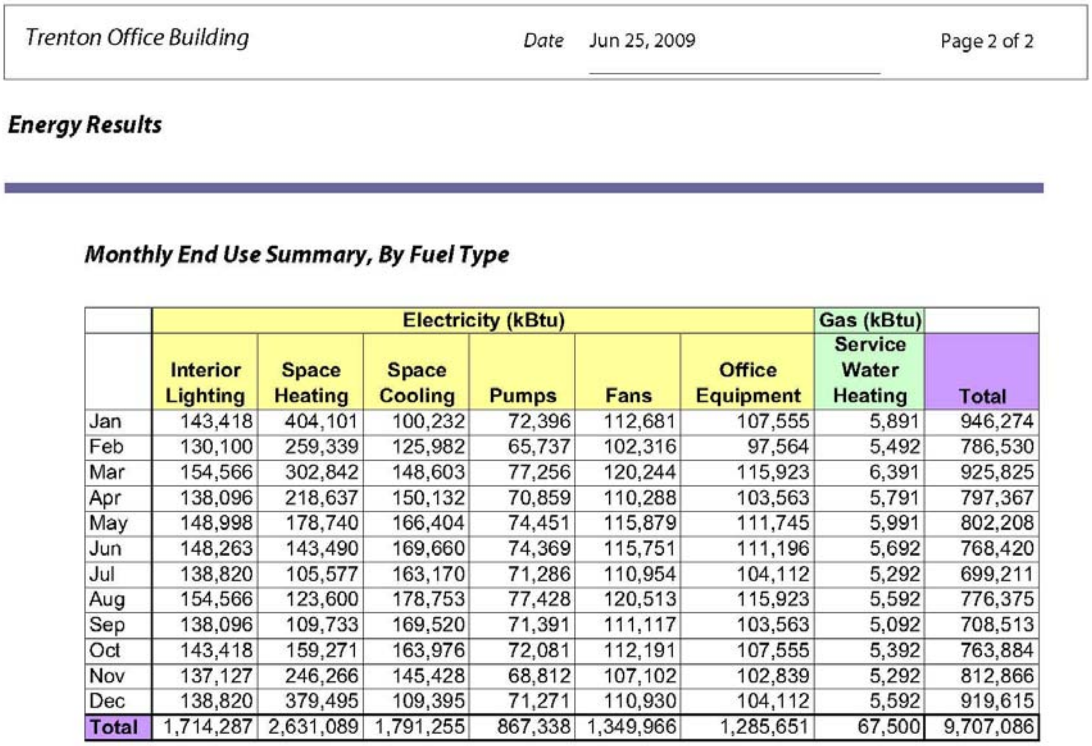
Currency: Source kBtu
Time Period: Annual

	Baseline (kBtu)	Proposed (kBtu)	Difference (kBtu)
Interior Lighting	1,714,287	1,542,935	171,352
Space Heating	2,631,089	2,083,102	547,987
Space Cooling	1,791,255	1,711,089	80,166
Pumps	867,338	744,899	122,439
Fans	1,349,966	1,286,433	63,533
Service Water Heating	67,500	67,500	0
Office Equipment	1,285,651	1,285,651	0

Total Building Consumption	9,707,086	8,721,609	985,477

Percent Savings	10.15%

Figure 14 – Sample First Page, Energy Results, Generated by Software



Trenton Office Building Date Jun 25, 2009 Page 2 of 2

Energy Results

Monthly End Use Summary, By Fuel Type

	Electricity (kBtu)						Gas (kBtu)	
	Interior Lighting	Space Heating	Space Cooling	Pumps	Fans	Office Equipment	Service Water Heating	Total
Jan	143,418	404,101	100,232	72,396	112,681	107,555	5,891	946,274
Feb	130,100	259,339	125,982	65,737	102,316	97,564	5,492	786,530
Mar	154,566	302,842	148,603	77,256	120,244	115,923	6,391	925,825
Apr	138,096	218,637	150,132	70,859	110,288	103,563	5,791	797,367
May	148,998	178,740	166,404	74,451	115,879	111,745	5,991	802,208
Jun	148,263	143,490	169,660	74,369	115,751	111,196	5,692	768,420
Jul	138,820	105,577	163,170	71,286	110,954	104,112	5,292	699,211
Aug	154,566	123,600	178,753	77,428	120,513	115,923	5,592	776,375
Sep	138,096	109,733	169,520	71,391	111,117	103,563	5,092	708,513
Oct	143,418	159,271	163,976	72,081	112,191	107,555	5,392	763,884
Nov	137,127	246,266	145,428	68,812	107,102	102,839	5,292	812,866
Dec	138,820	379,495	109,395	71,271	110,930	104,112	5,592	919,615
Total	1,714,287	2,631,089	1,791,255	867,338	1,349,966	1,285,651	67,500	9,707,086

Figure 15 – Sample of Second Page, Energy Results, Generated by Software

4.3.4 Representations Report

The representations report would include signed statements by those responsible for performing the energy calculations that, to the best of their knowledge, the data entered and the analysis performed accurately represents the conditions of the rated building. In the case of new construction, reference will be made to the construction documents upon which the calculations are based. In the case of existing buildings, separate statements may be appropriate for the person responsible for collecting field data and the person responsible for modeling, if these are different individuals. The representations are intended to impose a “standard of care” consistent with the work of licensed professionals.

5 Energy Costs and Currency Specification

5.1 Overview

The COMNET valuation methodology provides default time-of-use rate schedules for electricity, gas, steam and chilled water. COMNET software shall incorporate these rates into the calculation procedure so that the default rate schedules are easily available to the user. The default rates simplify the process and provide a means to take credit for measures that have large savings during peak periods. Local utility rates may be used instead of the defaults when desired. The software shall have the capability to assign energy charges for different seasons, day types, and periods within the day. Percent savings calculations shall be performed using Equation (1) for tax deductions and Equation (2) for green building ratings. A procedure is provided at the end of this chapter to convert TOU energy costs to EPA source energy. Appendix F of this document describes the methodology used to create the TOU energy costs presented in this chapter.

5.2 Geographic Regions

Default TOU energy costs are provided for 16 regions. These are consistent with the DOE/ASHRAE climate zones. Figure 1 below provides a map of the climate zones in the continental United States. Climate zone 1 is the tropical zone which includes Hawaii and the tip of Florida moving up to climate zone 8 which includes the northern arctic region of Alaska. Every county is in one unique climate zone.

There are 15 combinations of the 8 thermal zones and the 3 humidity zones. However, zone 3B is divided into two parts. Most of climate zone 3B is characterized by hot and dry summers; however, Los Angeles' climate is influenced by its coastal location. There are only five counties assumed to be in climate zone 3B (LA), Santa Barbara, Ventura, Los Angeles, Orange County, and San Diego. For each of the climate zones, the default TOU energy costs are shown in Table 18 through Table 33.

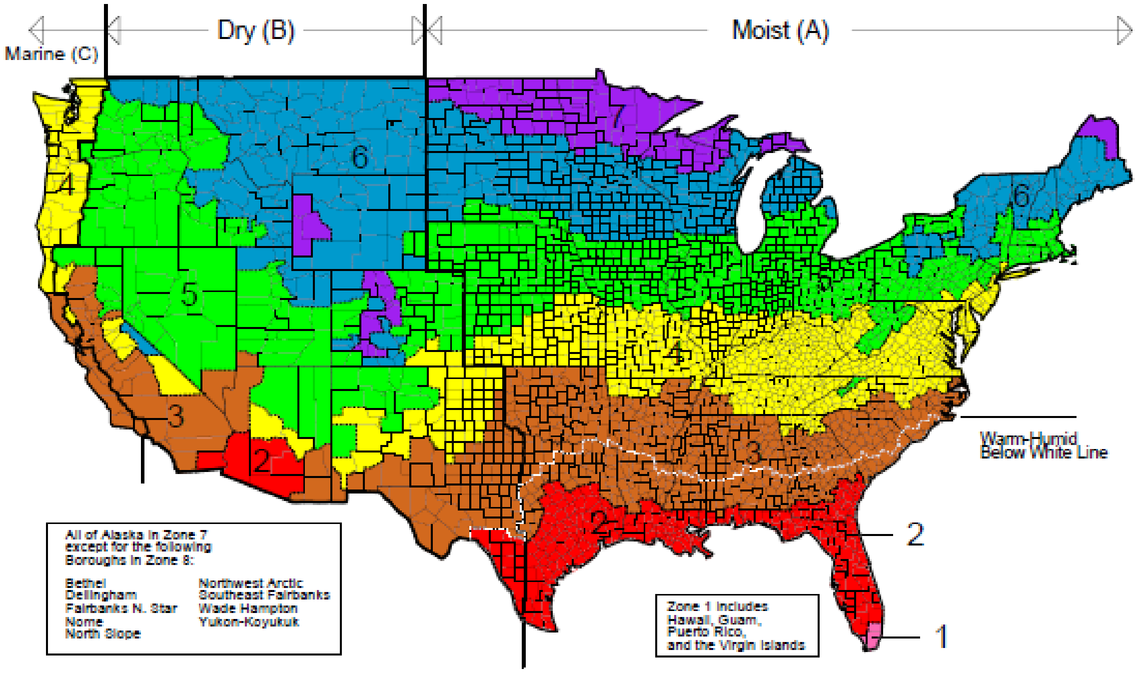


Figure 16 – United States Climate Zones

Table 18 – Energy Cost Specification by Season and TOU Period – Climate Zone 1A

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-21	$2.85
			Mid-Peak	9-11, 22-24	$0.91
			Off-Peak	1-8	$0.85
		Weekends/Holidays	Off-Peak	1-24	$0.85
	Fall (September-November)	Weekdays	Peak	12-21	$1.13
			Mid-Peak	8-11, 22-24	$0.81
			Off-Peak	1-7	$0.77
		Weekends/Holidays	Off-Peak	1-24	$0.77
	Winter (December-February)	Weekdays	Peak	NA	NA
			Mid-Peak	8-23	$0.78
			Off-Peak	24-7	$0.71
		Weekends/Holidays	Off-Peak	1-24	$0.71
	Spring (March-May)	Weekdays	Peak	13-21	$0.96
			Mid-Peak	9-12, 22-23	$0.84
			Off-Peak	24-8	$0.77
		Weekends/Holidays	Off-Peak	1-24	$0.77
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.33
	High Demand Season (November-March)	All	All	1-24	$11.42
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$133.74
	High Demand Season (November-March)	All	All	1-24	$163.80
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.15
	High Demand Season (November-March)	All	All	1-24	$1.41

Table 19 – Energy Cost Specification by Season and TOU Period – Climate Zone 2A

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-September)	Weekdays	Peak	14-21	$2.51
			Mid-Peak	22-1, 11-13	$0.85
			Off-Peak	2-10	$0.81
		Weekends/Holidays	Off-Peak	1-24	$0.81
	Fall (October-November)	Weekdays	Peak	13-23	$0.99
			Mid-Peak	9-12	$0.78
			Off-Peak	24-8	$0.75
		Weekends/Holidays	Off-Peak	1-24	$0.75
	Winter (December-February)	Weekdays	Peak	NA	NA
			Mid-Peak	8-22	$0.85
			Off-Peak	23-7	$0.77
		Weekends/Holidays	Off-Peak	1-24	$0.77
	Spring (March-May)	Weekdays	Peak	13-22	$1.06
			Mid-Peak	10-12, 23-24	$0.87
			Off-Peak	1-9	$0.82
		Weekends/Holidays	Off-Peak	1-24	$0.82
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.60
	High Demand Season (November-March)	All	All	1-24	$11.85
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$123.31
	High Demand Season (November-March)	All	All	1-24	$169.94
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.06
	High Demand Season (November-March)	All	All	1-24	$1.46

Table 20 – Energy Cost Specification by Season and TOU Period – Climate Zone 2B

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	9-21	$2.47
			Mid-Peak	NA	NA
			Off-Peak	22-8	$0.74
		Weekends/Holidays	Off-Peak	1-24	$0.74
	Fall (September-November)	Weekdays	Peak	13-21	$0.94
			Mid-Peak	11-12	$0.86
			Off-Peak	22-10	$0.79
		Weekends/Holidays	Off-Peak	1-24	$0.79
	Winter (December-February)	Weekdays	Peak	7-9, 18-22	$0.92
			Mid-Peak	10-13	$0.88
			Off-Peak	23-6, 14-17	$0.82
		Weekends/Holidays	Off-Peak	1-24	$0.82
	Spring (March-May)	Weekdays	Peak	13-21	$0.89
			Mid-Peak	10-12, 22-23	$0.80
			Off-Peak	24-9	$0.74
		Weekends/Holidays	Off-Peak	1-24	$0.74
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.37
	High Demand Season (November-March)	All	All	1-24	$11.78
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$120.05
	High Demand Season (November-March)	All	All	1-24	$168.88
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.03
	High Demand Season (November-March)	All	All	1-24	$1.45

Table 21 – Energy Cost Specification by Season and TOU Period – Climate Zone 3A

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-19	$3.48
			Mid-Peak	8-11, 20-23	$0.89
			Off-Peak	24-7	$0.82
		Weekends/Holidays	Off-Peak	1-24	$0.82
	Fall (September-October)	Weekdays	Peak	12-20	$0.91
			Mid-Peak	7-11, 21-22	$0.79
			Off-Peak	23-6	$0.76
		Weekends/Holidays	Off-Peak	1-24	$0.76
	Winter (November-February)	Weekdays	Peak	6-11, 18-21	$0.84
			Mid-Peak	12-17	$0.79
			Off-Peak	22-5	$0.75
		Weekends/Holidays	Off-Peak	1-24	$0.75
	Spring (March-May)	Weekdays	Peak	12-21	$0.97
			Mid-Peak	7-11	$0.88
			Off-Peak	22-6	$0.77
		Weekends/Holidays	Off-Peak	1-24	$0.77
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.90
	High Demand Season (November-March)	All	All	1-24	$11.95
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$127.61
	High Demand Season (November-March)	All	All	1-24	$171.38
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.10
	High Demand Season (November-March)	All	All	1-24	$1.47

Table 22 – Energy Cost Specification by Season and TOU Period – Climate Zone 3B (LA)

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	13-19	$3.59
			Mid-Peak	9-12, 20-23	$0.94
			Off-Peak	24-8	$0.59
		Weekends/Holidays	Off-Peak	1-24	$0.59
	Fall (September-November)	Weekdays	Peak	NA	NA
			Mid-Peak	9-22	$1.40
			Off-Peak	23-8	$0.71
		Weekends/Holidays	Off-Peak	1-24	$0.71
	Winter (December-March)	Weekdays	Peak	11-15, 18-22	$1.04
			Mid-Peak	8-10, 16-17	$0.96
			Off-Peak	23-7	$0.72
		Weekends/Holidays	Off-Peak	1-24	$0.72
	Spring (April-May)	Weekdays	Peak	12-18	$1.08
			Mid-Peak	8-11, 19-23	$0.97
			Off-Peak	24-7	$0.65
		Weekends/Holidays	Off-Peak	1-24	$0.65
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.77
	High Demand Season (November-March)	All	All	1-24	$11.22
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$125.72
	High Demand Season (November-March)	All	All	1-24	$160.95
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.08
	High Demand Season (November-March)	All	All	1-24	$1.38

Table 23 – Energy Cost Specification by Season and TOU Period – Climate Zone 3B

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-September)	Weekdays	Peak	14-20	$3.60
			Mid-Peak	9-13, 21-22	$0.83
			Off-Peak	23-8	$0.71
		Weekends/Holidays	Off-Peak	1-24	$0.71
	Fall (October-November)	Weekdays	Peak	17-21	$1.00
			Mid-Peak	7-16	$0.95
			Off-Peak	22-6	$0.83
		Weekends/Holidays	Off-Peak	1-24	$0.83
	Winter (December-February)	Weekdays	Peak	17-21	$0.91
			Mid-Peak	7-16	$0.79
			Off-Peak	22-6	$0.75
		Weekends/Holidays	Off-Peak	1-24	$0.75
	Spring (March-May)	Weekdays	Peak	12-21	$0.87
			Mid-Peak	7-11	$0.81
			Off-Peak	22-6	$0.73
		Weekends/Holidays	Off-Peak	1-24	$0.73
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.90
	High Demand Season (November-March)	All	All	1-24	$11.83
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$127.68
	High Demand Season (November-March)	All	All	1-24	$169.57
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.10
	High Demand Season (November-March)	All	All	1-24	$1.46

Table 24 – Energy Cost Specification by Season and TOU Period – Climate Zone 3C

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (July-September)	Weekdays	Peak	NA	NA
			Mid-Peak	8-11, 17-18	$1.53
			Off-Peak	19-7, 12-16	$1.11
		Weekends/Holidays	Off-Peak	1-24	$1.11
	Fall (October-November)	Weekdays	Peak	9-20	$0.95
			Mid-Peak	6-8, 21-23	$0.79
			Off-Peak	24-5	$0.74
		Weekends/Holidays	Off-Peak	1-24	$0.74
	Winter (December-April)	Weekdays	Peak	NA	NA
			Mid-Peak	8-22	$1.29
			Off-Peak	23-7	$0.77
		Weekends/Holidays	Off-Peak	1-24	$0.77
	Spring (May-June)	Weekdays	Peak	9-18	$1.01
			Mid-Peak	7-8, 19-23	$0.75
			Off-Peak	24-6	$0.66
		Weekends/Holidays	Off-Peak	1-24	$0.66
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.36
	High Demand Season (November-March)	All	All	1-24	$11.18
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$134.26
	High Demand Season (November-March)	All	All	1-24	$160.36
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.15
	High Demand Season (November-March)	All	All	1-24	$1.38

Table 25 – Energy Cost Specification by Season and TOU Period – Climate Zone 4A

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-20	$3.41
			Mid-Peak	8-11, 21-23	$1.02
			Off-Peak	24-7	$0.83
		Weekends/Holidays	Off-Peak	1-24	$0.83
	Fall (September-November)	Weekdays	Peak	NA	NA
			Mid-Peak	7-24	$0.88
			Off-Peak	1-6	$0.72
		Weekends/Holidays	Off-Peak	1-24	$0.72
	Winter (December-February)	Weekdays	Peak	NA	NA
			Mid-Peak	7-20	$0.96
			Off-Peak	21-6	$0.83
		Weekends/Holidays	Off-Peak	1-24	$0.83
	Spring (March-May)	Weekdays	Peak	NA	NA
			Mid-Peak	8-22	$0.95
			Off-Peak	23-7	$0.77
		Weekends/Holidays	Off-Peak	1-24	$0.77
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.07
	High Demand Season (November-March)	All	All	1-24	$11.99
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$130.05
	High Demand Season (November-March)	All	All	1-24	$171.95
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.12
	High Demand Season (November-March)	All	All	1-24	$1.48

Table 26 – Energy Cost Specification by Season and TOU Period – Climate Zone 4B

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	11-20	$3.04
			Mid-Peak	8-10, 21-22	$0.86
			Off-Peak	23-7	$0.85
		Weekends/Holidays	Off-Peak	1-24	$0.85
	Fall (September-October)	Weekdays	Peak	12-20	$0.91
			Mid-Peak	7-11, 21-22	$0.80
			Off-Peak	23-6	$0.76
		Weekends/Holidays	Off-Peak	1-24	$0.76
	Winter (November-February)	Weekdays	Peak	18-22	$0.84
			Mid-Peak	7-17	$0.81
			Off-Peak	23-6	$0.75
		Weekends/Holidays	Off-Peak	1-24	$0.75
	Spring (March-May)	Weekdays	Peak	11-16, 19-21	$0.96
			Mid-Peak	7-10, 17-18	$0.91
			Off-Peak	22-6	$0.77
		Weekends/Holidays	Off-Peak	1-24	$0.77
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.33
	High Demand Season (November-March)	All	All	1-24	$11.15
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$119.46
	High Demand Season (November-March)	All	All	1-24	$159.81
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.03
	High Demand Season (November-March)	All	All	1-24	$1.37

Table 27 – Energy Cost Specification by Season and TOU Period – Climate Zone 4C

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	10-18	$2.25
			Mid-Peak	7-9, 19-23	$0.96
			Off-Peak	24-6	$0.64
		Weekends/Holidays	Off-Peak	1-24	$0.64
	Fall (September-October)	Weekdays	Peak	NA	NA
			Mid-Peak	8-23	$0.91
			Off-Peak	24-7	$0.76
		Weekends/Holidays	Off-Peak	1-24	$0.76
	Winter (November-March)	Weekdays	Peak	8-12, 17-21	$1.52
			Mid-Peak	13-16, 22-23	$0.95
			Off-Peak	24-7	$0.76
		Weekends/Holidays	Off-Peak	1-24	$0.76
	Spring (April-May)	Weekdays	Peak	NA	NA
			Mid-Peak	8-23	$0.76
			Off-Peak	24-7	$0.60
		Weekends/Holidays	Off-Peak	1-24	$0.60
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.01
	High Demand Season (November-March)	All	All	1-24	$11.10
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$129.13
	High Demand Season (November-March)	All	All	1-24	$159.20
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.11
	High Demand Season (November-March)	All	All	1-24	$1.37

Table 28 – Energy Cost Specification by Season and TOU Period – Climate Zone 5A

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	13-21	$3.08
			Mid-Peak	10-12, 22-24	$1.05
			Off-Peak	1-9	$0.76
		Weekends/Holidays	Off-Peak	1-24	$0.76
	Fall (September-October)	Weekdays	Peak	13-22	$1.07
			Mid-Peak	9-12	$0.91
			Off-Peak	23-8	$0.72
		Weekends/Holidays	Off-Peak	1-24	$0.72
	Winter (November-March)	Weekdays	Peak	18-22	$1.21
			Mid-Peak	8-17, 23-24	$0.99
			Off-Peak	1-7	$0.80
		Weekends/Holidays	Off-Peak	1-24	$0.80
	Spring (April-May)	Weekdays	Peak	12-20	$1.20
			Mid-Peak	9-11, 21-24	$1.01
			Off-Peak	1-8	$0.78
		Weekends/Holidays	Off-Peak	1-24	$0.78
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.97
	High Demand Season (November-March)	All	All	1-24	$11.78
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$128.57
	High Demand Season (November-March)	All	All	1-24	$168.85
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.10
	High Demand Season (November-March)	All	All	1-24	$1.45

Table 29 – Energy Cost Specification by Season and TOU Period – Climate Zone 5B

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	11-20	$2.69
			Mid-Peak	8-10, 21-22	$0.81
			Off-Peak	23-7	$0.76
		Weekends/Holidays	Off-Peak	1-24	$0.76
	Fall (September-October)	Weekdays	Peak	13-20	$0.71
			Mid-Peak	6-12, 21-22	$0.61
			Off-Peak	23-5	$0.54
		Weekends/Holidays	Off-Peak	1-24	$0.54
	Winter (November-March)	Weekdays	Peak	9-17	$1.10
			Mid-Peak	7-8, 18-23	$1.07
			Off-Peak	24-6	$0.93
		Weekends/Holidays	Off-Peak	1-24	$0.93
	Spring (April-May)	Weekdays	Peak	NA	NA
			Mid-Peak	7-22	$0.96
			Off-Peak	23-6	$0.80
		Weekends/Holidays	Off-Peak	1-24	$0.80
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.28
	High Demand Season (November-March)	All	All	1-24	$10.71
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$118.69
	High Demand Season (November-March)	All	All	1-24	$153.51
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.02
	High Demand Season (November-March)	All	All	1-24	$1.32

Table 30 – Energy Cost Specification by Season and TOU Period – Climate Zone 6A

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-20	$3.32
			Mid-Peak	9-11, 21-24	$0.97
			Off-Peak	1-8	$0.78
		Weekends/Holidays	Off-Peak	1-24	$0.78
	Fall (September-October)	Weekdays	Peak	12-21	$1.11
			Mid-Peak	8-11, 22-23	$0.84
			Off-Peak	24-7	$0.80
		Weekends/Holidays	Off-Peak	1-24	$0.80
	Winter (November-March)	Weekdays	Peak	9-13, 18-22	$1.16
			Mid-Peak	14-17	$1.00
			Off-Peak	23-8	$0.83
		Weekends/Holidays	Off-Peak	1-24	$0.83
	Spring (April-May)	Weekdays	Peak	NA	NA
			Mid-Peak	8-23	$0.89
			Off-Peak	24-7	$0.71
		Weekends/Holidays	Off-Peak	1-24	$0.71
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.86
	High Demand Season (November-March)	All	All	1-24	$11.53
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$127.02
	High Demand Season (November-March)	All	All	1-24	$165.38
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.09
	High Demand Season (November-March)	All	All	1-24	$1.42

Table 31 – Energy Cost Specification by Season and TOU Period – Climate Zone 6B

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	12-21	$2.27
			Mid-Peak	8-11, 22-23	$0.79
			Off-Peak	24-7	$0.76
		Weekends/Holidays	Off-Peak	1-24	$0.76
	Fall (September-October)	Weekdays	Peak	NA	NA
			Mid-Peak	8-18	$0.84
			Off-Peak	19-7	$0.81
		Weekends/Holidays	Off-Peak	1-24	$0.81
	Winter (November-March)	Weekdays	Peak	8-11, 18-21	$1.44
			Mid-Peak	12-17	$0.87
			Off-Peak	22-7	$0.79
		Weekends/Holidays	Off-Peak	1-24	$0.79
	Spring (April-May)	Weekdays	Peak	NA	NA
			Mid-Peak	7-23	$0.86
			Off-Peak	24-6	$0.80
		Weekends/Holidays	Off-Peak	1-24	$0.80
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.32
	High Demand Season (November-March)	All	All	1-24	$10.63
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$119.26
	High Demand Season (November-March)	All	All	1-24	$152.40
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.02
	High Demand Season (November-March)	All	All	1-24	$1.31

Table 32 – Energy Cost Specification by Season and TOU Period – Climate Zone 7

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	10-21	$2.48
			Mid-Peak	7-9, 22-23	$0.77
			Off-Peak	24-6	$0.62
		Weekends/Holidays	Off-Peak	1-24	$0.62
	Fall (September-September)	Weekdays	Peak	NA	NA
			Mid-Peak	8-21	$0.90
			Off-Peak	22-7	$0.58
		Weekends/Holidays	Off-Peak	1-24	$0.58
	Winter (October-March)	Weekdays	Peak	8-13, 17-22	$1.28
			Mid-Peak	14-16	$1.00
			Off-Peak	23-7	$0.86
		Weekends/Holidays	Off-Peak	1-24	$0.86
	Spring (April-May)	Weekdays	Peak	NA	NA
			Mid-Peak	7-21	$1.13
			Off-Peak	22-6	$0.82
		Weekends/Holidays	Off-Peak	1-24	$0.82
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$8.95
	High Demand Season (November-March)	All	All	1-24	$11.41
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$128.26
	High Demand Season (November-March)	All	All	1-24	$163.63
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.10
	High Demand Season (November-March)	All	All	1-24	$1.40

Table 33 – Energy Cost Specification by Season and TOU Period – Climate Zone 8

Fuel	Seasons	Day Types	Time Periods	Hours in TOU Period (1-24)	Present Value of Energy Cost
Electricity ($/kWh)	Summer (June-August)	Weekdays	Peak	9-23	$0.78
			Mid-Peak	NA	NA
			Off-Peak	24-8	$0.65
		Weekends/Holidays	Off-Peak	1-24	$0.65
	Fall (September-September)	Weekdays	Peak	8-23	$0.79
			Mid-Peak	NA	NA
			Off-Peak	24-7	$0.68
		Weekends/Holidays	Off-Peak	1-24	$0.68
	Winter (October-April)	Weekdays	Peak	8-23	$1.61
			Mid-Peak	NA	NA
			Off-Peak	24-7	$0.81
		Weekends/Holidays	Off-Peak	1-24	$0.81
	Spring (May-May)	Weekdays	Peak	9-23	$0.77
			Mid-Peak	NA	NA
			Off-Peak	24-8	$0.64
		Weekends/Holidays	Off-Peak	1-24	$0.64
Gas ($/therm)	Low Demand Season (April-October)	All	All	1-24	$9.20
	High Demand Season (November-March)	All	All	1-24	$11.56
Steam ($/Mlb)	Low Demand Season (April-October)	All	All	1-24	$131.93
	High Demand Season (November-March)	All	All	1-24	$165.76
Chilled Water ($/ton-hr)	Low Demand Season (April-October)	All	All	1-24	$1.13
	High Demand Season (November-March)	All	All	1-24	$1.42

5.3 Calculating the Zero Energy Performance Index (zEPI)

The zero energy performance index (zEPI) is the ratio of energy consumption, measured in dollars of operating cost, to the average energy consumption for a similar building at the turn of the millennium that is operated in a similar climate, for similar hours of and for other similar operating conditions. The COMNET modeling rules and procedures result in the energy consumption for the proposed design. The energy consumption of the baseline building can be determined in a variety of ways, but often the results are expressed in kWh of electricity use, therms of gas use or Btu of steam or chilled water. For comparison, these consumption units need to be converted to COMNET TOU costs for consistent comparison. This section provides a method for making this conversion.

The process, using the COMNET tariffs, is similar except that the energy efficiency ratio in Step 3 is calculated as the ratio of energy cost instead of source energy. To achieve this, the EPA source energy (determined in Step 2 above) is converted to COMNET energy costs using the multipliers in Table 34. The process involves the following steps:

A. Estimate the energy cost of the candidate building or proposed design using the default tariffs provided in this chapter.

B. Estimate the electricity, gas, steam and chilled water of a similar building in a similar climate operated in a similar manner.

C. Use the EPA source energy multipliers to convert these estimates to EPA source energy. These multipliers are available at ___. The EPA source energy multipliers are static and do not vary with season, day, or hour.

D. Convert the EPA source energy to COMNET TOU costs using the conversion factors in Table 34.

E. Calculate the zEPI as the ratio of the proposed design energy costs divided by the baseline building energy costs, as determined in the previous step.

A benefit of using the COMNET tariffs for zEPI is that building features such as daylighting or thermal storage that reduce energy demand in periods when the utility grid is stressed and when more expensive generating sources are on-line are given more credit. The procedure in this section enables proper credit for thermal storage, daylighting, photovoltaic production and other measures that reduce energy consumption during peak periods.

Table 34 –Source Energy Conversion Factors ($/kBtu)[5]

Climate Zone	Vacant	Office	Laboratory	Refrigerated Warehouse	Food Sales	Public Order and Safety	Outpatient Health Care	Refrigerated Warehouse	Religious Worship	Public Assembly
1A	$0.0944	$0.0929	$0.0928	$0.0956	$0.0892	$0.0932	$0.0937	$0.0939	$0.0911	$0.0921
2A	$0.0915	$0.0908	$0.0900	$0.0929	$0.0880	$0.0902	$0.0898	$0.0904	$0.0909	$0.0874
2B	$0.0936	$0.1020	$0.1022	$0.0935	$0.0895	$0.1025	$0.1024	$0.0922	$0.1015	$0.1016
3A	$0.0974	$0.0942	$0.0950	$0.0983	$0.0893	$0.0960	$0.0961	$0.0954	$0.0954	$0.0957
3B (LA)	$0.0967	$0.0981	$0.0980	$0.0980	$0.0916	$0.0981	$0.0981	$0.0978	$0.1003	$0.1003
3B	$0.0959	$0.1010	$0.1005	$0.0955	$0.0945	$0.1008	$0.1011	$0.0949	$0.0967	$0.0953
3C	$0.0919	$0.0922	$0.0926	$0.0916	$0.0878	$0.0922	$0.0921	$0.0901	$0.0947	$0.0948
4A	$0.0973	$0.0984	$0.0984	$0.1010	$0.0947	$0.0980	$0.0973	$0.0984	$0.1040	$0.1008
4B	$0.0928	$0.0932	$0.0938	$0.0958	$0.0906	$0.0930	$0.0930	$0.0959	$0.0986	$0.0956
4C	$0.0924	$0.0955	$0.0950	$0.0928	$0.0876	$0.0948	$0.0949	$0.0910	$0.0962	$0.0945
5A	$0.1007	$0.1029	$0.1031	$0.0951	$0.0964	$0.1056	$0.1021	$0.0942	$0.1010	$0.0987
5B	$0.0943	$0.0984	$0.0993	$0.0875	$0.0915	$0.0984	$0.0984	$0.0866	$0.0948	$0.0948
6A	$0.0998	$0.1014	$0.1016	$0.1030	$0.0961	$0.1012	$0.1024	$0.1019	$0.1018	$0.1022
6B	$0.0901	$0.0915	$0.0923	$0.0937	$0.0879	$0.0914	$0.0915	$0.0917	$0.0929	$0.0928
7	$0.0994	$0.1013	$0.1015	$0.1027	$0.0957	$0.1011	$0.1024	$0.1020	$0.1032	$0.1041
8	$0.0949	$0.0933	$0.0959	$0.0977	$0.0883	$0.0938	$0.0943	$0.0918	$0.0998	$0.0984

---

[5] Source energy conversions from “ENERGY STAR Performance Ratings Methodology for Incorporating Source Energy Use”, December 2007, were used to generate this table.

Table 34 (continued)

Climate Zone	Education	Food Service	Inpatient Health Care	Nursing	Lodging	Strip Shopping Mall	Enclosed Mall	Retail Other than Mall	Service	Other
1A	$0.0952	$0.0930	$0.0923	$0.0909	$0.0916	$0.0939	$0.0940	$0.0940	$0.0957	$0.0942
2A	$0.0874	$0.0913	$0.0897	$0.0888	$0.0900	$0.0914	$0.0911	$0.0917	$0.0926	$0.0912
2B	$0.1021	$0.0926	$0.0917	$0.0911	$0.0901	$0.0975	$0.0961	$0.0973	$0.0972	$0.0934
3A	$0.0957	$0.0930	$0.0926	$0.0914	$0.0917	$0.0952	$0.0945	$0.0960	$0.0967	$0.0956
3B (LA)	$0.1004	$0.0954	$0.0938	$0.0939	$0.0936	$0.0986	$0.0987	$0.0986	$0.0975	$0.0966
3B	$0.0966	$0.0978	$0.0963	$0.0948	$0.0987	$0.1012	$0.1011	$0.1019	$0.1018	$0.0956
3C	$0.0948	$0.0919	$0.0914	$0.0917	$0.0903	$0.0908	$0.0905	$0.0910	$0.0948	$0.0922
4A	$0.1005	$0.1009	$0.0972	$0.0966	$0.0937	$0.1029	$0.1021	$0.1046	$0.1040	$0.0984
4B	$0.0991	$0.0956	$0.0917	$0.0916	$0.0905	$0.0989	$0.0981	$0.0990	$0.0996	$0.0922
4C	$0.0954	$0.0918	$0.0914	$0.0911	$0.0894	$0.0937	$0.0923	$0.0937	$0.0949	$0.0935
5A	$0.1001	$0.1014	$0.1036	$0.1042	$0.0936	$0.1040	$0.1037	$0.1047	$0.1053	$0.1001
5B	$0.0947	$0.0925	$0.0985	$0.0985	$0.0882	$0.0973	$0.0978	$0.0981	$0.0984	$0.0948
6A	$0.1030	$0.0981	$0.0979	$0.0976	$0.0995	$0.1023	$0.1024	$0.1022	$0.1020	$0.0997
6B	$0.0928	$0.0893	$0.0891	$0.0892	$0.0900	$0.0917	$0.0921	$0.0922	$0.0924	$0.0903
7	$0.1046	$0.0977	$0.0975	$0.0972	$0.0982	$0.1012	$0.1012	$0.1012	$0.1011	$0.0993
8	$0.0996	$0.0911	$0.0920	$0.0917	$0.0892	$0.0919	$0.0915	$0.0918	$0.0919	$0.0943

6 Building Descriptors Reference

6.1 Overview

This chapter methodically goes through the building descriptors for the proposed design and the baseline building. The baseline building must be specified for tax deductions and green building ratings. It is not needed for energy labels. The building descriptors discussed in this chapter are also summarized in Appendix A in a more brief and tabular form.

6.1.1 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 one particular energy simulation engine. The building descriptors in this chapter are consistent with commonly used simulation software. Other building descriptors may be substituted as long as the input restrictions and definition of the baseline building conditions are consistent.

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 responsibility of the COMNET software developer to translate the generic terms used in this chapter into the "native language" of the simulation program used by the software. Figure 17 illustrates the flow of information.

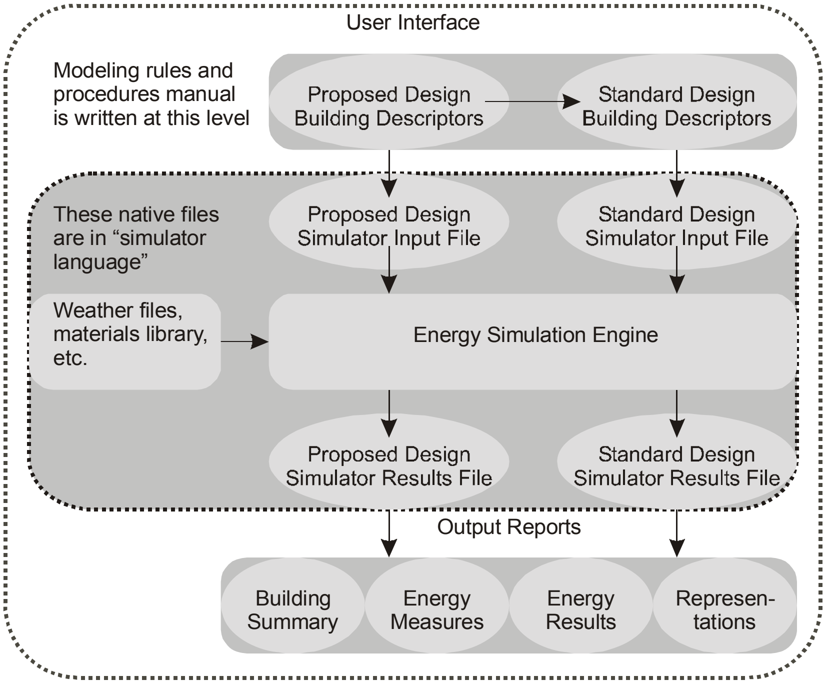


Figure 17 – Information Flow

6.1.2 HVAC System Map

The HVAC system in the baseline building depends on the primary building activity, the size of the building and the energy source used for heating in the proposed design. Figure 18 shows the HVAC system types that apply in each case. Details about these systems are provided in subsequent sections.[6]

Many of the building descriptors have 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. For HVAC systems, this one-to-one relationship generally does not hold. The HVAC system serving the proposed design and the baseline building may be completely different, each with different components, etc.

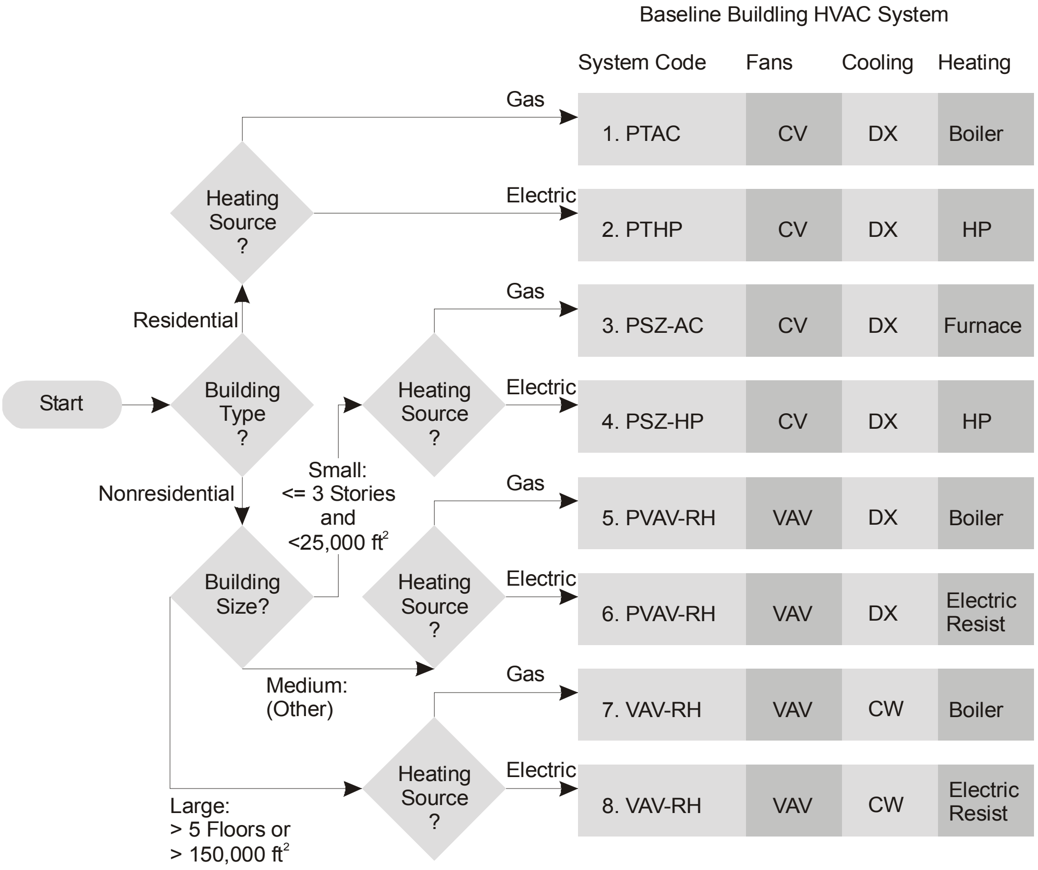


Figure 18 – HVAC Mapping

---

[6] Reviewers of this rules and procedures manual have argued that baseline building systems 6 and 8 are inappropriate for tax deduction calculations. A conference committee report on the EPACT 2005 commercial building energy tax deductions contains the following language, "The Committee intends that the methods for calculation be fuel neutral, such that the same energy efficiency features qualify a building for the deduction under this provision regardless of whether the heating source is a gas or oil furnace or boiler or an electric heat pump." This clause may be interpreted to mean that gas heating should be equivalent to a heat pump, not to resistance heating as prescribed for baseline building systems 6 and 8. A building that maps to baseline building systems 6 or 8 and one that uses a heat pump or other non-resistance sources for heating would get inappropriate credit from the PRM system mapping and would be able to reduce insulation, increase lighting power or make other trade-offs. Reviewers have noted that this was not the intent of the conference committee and that the IRS bulletins that reference the PRM are in conflict with the statute. COMNET will work to reconcile the conflict.

As part of the COMNET development process, two alternative HVAC system mappings were developed. Alternative one eliminated baseline building systems 6 and 8 and all medium and large nonresidential buildings were mapped to either baseline building system 5 or 7. Alternative two substituted a water loop heat pump system for systems 6 and 8.

For systems 1 through 4, each thermal block shall be served by a separate system. For systems 5 through 8, a single system serves the whole building with a separate air handler for each floor. Systems 5 and 6 are packaged equipment with DX cooling and fans combined in the same box. For these systems, each floor will have its own system.

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. These exceptions will typically apply to laboratories, data centers, and many spaces in healthcare facilities. See Chapter 7 for the special requirements for these building types. The exceptions are described below:

- Separate occupancies in mixed use buildings are served by separate baseline building systems. Examples include residential spaces located over retail and other similar conditions. (See the PRM, G3.1.1, Exception a.)
- A separate baseline building system shall serve laboratories or group of laboratories with an exhaust system designed for 5,000 cfm or more of air movement. The baseline building system serving the laboratory spaces shall be either system 5 (PVAV with hot water reheat) or system 6 (PVAV with parallel fan-powered boxes and electric reheat), depending on the heating source in the building. The PVAV system must be capable of reducing the exhaust and makeup air volume to 50% of design values during unoccupied periods. This exception essentially requires VAV for both the supply fan and the exhaust system. (See the PRM, G3.1.1, Exception c.)
- Spaces that do not trigger the laboratory exception above may still have a separate baseline building system. Either system 3 (PSZ-AC) or system 4 (PSZ-HP) shall serve spaces in the baseline building (depending on the heating source for the building) when one of the following conditions apply:
    - Spaces on a floor have significantly different schedules or internal heat loads. Heat gain differences of more than 10 Btu/h or operation schedule differences of more than 40 hours/week trigger this exception. (See the PRM, G3.1.1, Exception b.)
    - Spaces on a floor have "special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates". Many laboratory spaces with fume hoods would likely trigger this exception. (See the PRM, G3.1.1, Exception c.)

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 and air handlers shown in Figure 18.

6.1.3 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 pieces of information.

Building Descriptor Title	
Applicability	Information on when the building descriptor applies to the proposed design
Definition	A definition for the building descriptor
Units	The units that are used to prescribe the building descriptor
Input Restrictions	Any restrictions on information that may be entered for the proposed design
Baseline Rules	How the building descriptor applies to the baseline building

6.2 Project Data

6.2.1 General Information

Project Name

Applicability	All projects
Definition	Name used for the project, if one is applicable
Units	Up to 50 alphanumeric characters
Input Restrictions	Input is optional for the proposed design.
Baseline Rules	Not applicable

Project Address

Applicability	All projects
Definition	Street address, city, state, and zip code
Units	Up to 50 alphanumeric characters on each of two lines
Input Restrictions	Input is mandatory for the proposed design.
Baseline Rules	Not applicable

Project Owner

Applicability	All projects
Definition	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.
Units	Up to 50 alphanumeric characters
Input Restrictions	Input is optional for the proposed design.
Baseline Rules	Not applicable

Architect

Applicability	All projects
Definition	Architect responsible for the building design. Information should include name, title, organization, email, and phone number.
Units	Up to 50 alphanumeric characters
Input Restrictions	Input is mandatory for the proposed design.
Baseline Rules	Not applicable

HVAC Engineer

Applicability	All projects
Definition	HVAC Engineer responsible for the building design. Information should include name, title, organization, email, and phone number.
Units	

	Up to 50 alphanumeric characters
Input Restrictions	Input is mandatory for the proposed design. Information should include name, title, organization, email, and phone number.
Baseline Rules	Not applicable

Lighting Engineer/Designer

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

Energy Modeler

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

Date

Applicability	All projects
Definition	Date of completion of the rating analysis or the date of its most-recent revision
Units	Date format
Input Restrictions	Input is mandatory for the proposed design.
Baseline Rules	Not applicable

6.2.2 Baseline Standard

Purpose

Applicability	All projects
Definition	There are three possible purposes for which the COMNET software may be used: • Calculation of federal tax deductions • Credits under green building rating systems • Energy labels The choice here is a trigger for many of the building descriptor rules and procedures that follow.
Units	List: (see above)
Input Restrictions	

	Required input
Baseline Rules	The definition of the baseline building is derived from this input.

Building Classification

Applicability	When the whole building method is used instead of the space-by-space method of classifying activity in the building
Definition	The building type or principle 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 energy-related requirements for the baseline building design. Appendix B lists the building classifications that are available under the building area method.
Units	List: Choose a building activity from Appendix B or select "Space-by-Space" if the space-by-space method is used.
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 classification method or the space-by-space classification method must be used, but the two classification methods may not be mixed within a single rating.
Baseline Rules	The proposed design designations apply to the baseline building.

Baseline Standard

Applicability	All projects
Definition	The baseline standard that defines the baseline building. ASHRAE Standard 90.1-2001 is the baseline standard for tax deduction calculations. ASHRAE Standard 90.1-2007 is the baseline standard for green building ratings. This is determined from the Purpose (see above) and it may not be necessary to enter it explicitly.
Units	List: Either ASHRAE Standard 90.1-2001 or ASHRAE Standard 90.1-2007, depending on Purpose (see above).
Input Restrictions	None
Baseline Rules	Not applicable

Percent Savings Method

Applicability	Tax deduction calculations and green building ratings
Definition	The method used to calculate percent savings. For tax deductions, only regulated energy is addressed in the numerator and denominator of the percent savings calculation, while with green building ratings, all energy uses in the building are accounted for. Regulated energy includes interior lighting, heating, cooling, fans and hot water. Non-regulated energy is everything else. The same equation is used with both methods (see Equation (3)), however, the Q term only includes regulated energy for tax deductions, but total energy for green building ratings.

$$Percent\ Savings = \left(\frac{Q_{Baseline} - Q_{\Pr oposed}}{Q_{Baseline}} \right) \times 100 \tag{3}$$

Units	List
Input Restrictions	This building descriptor is determined from the purpose and is not generally input directly by the software user.

Baseline Rules	Not applicable

6.2.3 Geographic and Climate Data

The following data needs to be specified or derived in some manner. Software developers may use any acceptable method to determine the data. For instance, zip code could be entered and every thing else could be derived from this. Alternatively, state, county and city could be entered and the other variables could be derived from those. If the software allows for the parameters to be individually specified, then data validation should be employed to verify that the inputs are consistent with each other.

Zip Code

Applicability	All projects
Definition	One of approximately 44,000 postal designations in the United States
Units	List
Input Restrictions	None
Baseline Rules	Not applicable

Latitude

Applicability	All projects
Definition	The latitude of the project site
Units	Degrees (°)
Input Restrictions	None
Baseline Rules	Not applicable

Longitude

Applicability	All projects
Definition	The longitude of the project site
Units	Degrees (°)
Input Restrictions	None
Baseline Rules	Not applicable

Elevation

Applicability	All projects
Definition	The height of the building site above sea level
Units	Feet (ft)
Input Restrictions	None
Baseline Rules	Not applicable

Thermal Zone

Applicability	All projects

Definition	One of eight thermal zones defined in ASHRAE 90.1-2004 and later
Units	List
Input Restrictions	None
Baseline Rules	Used to determine building envelope and other criteria

Moisture Zone

Applicability	All projects
Definition	One of three moisture zones defined in ASHRAE 90.1-2004 and later
Units	List: Moist (A), Dry (B), or Marine (C)
Input Restrictions	None
Baseline Rules	Used to determine building envelope and other criteria

Time Zone

Applicability	All projects
Definition	The time zone measured from GMT
Units	List
Input Restrictions	Typically derived from other inputs such as zip code or state
Baseline Rules	Same time zone as the proposed design

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	Typically derived from other inputs such as zip code or state
Baseline Rules	Same as the proposed design

State

Applicability	All projects
Definition	The state where the project is located
Units	List
Input Restrictions	None
Baseline Rules	Not applicable

County

Applicability	All projects
Definition	The county where the project is located
Units	List
Input Restrictions	

	None
Baseline Rules	Not applicable

City

Applicability	All projects
Definition	The city where the project is located
Units	List
Input Restrictions	None
Baseline Rules	Not applicable

Weather Data for Simulation

Applicability	All projects
Definition	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.
Units	Various
Input Restrictions	Weather data should be representative of the long term conditions at the site
Baseline Rules	Weather data shall be the same for both the proposed design and baseline building

Ground Reflectance

Applicability	All projects
Definition	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.
Units	Data structure: schedule, fraction
Input Restrictions	None
Baseline Rules	Ground reflectance shall be the same for both the proposed design and the baseline building when it is specified to capture snow cover. When specific design features are incorporated to increase or reduce reflectance for the purpose of enhancing daylighting, there can be variation between the proposed design and the standard design, when appropriately documented.

6.2.4 Building Site Characteristics

Shading of Building Site

Applicability	All projects
Definition	Shading of building fenestration, roofs, or walls by other structures, surrounding terrain, vegetation, and the building itself
Units	Data structure
Input Restrictions	The default is for the site to be unshaded. The user may input the necessary

	information to model shading of the building site by any permanent object or feature likely to significantly reduce incident solar loads on the building site. *Permanent* here means likely to remain for the life of the building or likely to be replaced by objects that will produce similar shading over the life of the building.
Baseline Rules	The proposed and baseline building designs are modeled with identical assumptions regarding shading of the building site.

6.2.5 Calendar

Year for Analysis

Applicability	All projects
Definition	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.
Units	List: choose a year (other than a leap year).
Input Restrictions	Any calendar year that does not include a leap year.
Baseline Rules	Same calendar year as the proposed design

Schedule of Holidays

Applicability	All projects
Definition	A list of dates on which holidays are observed and on which holiday schedules are used in the simulations
Units	Data structure
Input Restrictions	The following ten holidays represent the default set. When a holiday falls on a Saturday, the holiday is observed on the Friday proceeding the Saturday. If the holiday falls on a Sunday, the holiday is observed on the following Monday.

New Years 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

	Other holiday sets may be observed when input by the user.
Baseline Rules	The baseline building model shall observe the same holidays specified for the proposed design.

6.2.6 Energy Price Data

The default energy rates for electricity and gas are shown in Chapter 5. Tables are provided for each of the thermal and moisture zones that include time-of-use rates for electricity and seasonal rates for gas, steam and chilled water.

Currency

Applicability	All projects
Definition	The currency used to compare the proposed design and the baseline building
Units	List: local energy costs, default time-of-use energy costs, EPA source energy, or site energy.
Input Restrictions	The default is time-of-use energy costs specified in Chapter 5.
Baseline Rules	Same as the proposed design

Local Electric Utility Rates

Applicability	When *Currency* (see above) is "local energy costs"
Definition	The local utility rate for electricity delivered to the building. The utility rate data entered under this descriptor may include a variety of rate features, such as demand charges, time of day rates, service charges, and taxes.
Units	Data structure
Input Restrictions	None
Baseline Rules	The baseline building shall use the same utility rate as the proposed design.

Local Gas Utility Rates

Applicability	When *Currency* (see above) is "local energy costs"
Definition	The utility rates for natural gas delivered to the building. The utility rate data entered under this descriptor may include seasonal variations, service charges, and taxes.
Units	Data structure
Input Restrictions	None
Baseline Rules	The baseline building shall use the same utility rate as the proposed design.

Local Other Utility Rates

Applicability	When *Currency* (see above) is "local energy costs"
Definition	The utility rates for chilled water, steam or other energy sources delivered to the building. The utility rate data entered under this descriptor may include seasonal variations, service charges, taxes, and other factors.
Units	Data structure
Input Restrictions	None
Baseline Rules	The baseline building shall use the same utility rate as the proposed design.

6.3 Thermal Blocks

A thermal block is a space or collection of spaces having similar space-conditioning requirements and is the basic thermal unit (or zone) used in modeling the building. A thermal block can include more than one HVAC zone, but HVAC zones are not split between thermal blocks.

6.3.1 General Information

Thermal Block Name

Applicability	All projects
Definition	A unique identifier for the thermal block made up of 50 or fewer alphanumeric characters.
Units	Text
Input Restrictions	None
Baseline Rules	Not applicable

Thermal Block Description

Applicability	All projects
Definition	A brief description of the thermal block that identifies the spaces that make up the thermal block or other descriptive information. The description should tie the thermal block to the building plans.
Units	Text
Input Restrictions	None
Baseline Rules	Not applicable

Thermal Block Type

Applicability	All projects
Definition	Designation of the thermal block as directly conditioned space, indirectly conditioned space (i.e., conditioned only by borrowed heating or cooling from an adjacent thermal block), or plenum (i.e., unoccupied but partially conditioned as a consequence of its role as a path for returning air).
Units	List: directly conditioned, indirectly conditioned, unconditioned or plenum
Input Restrictions	The default thermal block type is “directly conditioned.”
Baseline Rules	The descriptor is identical for proposed and baseline building designs.

System Name

Applicability	All projects
Definition	The HVAC system name of the system that serves this thermal block.
Units	Text, unique
Input Restrictions	None
Baseline Rules	The baseline may have a different system mapping if the baseline building has a different HVAC type than the proposed design.

Occupancy Type

Applicability	All projects
Definition	One of three occupancy categories used in determining the baseline building envelope requirements. The three categories are residential, nonresidential, and semi-heated.
Units	List: residential, nonresidential, or semi-heated
Input Restrictions	The input is derived from the building classification or from the classification of the spaces that make up the thermal block.
Baseline Rules	Same as the proposed design

Floor Area

Applicability	All projects
Definition	The gross floor area of a thermal block including walls and minor spaces for mechanical or electrical services, such as chases, that are not assigned to other thermal blocks; larger mechanical spaces and electrical rooms should not be combined. User input of floor areas of individual thermal blocks should be accurate to within 5% of actual, while user inputs of gross building areas should be accurate to within 2% of actual when measured to the outside surface of exterior walls.
Units	Square Feet (ft^2)
Input Restrictions	The floor area of the thermal block is derived from the floor area of the individual spaces that make up the thermal block.
Baseline Rules	Identical to the proposed design

6.3.2 Interior Lighting

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

For those instances when a thermal block contains more than one space, the software shall either model the lighting separate for each space and sum energy consumption and heat gain for each time step of the analysis or it must incorporate some procedure to sum inputs or calculate weighted averages such that the lighting data used at the thermal block level is equal to the combination of lighting data for each of the spaces contained in the thermal block.

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

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

6.3.3 Receptacle and Process Loads

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

For those instances when a thermal block contains more than one space, the software shall either model the receptacle and process loads separate for each space and sum energy consumption and heat gain for each time step of the analysis or it must incorporate some procedure to sum inputs or calculate weighted averages such that the receptacle and process loads used at the thermal block level are equal to the combination of receptacle and process loads for each of the spaces contained in the thermal block.

When the spaces contained in a thermal block 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 time step in the simulation. See discussion above on lighting.

6.3.4 Occupants

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

For those instances when a thermal block contains more than one space, the software shall either model the occupant loads separate for each space and the heat gain for each time step of the analysis or it must incorporate some procedure to sum inputs or calculate weighted averages such that the occupant loads used at the thermal block level are equal to the combination of occupant loads for each of the spaces contained in the thermal block.

When the spaces contained in a thermal block 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 time step in the simulation. See discussion above on lighting.

6.3.5 Infiltration

Infiltration Method	
Applicability	All projects
Definition	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 (ft²). Other methods require the specification of a maximum rate, which is modified by a schedule.
Units	List: effective leakage area, component leakage, air changes per hour, or other method supported by the energy analysis software.
Input Restrictions	For the purpose of federal tax credits, a fixed infiltration rate shall be specified and calculated 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. For green building ratings and energy labels, the default method is the component leakage method, however, there are no restrictions on other reasonable methods.
Baseline Rules	The infiltration method used for the proposed design shall be used for the baseline building.

Infiltration Data

Applicability	All projects
Definition	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 area in ft^2 or other suitable units and information to indicate the height of the building and how shielded the site is from wind pressures. The air-changes per hour (ACH) method requires an estimate of the ACH and a schedule which modifies the ACH for various periods during the year. Similar data would be specified for the leakage per component area method. Only zones with exterior wall area are assumed to be subject to infiltration.
Units	A *data structure* is required to define the effective leakage area model, while a single numeric value can define the ACH or the leakage per area of exterior envelope method.
Input Restrictions	For the purpose of federal tax credits, infiltration shall be equal to 0.038 times the gross wall area exposed to ambient outdoor air. For green building ratings and energy labels, 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.
Baseline Rules	The infiltration data for the baseline building shall be the same as the proposed design unless the proposed design employs specific measures that go beyond the mandatory measures specified by the *baseline standard*. When credit is taken for reductions in infiltration (see above), test results or research reports shall be provided that document and support the inputs used for the baseline building and the proposed design.

Infiltration Schedule

Applicability	When an infiltration method is used that requires the specification of a schedule
Definition	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 can also be fractional.
Units	Data structure: schedule, fractional
Input Restrictions	For the purpose of federal tax credits, the infiltration schedules from Appendix C, Tables 12 through 16 shall be used. The infiltration method and rate (see above) are also specified. For green building ratings and energy labels, the default infiltration schedule is 1.0 (100% of specified infiltration rate for periods of time when the fans serving the thermal block are not operating and a zero [no infiltration] for periods of time when the fans are operating). This is based on the assumption that the fans pressurize the space and that the impact of introducing outside air into the thermal block is accounted for in the operation of the HVAC system.
Baseline Rules	The infiltration schedule for the baseline building shall be the same as the proposed design.

6.3.6 Natural Ventilation

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

- The thermal block does not have an air conditioning system.

- The temperature of the thermal block does not exceed the cooling setpoint temperature for more than 300 hours for the year of the simulation with just the natural ventilation system operating.

Under these circumstances, the thermal block in the proposed design is modeled with no air conditioning when the natural ventilation system maintains temperature. For periods when the space temperature is greater than the cooling setpoint, an air conditioner 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 block in the baseline building is modeled with air conditioning and the fans operate continuously.

Natural Ventilation Method

Applicability	All thermal blocks with natural ventilation
Definition	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 is capable of estimating the cooling benefit of natural ventilation and relating it to climate so that the schedule can be developed.
Units	List: choices depend on the capabilities of the energy simulation program.
Input Restrictions	None
Baseline Rules	Baseline building is not modeled with natural ventilation.

Air Flow Rate

Applicability	All projects with natural ventilation that use a method that require the specification of an air flow rate
Definition	The rate of air flow through the thermal block when the natural ventilation system is operating
Units	Air changes per hour or cfm
Input Restrictions	The air flow rate for the proposed design shall be determined using sound engineering methods and supporting documentation shall be provided.
Baseline Rules	Baseline building is not modeled with natural ventilation.

Natural Ventilation Schedule

Applicability	All projects with natural ventilation that use a method that requires a schedule
Definition	A schedule that modifies the airflow rate through the thermal block dictates when windows can be opened to provide natural ventilation.
Units	Data structure: schedule, fractional
Input Restrictions	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.
Baseline Rules	The baseline building is not modeled with natural ventilation.

6.3.7 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

Applicability	All projects
Definition	This building descriptor only addresses the building contents. The 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. The thermal capacitance of the building contents are typically specified in terms of the composite weight of the building contents in lb/ft² 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 times the specific heat of the contents. The latter method would be a summation, since each item may have a different specific heat.
Units	lb/ft² or lb
Input Restrictions	Any reasonable inputs, consistent with the proposed design and the method used by the simulation program to model interior thermal mass
Baseline Rules	The interior thermal mass in the baseline building shall be the same as the proposed design.

Furniture and Contents

Applicability	All projects
Definition	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 gains that enters the space is directed to the floor with delayed heat gain and how much becomes a more instantaneous load.
Units	Data structure
Input Restrictions	Any reasonable inputs, consistent with the proposed design and the method used by the simulation program to model interior thermal mass.
Baseline Rules	The interior thermal mass and modeling assumptions in the baseline building shall be the same as the proposed design.

6.4 Space Uses

Each thermal block discussed above may be subdivided into HVAC zones and the HVAC zones may be further 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 Appendix B. Every thermal block shall have at least one space, as defined in this section.

6.4.1 General Information

Classification

Applicability	When building space type uses are known and can be delineated within the building area
Definition	

	Space-by-space classification is one of two available classification methods for identifying the function of the building, which in turn determine certain energy-related requirements for the baseline and create defaults for the proposed building design. See Appendix B for a list of the building types and space types that may be selected.
Units	List: See the tables in Appendix B. If the building activity is specified by the whole building method, then this input is not applicable.
Input Restrictions	The space-by-space method is restricted to the common space types defined in Section 9 of ASHRAE 90.1 and listed in Appendix B. Detailed information about each space must be known in order for the space-by-space method to be used over the whole building method. Either method may be used, but the two may not be mixed within a single rating.
Baseline Rules	The baseline building shall have a corresponding space type for each one in the proposed design and the classifications shall be the same.

Floor Area

Applicability:	All projects that use the space-by-space classification method (see above)
Definition:	The floor area of the space. The area of the spaces that make up a thermal block shall sum to the floor area of the thermal block.
Units	Square Feet (ft^2)
Input Restrictions:	Area shall be measured to the outside of exterior walls and to the center line of partitions.
Baseline Rules	Area shall be identical to the proposed design.

6.4.2 Occupants

Number of Occupants

Applicability	All projects
Definition	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.
Units	The number of persons may be specified in an absolute number, ft^2/person, or persons/1000 ft^2.
Input Restrictions	The number of occupants is prescribed for tax deductions, but is a default for green building ratings and energy labels. For tax deductions, the values in Appendix B from the California 2005 ACM shall be used. Other defaults are also shown in Appendix B.
Baseline Rules	The number of occupants must be identical for both the proposed and baseline design cases.

Occupant Heat Rate

Applicability	All projects
Definition	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.

Units	Btu/h specified separately for sensible and latent gains
Input Restrictions	The occupant heat rate is prescribed for tax deductions, but is a default for green building ratings and energy labels. For tax deductions, the values in California 2005 ACM Appendix B from the shall be used.
Baseline Rules	The occupant heat rate for the baseline building shall be the same as the proposed design.

Occupancy Schedule

Applicability	All projects
Definition	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 on an hourly basis 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.
Units	Data structure: schedule, fractional.
Input Restrictions	The occupant schedule is prescribed for tax deductions, but is a default for green building ratings and energy labels. For tax deductions, an appropriate schedule from Appendix C Tables 12-16 (California 2005 ACM) shall be used.
Baseline Rules	Occupancy schedules are identical for proposed and baseline building designs.

6.4.3 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 a general and task lighting system in offices or hotel multi-purpose rooms that have lighting systems for different functions.

Regulated Interior Lighting Power

Applicability	All projects
Definition	Total connected lighting power for all regulated interior lighting power. This includes the loads for lamps and ballasts.
Units	W/ft²
Input Restrictions	As designed. The connected power should be cross-referenced to a space type and to the construction documents
Baseline Rules	With the building classification method, use the product of the lighting power density for the building classification from Appendix B and the floor area of the space. With the space-by-space method, use the product of the lighting power densities for the space-by-space from Appendix B and the floor areas for the corresponding spaces. Choose values from ASHRAE Standard 90.1-2001 or ASHRAE Standard 90.1-2007, depending on the purpose of the analysis.

Non-Regulated Interior Lighting Power

Applicability	All projects
Definition	Power for the following lighting equipment and applications are exempt from the

baseline standards, provided they are controlled by an independent control device:

(a) Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments.

(b) Lighting that is integral to equipment or instrumentation and is installed by its manufacturer.

(c) Lighting specifically designed for medical or dental procedures and lighting integral to medical equipment.

(d) Lighting integral to both open and glass enclosed refrigerator and freezer cases.

(e) Lighting integral to food warming and food preparation equipment.

(f) Lighting for plant growth or maintenance.

(g) Lighting in spaces specifically designed for use by the visually impaired.

(h) Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.

(i) Lighting in interior spaces that have been specifically designated as registered historic landmark interiors.

(j) Lighting that is an integral part of advertising or directional signage.

(k) Exit signs

(l) Lighting that is for sale or lighting educational demonstration systems.

(m) Lighting for theatrical purposes including performance, stage, motion picture or television production.

(n) Lighting for television broadcasting in sporting activity areas.

(o) Casino gaming areas.

(p) Furniture mounted supplemental task lighting that is controlled by automatic shut-off and local control (added in ASHRAE 90.1-2007).

In addition, lighting is exempt that is specifically designated as required by a health or life safety statute, ordinance, or regulation for reasons of safety or security.

Emergency lighting that is automatically off during normal building operation is not considered.

Units	W/ft^2
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 Rules	The non-regulated interior lighting in the baseline building shall be the same as the proposed design.

Lighting Schedules

Applicability	All projects
Definition	Schedule of operation for interior lighting power used to adjust the energy use of lighting systems on an hourly basis to reflect time-dependent patterns of lighting usage. Different schedules may be defined for different lighting circuits, depending on the capabilities of the software.
Units	Data structure: schedule, fractional
Input Restrictions	

The lighting schedule is prescribed for tax deductions, but is a default for green building ratings and energy labels. For tax deductions, an appropriate schedule from Appendix C Tables 12-16 for the California 2005 ACM shall be used. For green building ratings and energy labels, the default schedules are presented in Appendix C.

Baseline Rules

The baseline building shall use the same lighting schedules as the proposed design. The only exception to this rule is when the proposed design has a task/ambient lighting system. In this case the proposed design task lighting system may be controlled on a different schedule and the proposed design schedule proposed for the ambient lighting system is used for all the lighting in the baseline building.

Retail Display Lighting Power

Applicability

Display lighting in retail display and other space-by-space classifications

Definition

Display lighting is special lighting to highlight merchandise. Its purpose is to enhance the visual appearance of the merchandise and not to provide lighting for a visual task. Display lighting is treated as use-it-or-loose-it in ASHRAE Standard 90.1-2001 and ASHRAE Standard 90.1-2007, the baseline standards. To qualify for display lighting under these standards, the lighting must be separately controlled from the general lighting.

ASHRAE Standard 90.1-2001 defines two categories of display lighting:

- General display
- Valuable merchandise display (this includes “jewelry, fine apparel and accessories, china and silver, art, and similar items, where detailed display and examination of merchandise are important”)

ASHRAE Standard 90.1-2007 defines four categories of display lighting:

- Retail Area 1 (all other)
- Retail Area 2 (vehicles, sporting goods)
- Retail area 3 (furniture clothing cosmetics)
- Retail area 4 (jewelry, crystal, china).

Units

W or W/ft²

Input Restrictions

As designed. The default for lighting power for retail display wattage is 0.0 watts. When display lighting is entered in the software, its purpose shall be defined (see the categories above in the definitions section).

Baseline Rules

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 allowances in Table 35.

Table 35 – Lighting Power Allowances for Retail Display Lighting

ASHRAE Standard 90.1-2001		ASHRAE Standard 90.1-2007	
Category	Allowed Power (W/ft²)	Category	Allowed Power (W/ft²)
General merchandise	1.6	Retail Area 1	1.0
Valuable merchandise	3.9	Retail Area 2	1.7
		Retail area 3	2.6
		Retail area 4	4.2

Decorative Lighting Power

Applicability

All projects that have decorative lighting and are rated using the space-by-space

	method
Definition	Decorative lighting includes wall sconces, chandeliers and other decorative lighting that is provided for purposes other than illuminating visual tasks. The baseline standards treat this lighting as use-it-or-lose-it.
Units	W or W/ft²
Input Restrictions	As designed. The default for decorative lighting power is 0.0 watts/ft² . 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.
Baseline Rules	For the space-by-space method, decorative lighting power in the baseline building is equal to the lesser of the actual wattage of decorative lighting specified for the proposed design or 1.0 W/ft².

Lighting Power for VDT Viewing

Applicability	Tax deductions only (ASHRAE Standard 90.1-2001 baseline)
Definition:	ASHRAE Standard 90.1-2001 provided additional lighting in spaces that are intended for use with video display terminals (VDT). This special allowance was eliminated with ASHRAE Standard 90.1-2007 and only applies for the purpose of calculating tax deductions. In order for a space to qualify for the special allowance, the specified luminaires must have special optical characteristics that direct most of the light down and minimize light cast to the sides. Specifically, a qualifying luminaire must serve a VDT viewing task and provide a maximum luminance measured from the vertical of 80 candelas/ft² at 65 degrees, 33 candelas/ft² 75 degrees and 17 candelas/ft² at 85 degrees or greater.
Units	W/ft²
Input Restrictions	As designed. The default for lighting power for VDT viewing is 0.0 watts/ft² . The user may input qualifying lighting power for qualifying areas with cross-references to lighting schedules and spaces on the construction documents. A cut-sheet tabulating the candela distribution of the luminaires shall be provided.
Baseline Rules	The allowed lighting power for qualifying spaces is increased by 0.35 W/ft² from the allowed values in Appendix B.

Light Heat Gain Distribution

Applicability	All projects
Definition	The distribution of the heat generated by the lighting system that is directed to the space, the plenum, the HVAC return air, or to 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 – Fundamentals, summarized in Table 36 below. Typically the data will be linked to list of common luminaire configurations similar to Table 36 so that the user chooses a luminaire type category and heat gain is automatically distributed to the appropriate locations. This input may also be used to approximate the benefit of displacement ventilation (see Chapter 7).
Units	List (of luminaire types) or data structure consisting of a series of decimal fractions that assign heat gain to various locations.

Input Restrictions	Default values listed in Table 36 shall be used as a default when the luminaire categories apply. Values within the ranges of Table 36 may be used when following the rules in the 2009 HOF. Other values may be used when manufacturers' literature and/or testing data is available, and adequate documentation is provided to the rating authority. 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.
Baseline Rules	The baseline building shall use the above referenced defaults.

Table 36 – Light Heat Gain Parameters for Typical Operating Conditions
Source: 3, Table 3, Chapter 18, 2009 ASHRAE Handbook – Fundamentals

Luminaire Category	Space Fraction	Radiative Fraction
Recessed fluorescent luminaire without lens	0.64 to 0.74 (default 0.69)	0.48 to 0.68 (default 0.58)
Recessed fluorescent luminaire with lens	0.40 to 0.50 (default 0.45)	0.61 to 0.73 (default 0.67)
Downlight compact fluorescent luminaire	0.12 to 0.24 (default 0.18)	0.95 to 1.00 (default 0.97)
Downlight incandescent luminaire	0.70 to 0.80 (default 0.75)	0.95 to 1.00 (default 0.97)
Non-in-ceiling fluorescent luminaire	1.0 (default 1.0)	0.50 to 0.57 (default 0.53)

Power Adjustment Factors (PAF)

Applicability	All projects
Definition	Automatic controls that are not already required by the baseline standard and which reduce lighting power more or less uniformly over the day can be modeled as power adjustment factors. Power adjustment factors represent the percent reduction in lighting power that will approximate the effect of the control. Models account for such controls by adjusting the installed power by (1 – PAF). The types of controls that are recognized for credit are listed in ASHRAE Standard 90.1-2007, Appendix G, Table G3.2 and shown below in Table 37.
Units	List: control types (see above) linked to PAFs
Input Restrictions	As designed
Baseline Rules	PAF is zero

Table 37 – Power Adjustment Factors

Automatic Control Device	Non-24-hour occupied buildings that are less than 5,000 ft²	Other buildings
Programmable timing control	10%	0%
Occupant sensor	15%	10%
Occupant sensor and programmable timing controls	15%	10%
Bi-level parking garage controls7	30%	30%
Bi-level controls in hotel corridors	20%	20%
Scene controller with timeclock	20%	20%

6.4.4 Daylighting Control

This group of building descriptors is applicable for spaces that have daylighting controls.

---

[7] Bi-level Smart LED Parking Garage Lighting, Public Interest Energy Research Program IOU Partnership Draft-Case Study http://cltc.ucdavis.edu/images/_projects/demonstration/bi_level_smart_led_parking_garage_lighting/pier_demo_uc_csu_bi_level_smart_led_parking_garage_lighting.pdf

Daylight Modeling Method

Applicability All spaces with daylighting controls

Definition The method used to model daylighting. Daylighting credits must be calculated based on the local climate and daylight models of the space (i.e. default credits are not sufficient). Building descriptors are provided in this section for an internal daylighting model and two variations of an external daylighting model:

1. **Internal daylighting model**. With this method the simulation model has the capability to model the daylighting contribution for each hour of the simulation and make an adjustment to the lighting power for each hour, taking into account factors such as daylighting availability, geometry of the space, daylighting aperture, control type and the lighting system. The assumption is that the geometry of the space, the reflectance of surfaces, the size and configuration of the daylight apertures, and the light transmission of the glazing are taken from other building descriptors.
2. **External daylighting model**. An external daylighting model may be used in combination with an hourly simulation program to calculate daylighting savings as long as it produces consistent results and makes use of the key assumptions described below for internal daylighting models. Exterior daylight models include, but are not limited to, the following types of methods:
    A. **Schedule adjustments**. With this method, a space is modeled in a stand alone daylighting program to determine the amount of interior daylight available different times of the year and for different times of the day. In addition this program has an electric lighting model that calculates the electricity savings by hour based on interior illuminance and the daylighting control type (switching, dimming etc.). These savings values are converted into a schedule of electric lighting power reduction multipliers. This lighting power reduction schedule is applied to the proposed design energy simulation model and results in reduced electric lighting energy consumption and reduced internal heat gain, both of which are reflected in the proposed design energy consumption.

    B. **Daylight ratio**. With this method, an outside program pre-calculates a relationship between outdoor daylight conditions (illuminances or luminances) and interior illuminance. Within the rating software, interior illuminance is calculated from the daylighting ratios and the daylight conditions derived from data on the local weather file. The remainder of the calculations are the same as for an internally calculated daylight model where the interior illuminances are compared to an illuminance setpoint and electric lighting power is calculated based on control type. The two most widely used methods of pre-calculating daylighting ratios are the modified daylight factor method and the daylight coefficients method.

        (a) The modified daylight factor method uses pre-calculated diffuse and direct illuminance daylight factors and multiplies these by diffuse and direct beam outdoor illuminance from the weather file to calculate interior illuminance.[8] Daylight factors are calculated from a simulation of the space that relies on user entered information about the space modeled such as orientation, geometry, material properties (transmittances and reflectances) etc. For any given hour, the interior illuminance at the reference point is calculated by the direct beam angle specific daylight factor multiplied by the outdoor direct beam and clear sky illuminance and

---

[8] F. Winkelmann & S. Selkowitz. "Daylighting Simulation in DOE-2: Theory, Application, Validation and Applications." LBL-19829. http://simulationresearch.lbl.gov/dirpubs/19829.pdf

this is added to the overcast daylight factor multiplied by the overcast sky illuminance. Outdoor direct beam, clear sky and overcast sky illuminances are calculated from the weather data used in the proposed building energy simulation.

(b) The daylight coefficients method is essentially a similar but more accurate method that relates internal illuminance to the luminance of patches of the sky.[9] The sky is divided up into patches as defined by altitude and azimuth. The daylight coefficients are ratios of interior illuminance to luminance for patches or areas on the sky dome. An outside daylight simulation program uses information about the space modeled: its orientation, geometry, material properties (transmittances and reflectances) etc, and calculates daylight coefficients for each sky patch. The precalculated daylight coefficients are then used to calculate interior illuminances for each hour. The illuminance for a location with the space at any point in time is the product of the luminance for each sky patch multiplied by the specific daylight coefficient for each sky patch integrated over the entire sky dome. The luminance for each sky patch is calculated from the weather data used in the proposed building energy simulation.

Other methods may be used by software developers as long as they produce consistent results. Regardless of the method used, it is desirable that all methods have the same key assumptions.

Daylight Modeling Method (continued)

Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Not applicable

Lighting Schedules for Daylighting

Applicability	Daylighted spaces that use the *schedule adjustment* method
Definition	A schedule that indicates the reduction in electric lighting for the lighting system that is being controlled. This schedule is applied to the *lighting schedule* (see above) to produce a schedule for lighting with daylighting controls.
Units	Data structure: schedule, fractional
Input Restrictions	The schedule of adjustments should account for seasonal variations in the time of day. Since the schedule will apply for both sunny days and overcast days, the adjustments should represent the conservative condition, e.g. the smallest savings.
Baseline Rules	Baseline does not have daylighting

Daylight Ratios

Applicability	Daylighted spaces that use the *daylight ratio* method
Definition	A matrix of daylight factors for the space that represent the ratio on illumination at the daylighting reference point to the exterior illumination. The simulation engine calculates the daylighting illumination at the reference point based on this information

---

[9] Tregenza P., Waters I, “ Daylight coefficients”, Lighting Research and Technology, 15(2), pp. 65- 71, 1983

	and the exterior illumination and uses the daylighting control building descriptors to determine for each hour how the lighting power is reduced.
Units	Data structure: matrix
Input Restrictions	The special daylighting program used to calculate the daylight factors should use inputs consistent with those described below for the *internal daylight model* method.
Baseline Rules	The baseline building does not have daylighting

Daylighted Area

Applicability	All daylighted spaces
Definition	The floor area that is daylighted. Two types of 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.
Units	Data structure
Input Restrictions	The default primary daylight area for sidelighting is a band near the window with a depth equal to the distance from the floor to the top of the window. The default secondary daylight area for sidelighting is a band beyond the primary daylighted area that extends a distance double the distance from the floor to the top of the window. Other daylight areas may be defined with appropriate documentation. The default primary daylight area for toplighting is a band around the skylight well that has a depth equal to the 70% of the ceiling height. The default secondary daylight area for toplighting is a band beyond the primary daylighted area that extends 140% of the ceiling height. Daylighted areas may not overlap or extend beyond partitions higher than 5 ft. Error checking includes ensuring that the following is true: • Sidelit depth is less than or equal to ceiling height. • Total daylit area is no greater than space area.
Baseline Rules	The baseline building does not have daylighting

Reference Position for Illuminance Calculations

Applicability	Daylighted spaces that use the *internal daylight model* method
Definition	The position of the daylight reference point within the daylighted space. Lighting controls are simulated so that the illuminance at the reference position is always 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 stage of lighting can be tuned off. 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.
Units	Data structure
Input Restrictions	The reference location shall be as far away from daylight apertures as possible (but still within the daylighted area) so that all occupants have sufficient amounts of total illuminance (combined daylight and electric light) under all daylighting conditions.
Baseline Rules	The baseline building does not have daylighting.

Illuminance Setpoint

Applicability	Daylighted spaces that use the *internal daylight model* method
Definition	The design illuminance for the daylighted space. The daylighting control adjusts the controlled lighting to maintain this level of illuminance at the reference point.
Units	Footcandles
Input Restrictions	As designed, but should be consistent with the visual tasks in the space and the recommendations of the IESNA.
Baseline Rules	Baseline does not have a daylighting control.

Fraction of Controlled Lighting

Applicability	Daylighted spaces that use the *internal daylight model* method or the *daylight ratio* method
Definition	The fraction of the lighting power in the daylighted space that is controlled by daylight. This is applicable when some of the luminaires in the space are controlled by daylighting and others are not. This input can be eliminated if multiple lighting systems are modeled for each space and the system that is controlled by daylight is separately specified.
Units	Numeric: fraction
Input Restrictions	As designed
Baseline Rules	Baseline does not have a daylighting control.

Daylighting Control Type

Applicability	Daylighted spaces that use the *internal daylight model* method or the *daylight ratio* method
Definition	The type of control that is used to control the electric lighting in response to daylight available at the reference point. The options are: • Step Switching controls have discrete steps of light output, where the fraction of rated power matches the fraction of light output. See Figure 19. • Step Dimming controls also 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. See Figure 19. • 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 diming light fraction* to rated power (power fraction = 1.0) at full light output. See Figure 20. • 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 20.

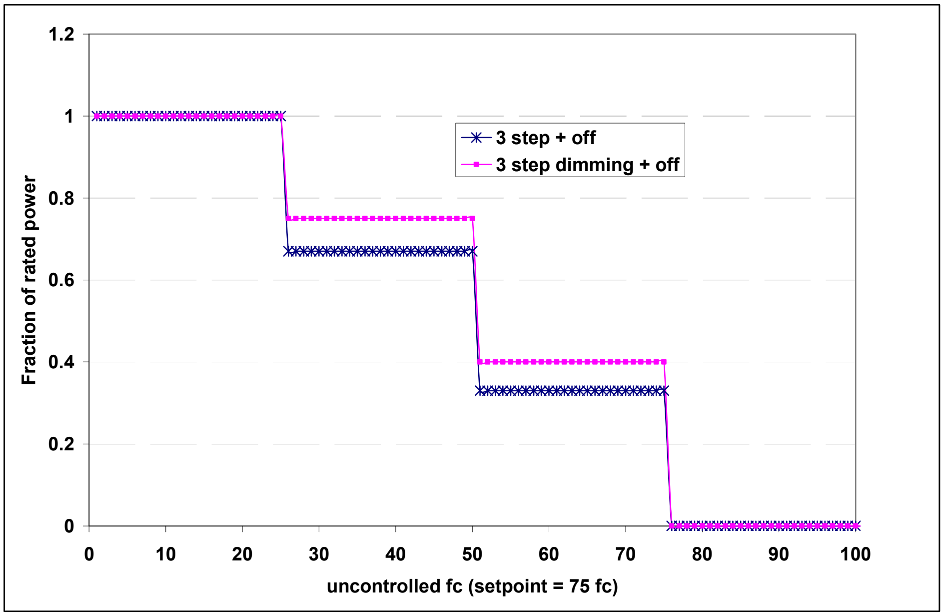


Figure 19 – Example Stepped Daylighting Control

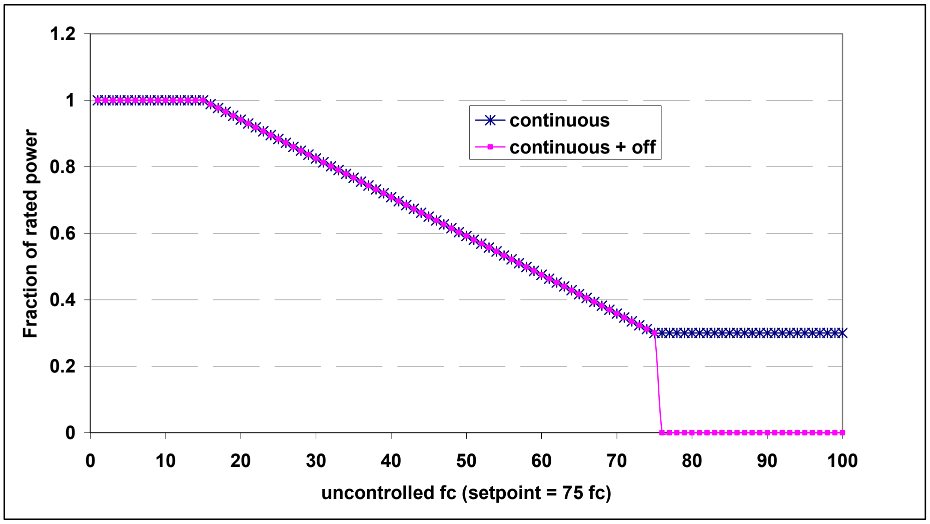


Figure 20 – Example Dimming Daylight Control

Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Baseline does not have a daylighting control.

Minimum Dimming Power Fraction

Applicability	Daylighted spaces that use the *internal daylight model* method or the *daylight ratio* method and dimming controls
Definition	The minimum power fraction when controlled lighting is fully dimmed. Minimum power fraction = (Minimum power) / (Full rated power). See Figure 20.
Units	Numeric: fraction

Input Restrictions	As designed
Baseline Rules	Baseline does not have a daylighting control.

Minimum Dimming Light Fraction

Applicability	Daylighted spaces that use the *internal daylight model* method or the *daylight ratio* method and dimming controls
Definition	Minimum light output of controlled lighting when fully dimmed. Minimum light fraction = (Minimum light output) / (Rated light output). See Figure 20.
Units	Numeric: fraction
Input Restrictions	As designed
Baseline Rules	Baseline does not have a daylighting control.

Number of Control Steps

Applicability	Daylighted spaces that use the *internal daylight model* method or the *daylight ratio* method and stepped controls
Definition	Number of control steps. For step switching, this term defines even steps of light output and even steps of rated power fractions. For step dimming, identifies number of steps that require fraction of rated light output and rated power fraction.
Units	Numeric: integer
Input Restrictions	Integer less than 10.
Baseline Rules	Baseline does not have a daylighting control.

Step Dimming Control Points

Applicability	Daylighted spaces that use the *internal daylight model* method or the *daylight ratio* method and stepped dimming controls
Definition	Number of control steps. For step switching, this term defines even steps of light output and even steps of rated power fractions. For step dimming, identifies number of steps that require fraction of rated light output and rated power fraction.
Units	Data structure. Matched pairs of data (light output and fraction of rated power) for the defined number of control steps
Input Restrictions	Integer less than 10. More than 10 steps approximate with continuous dimming.
Baseline Rules	Baseline does not have a daylighting control.

6.4.5 Receptacle and Process Loads

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

Receptacle and Process Power

Applicability	All building projects
Definition	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 will 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/ft²)

Input Restrictions

For federal tax deductions, values from the California 2005 ACM column from Appendix B shall be used as a prescribed value. For this purpose, there is no credit for reductions in receptacle loads.

For green building ratings and energy labels, receptacle loads in the proposed design may be calculated in one of three ways:

- The COMNET recommended defaults from Appendix B may be used, in which case the same values are used for the baseline building and there is no credit for reductions.
- If detailed information is known, the receptacle power can be calculated using Equations (4) and (5). In this instance, the energy analyst must be able to estimate the number of personal computers, the number of printers and the number of other equipment in the space. If this detail is not available, then Method 1 above must be used. With Method 2, the multipliers in Equation (5) shall be equal to 1.0, e.g. no credit for reductions.
- If detailed information is known and the owner is willing to make a long term commitment to purchase ENERGY STAR equipment, then Method 3 may be used. Method 3 is the same as Method 2, except that credit may be taken in the proposed design for reductions in receptacle power. The magnitude of the reduction depends on the length of the commitment, as determined from Table 40.

Baseline Rules

With Methods 1 and 2, the receptacle power in the baseline building shall be the same as the proposed design. When Method 3 is used for the proposed design, the baseline building receptacle power is established using Method 2, thereby providing a credit.

Requirements for Long Term Commitment

One of the largest hurdles is establishing accountability; savings must be verified and credible. A commitment to good behavior will have to be documented appropriately, either in leasing language, within corporate (or organizational) resolutions, or in tenant manuals to ensure that energy efficient equipment will be used not only initially but also for future replacements. The inability to make long term commitments has prevented credits from being offered, since the equipment that makes up receptacle loads is short lived and replaced frequently. It is unfortunate that buildings have been restricted in this dimension since there is significant room for saving energy, especially as state and local regulations become more stringent and some strive for zero net-energy.

Equations for Estimating Receptacle Loads

This section describes the COMNET procedure for estimating receptacle and process power when detailed information is known. The procedure provides a means for taking credit for energy reductions when the owner is willing to make a long term commitment to purchase ENERGY STAR equipment. COMNET Methods 2 and 3 are based on procedures developed by NREL[10] which estimate receptacle and process power density based on a count of computers, printers and other equipment in the space. The procedure is shown in Equations (4) and (5).

$$P = \left(\mathrm{Csd} \cdot \mathrm{PDsd} + \mathrm{PDmisc}\right) \cdot d \tag{4}$$

where

P	is the estimated power density for the space in W/ft².
PD_{sd}	is an estimate of receptacle power from personal computers, monitors, servers, printers and other equipment determined from Equation (5). Units are W/ft².
PD_{misc}	is an estimate of miscellaneous receptacle power for equipment not specifically accounted for in PD_{sd}.
$C_{sd,}$	is an adjustment coefficient from Appendix B, Table 2 based on the occupancy of the space. This coefficient along with PD_{misc} accounts for unreported equipment. C_{sd} scales with the estimated equipment power, while PD_{misc} is a constant.
d	is a diversity factor from Appendix B, Table 2 based on the occupancy of the space.

$$PD_{sd} = \frac{\begin{array}{c} M_{PC} \cdot P_{PC} \cdot N_{PC} + M_{CRT} \cdot P_{CRT} \cdot N_{CRT} + M_{LCD} \cdot P_{LCD} \cdot N_{LCD} + M_{Server} \cdot P_{Server} \cdot N_{Server} + M_{POS} \cdot P_{POS} \cdot N_{POS} + \\ M_{Las} \cdot P_{Las} \cdot N_{Las} + M_{Ink} \cdot P_{Ink} \cdot N_{Ink} + M_{Copy} \cdot P_{Copy} \cdot N_{Copy} + M_{\mathrm{Re}frig} \cdot P_{\mathrm{Re}frig} \cdot N_{\mathrm{Re}frig} + M_{Vend} \cdot P_{Vend} \cdot N_{Vend} \end{array}}{Area} \tag{5}$$

where

M_{xx}	is the energy efficiency multiplier from Table 40 for the “xx” device in question. For Method 2, M_{xx} is always unity (1.0), e.g. no credit.
N_{xx}	is the number of devices in the proposed design for the “xx” device in question.
P_{xx}	is the nominal mean power from Table 38 for the “xx” device in question.
Area	is the area of the space in ft².

Credit is limited to equipment where the ENERGY STAR program applies, including PCs, monitors, copiers, laser and inkjet printers, vending machines, and refrigerators. No credit is offered for equipment for which the program does not apply.

---

[10] Griffith, B, *et. al.*, Methodology for Modeling Building Energy Performance across the Commercial Sector, Technical Report, (NREL/TP-550-41956, March 2008, Appendix C, Section C.14. Note that elevators and escalators have been removed from the NREL equation, since they are treated separately.

Table 38 – Nominal Mean Power for Surveyed Devices

Subscript	Mean Nominal Peak Power Levels of Surveyed Devices	CBECS Variable	Data Source	Nominal Mean Power (W)
PC	Personal computers	PCNUM8	Roth et al. 2002	55
CRT	CRT personal computer monitors	PCNUM8	Roth et al. 2002	90
LCD	Flat personal computer monitors	PCNUM8	Roth et al. 2002	25
Server	Servers	SRVNUM8	Roth et al. 2002	650
POS	Point of sale (cash registers)	RGSTRN8	Roth et al. 2002	50
Las	Laser Printers	PRNTRN8	Roth et al. 2002	263
Ink	Ink Jet Printers	PRNTRN8	Roth et al. 2002	42.5
Copy	Copy machines	COPRN8	Roth et al. 2002	660
Refrig	Residential refrigerators	RFGRSN8	Assumption	350
Vend	Vending machines	RFGVNN8	Assumption; see ADL 1993)	450

Table 39 – Credits for Energy Efficient Equipment

The credits are based on a 4% discount rate, which is consistent with the ENERGY STAR program.

		Credit for Energy STAR Equipment							
Subscript	Equipment	1 Year	2 Years	4 Years	5 Years	10 Years	15 Years	20 Years	30 Years
PC	PC	0.014	0.028	0.054	0.067	0.121	0.165	0.201	0.254
CRT	CRT Monitors	0.031	0.060	0.115	0.141	0.256	0.349	0.425	0.538
LCD	LCD Monitors	0.019	0.037	0.071	0.087	0.158	0.216	0.263	0.333
Server	Servers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
POS	POS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Las	Laser Printers	0.015	0.029	0.056	0.069	0.125	0.171	0.209	0.264
Ink	Inkjet Printers	0.027	0.052	0.100	0.123	0.223	0.304	0.370	0.469
Copy	Copiers	0.004	0.007	0.014	0.018	0.032	0.044	0.053	0.067
Refrig	Residential Refrigerators	0.011	0.022	0.043	0.052	0.095	0.130	0.159	0.201
Vend	Vending Machines	0.020	0.039	0.075	0.092	0.168	0.229	0.279	0.353

Table 40 – Multipliers for Energy Efficient Equipment (1 – Credit)

The credits are based on a 4% discount rate, which is consistent with the ENERGY STAR program.

		Multiplier for Energy STAR Equipment							
Subscript	Equipment	1 Year	2 Years	4 Years	5 Years	10 Years	15 Years	20 Years	30 Years
PC	PC	0.986	0.972	0.946	0.933	0.879	0.835	0.799	0.746
CRT	CRT Monitors	0.969	0.940	0.885	0.859	0.744	0.651	0.575	0.462
LCD	LCD Monitors	0.981	0.963	0.929	0.913	0.842	0.784	0.737	0.667
Server	Servers	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
POS	POS	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Las	Laser Printers	0.985	0.971	0.944	0.931	0.875	0.829	0.791	0.736
Ink	Inkjet Printers	0.973	0.948	0.900	0.877	0.777	0.696	0.630	0.531
Copy	Copiers	0.996	0.993	0.986	0.982	0.968	0.956	0.947	0.933
Refrig	Residential Refrigerators	0.989	0.978	0.957	0.948	0.905	0.870	0.841	0.799
Vend	Vending Machines	0.980	0.961	0.925	0.908	0.832	0.771	0.721	0.647

Receptacle Schedule

Applicability	All projects

Definition	Schedule for receptacle power loads used to adjust the intensity on an hourly basis to reflect time-dependent patterns of usage.
Units	Data structure: schedule, fraction
Input Restrictions	For tax deductions, the schedule is prescribed. For green building ratings and energy labels it is a default. The schedule from Appendix B, Tables 12 through 16 shall be used for tax deductions. The default schedule for green building ratings and energy labels is taken from Tables 1 through 11 of Appendix C.
Baseline Rules	Schedules for the baseline building shall be identical to the proposed design.

6.4.6 Commercial Refrigeration Equipment

Commercial refrigeration equipment includes the following:

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

The 2008 California energy efficiency standards include refrigerated warehouses for the first time and there are plans to include walk-in refrigerators and freezers in the next update for 2011. ASHRAE has expanded the scope for Standard 90.1 to include more process energy, including commercial refrigeration. The building energy efficiency standards generally do not address commercial refrigeration, however, a recent USDOE standard scheduled to become effective in 2012 does address some of the equipment.

Walk-in refrigerators and freezers typically have remote condensers. Some refrigerated casework has remote condensers, while some have a self-contained condenser built into the unit. Refrigerated casework with built-in condensers reject 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. USDOE has developed standards for refrigerated casework. Table 41 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 41 – USDOE Requirements for Refrigerated Casework (kWh/d)

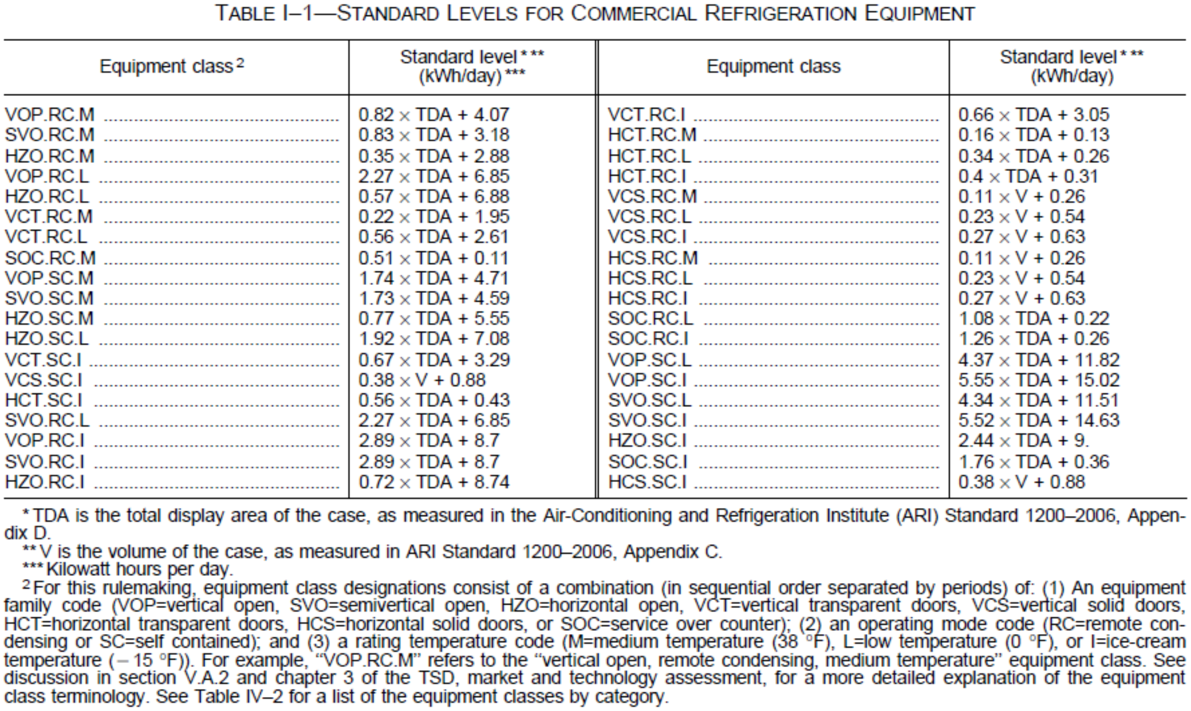


TABLE I–1—STANDARD LEVELS FOR COMMERCIAL REFRIGERATION EQUIPMENT

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

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

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

*** Kilowatt hours per day.

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

Walk-in refrigerators and freezers are not covered by the USDOE standards and test procedures. COMNET default values for these are given in Table 42. These values are expressed in W/ft² 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 (6).

$$P_{Walk-in} = \left(\mathrm{A}_{\mathrm{Ref}} \cdot \mathrm{PD}_{\mathrm{Ref}} + N_{\mathrm{Re}f} \cdot D_{\mathrm{Re}f}\right) + \left(\mathrm{A}_{\mathrm{Frz}} \cdot \mathrm{PD}_{\mathrm{Frz}} + N_{\mathrm{Frz}} \cdot D_{\mathrm{Frz}}\right) \qquad (6)$$

Where

$P_{\text{Walk-in}}$ is the estimated power density for the walk-in refrigerator or freezer in (W)

A_{xxx} the area of the walk-in refrigerator or freezer (ft²)

N_{xxx} the number of glass display doors (unitless)

PD_{xxx} the power density of the walk-in refrigerator or freezer taken from Table 42 (W/ft²)

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

$_{xxx}$ subscript indicating a walk-in freezer or refrigerator (Ref or Frz)

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

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

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

Refrigeration Modeling Method

Applicability	All buildings that have commercial refrigeration for cold storage or display

Definition The method used to estimate refrigeration energy and to model the thermal interaction with the space where casework is located. Three methods are included in this manual:

- **COMNET defaults**. With this method, the power density values provided in Appendix B, Table 6[11] are used; schedules are assumed to be continuous operation.
- **USDOE 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 (6) and the values from Table 42. All refrigeration equipment is then assumed to operate continuously.
- **Explicit refrigeration model**. With this method, all components of the refrigeration system are explicitly modeled in DOE-2.2R or other hourly simulation program with this capability.[12]

The remaining building descriptors in this section apply to buildings that use either the COMNET defaults or the USDOE performance ratings.

Units	List (see above)
Input Restrictions	None
Baseline Rules	Method used to model the proposed design shall be used for the baseline building. Note that credit is offered only when the *USDOE performance ratings* method is used.

---

[11] See Table C-43, p. 146 of NREL/TP-550-41956, Methodology for Modeling Building Energy Performance across the Commercial Sector, Technical Report, Appendix C, March 2008. The values in this report were taken from Table 8-3 of the California Commercial End-Use Survey, Consultants Report, March 2006, CEC-400-2006-005

[12] Direct modeling of refrigeration equipment in buildings is not broadly supported by energy simulation programs. The simulation program that is used in most energy analysis of refrigeration equipment is DOE-2.2R, which is a proprietary and limited release version of the DOE-2.2 simulation engine used by EQuest. EnergyPlus also has refrigeration modeling capabilities. These software applications allow the user to define the configuration of equipment and to specify the performance characteristics of each piece of equipment. These applications can also account for the interaction of the equipment with the temperature and humidity of the space where it is located. The complexity and variation of input for these models makes it very difficult to specify baseline conditions. For this reason, credit for efficient refrigeration systems is not offered in COMNET Phase I when explicit refrigeration models are used.

Refrigeration Power

Applicability	All buildings that have commercial refrigeration for cold storage or display and do not use the explicit refrigeration model
Definition	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 *receptacle power*.
Units	Kilowatts (kW)
Input Restrictions	With the *COMNET defaults* method, the values in Appendix B, Table 6 are prescribed. These values are multiplied times the floor area of the rated building to estimate the refrigeration power. With the *USDOE 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.
Baseline Rules	Refrigeration power is the same as the proposed design when the COMNET defaults are used. When the *USDOE performance ratings* method is used, refrigeration power for casework shall be determined from Table 41; the power for walk-in refrigerators and freezers shall be the same as the proposed design.

Remote Condenser Fraction

Applicability	All buildings that have commercial refrigeration for cold storage or display and use the *COMNET defaults* or *USDOE performance ratings* methods
Definition	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 refrigeration capacity. 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 *USDOE 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 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 *USDOE performance ratings* methods, the heat that is removed from the space is determined as follows:

(7)

$$Q = \left[(1 - F) \times kW - (F \times kW \times COP)\right] \times 3.413$$

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 *USDOE 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 block. Other modeling techniques are acceptable as long as they are thermodynamically equivalent.

Units	Fraction
Input Restrictions	None
Baseline Rules	Same as the proposed design

Refrigeration COP

Applicability	All buildings that have commercial refrigeration for cold storage or display and use the *COMNET defaults* or *USDOE performance ratings* methods
Definition	The coefficient of performance 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.
Units	Fraction
Input Restrictions	This value is prescribed to be 3.6 for refrigerators and 1.8 for freezers.[13]
Baseline Rules	Same as the proposed design

Refrigeration Schedule

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

---

[13] 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.

6.4.7 Elevators, Escalators and Moving Walkways

Elevators, escalators and moving walkways account for 3% to 5% of electric energy use in buildings.[14] 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.[15]

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.

Little information 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[16] however for Phase I of this rules and procedures manual, 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 43.[17]

Table 43 – Unit Energy Consumption Data for Elevators, Escalators and Moving Walkways[18]

	Elevators		Escalators and Moving Walkways	
Mode	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

Applicability	All buildings that have commercial elevators, escalator, or moving walkways
Definition	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

---

[14] Sachs, Harvey M., Opportunities for Elevator Energy Efficiency Improvements, American Council for an Energy Efficiency Economy, April 2005

[15] Ibid.

[16] Al-Sharif, Lutfi, Richard Peters and Rory Smith, Elevator Energy Simulation Model, Elevator World, November 2005, Volume LII, No11

[17] TIAX, Commercial and Residential Sector Miscellaneous Electricity consumption: Y20005 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.

[18] 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.

	not moving), and standby (when the lights and ventilation systems are off). Escalators and moving walkways are either active or turned off.
Units	W/unit
Input Restrictions	The power values from Table 43 for different modes of operation are prescribed for the proposed design.
Baseline Rules	Same as the proposed design

Elevator/Escalator Schedule	
Applicability	All buildings that have commercial elevators, escalator, or moving walkways
Definition	The schedule of operation for elevators, escalators, and moving walkways. This is used to convert elevator/escalator power to energy use.
Units	Data structure: schedule, state
Input Restrictions	The schedule specified for the building should match the operation patterns of the building. The total number of hours for each mode of operation should match the values in Table 43 (the default) unless documentation is provided to demonstrate that other schedules are appropriate.
Baseline Rules	Same as the proposed design

6.4.8 Process, Gas

Commercial gas equipment includes the following:

- Ovens
- Fryers
- Grills
- Other equipment

The majority of gas equipment is located in the space 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 COMNET procedure for commercial gas is limited in this first release of the rules and procedures. The procedure consists of prescribed power and energy values for use with both the proposed design and the baseline building. No credit for commercial gas energy efficiency features is offered.

The prescribed values are provided in Appendix B, Table 6[19]. Schedules are defaulted to be continuous operation.

Gas Equipment Power	
Applicability	All buildings that have commercial gas equipment
Definition	Commercial gas power is the average power for all commercial gas equipment, assuming constant year-round operation.

---

[19] See Table C-43, p. 146 of NREL/TP-550-41956, Methodology for Modeling Building Energy Performance across the Commercial Sector, Technical Report, Appendix C, March 2008. The values in this report were taken from Table 8-3 of the California Commercial End-Use Survey, Consultants Report, March 2006, CEC-400-2006-005

Units	Btu/h-ft²
Input Restrictions	The values in Appendix B, Table 6 are prescribed.
Baseline Rules	Same as the proposed design

Gas Equipment Schedule

Applicability	All buildings that have commercial gas equipment
Definition	The schedule of operation for commercial gas equipment. This is used to convert gas power to energy use.
Units	Data structure: schedule, fractional
Input Restrictions	Continuous operation is prescribed.
Baseline Rules	Same as the proposed design

Gas Equipment Location

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

Radiation Factor

Applicability	Gas appliances located in the space
Definition	The fraction of heat gain to appliance energy use
Units	Fraction
Input Restrictions	Default value is 0.15. Other values can be used when a detailed inventory of equipment is known. The override value shall be based on data in Table 5C, Chapter 18, ASHRAE HOF, 2009, or similar tested information from the manufacturer.
Baseline Rules	Same as the proposed design

6.5 Building Envelope Data

6.5.1 Materials

Energy simulation programs commonly define construction assemblies by listing a sequence of materials that make up construction assembly. Appendix D has a list of standard materials that may be referenced by construction assemblies. Additional materials not listed in Appendix D may be defined as described below. Alternate methods may be used to define construction assemblies such as specifying the U-factor and optionally, a metric describing thermal mass such as *heat capacity* (HC). These alternate methods may not require identification of materials. When a material is defined, all of the properties listed below must be defined. Some materials listed in Appendix D are non-homogeneous, for instance, framing members with insulation in the cavity.

Material Name

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

Density

Applicability	All non-standard materials
Definition	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.
Units	Numeric input: lb/ft^3
Input Restrictions	Density is a required input when non-standard materials are specified.
Baseline Rules	Not applicable

Specific Heat

Applicability	All non-standard materials
Definition	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 degree F.
Units	Btu/lb·°F
Input Restrictions	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.
Baseline Rules	Not applicable

Thermal Conductivity

Applicability	All non-standard materials
Definition	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 degree F.
Units	Btu/h·ft·°F
Input Restrictions	Thermal conductivity is a required input for non-standard materials.
Baseline Rules	Not applicable

Thickness

Applicability	All non-standard materials
Definition	The thickness of a material
Units	ft or in. (cm)
Input Restrictions	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.
Baseline Rules	Not applicable

6.5.2 Construction Assemblies

Assembly Name	
Applicability	All projects
Definition	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.
Units	Text, unique
Input Restrictions	Construction name is a required input.
Baseline Rules	Not applicable

Specification Method	
Applicability	All projects
Definition	The method of describing a construction assembly. The more simple method is to describe the U-factor of the construction assembly which can account for thermal bridging and other factors. However with this method, the time delay of heat transfer through the construction assembly is not accounted for. 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.
Units	List: choices are U-factor or Layers
Input Restrictions	The layers method shall be used for all constructions except for metal building or similar constructions with negligible thermal mass.
Baseline Rules	For each construction, the proposed design specification method shall be used.

U-factor	
Applicability	All construction assemblies that are specified by a U-factor
Definition	The steady state rate of heat transfer through a construction assembly
Units	Btu/h-ft²-°F
Input Restrictions	U-factors should be consistent with values in Appendix A of ASHRAE Standard 90.1-2007.
Baseline Rules	Not applicable

Layers	
Applicability	All construction assemblies that use the layers method of specification
Definition	A structured list of pairs of material names that describe a construction assembly, beginning with exterior finish and progressing through to the interior finish. Material names must be from the standard list (Appendix E) or defined (see above).
Units	Data structure: construction assembly

Input Restrictions	The user is required to describe all layers in the actual roof assembly and the proposed design will be modeled as input by the user.
Baseline Rules	See building descriptors for roofs, walls, and floors.

U-factor Derating Factor

Applicability	All construction assemblies that use the layers method of specification
Definition	A derating factor to account for thermal bridges and other non-homogeneous construction features. The factor is a multiplier on the U-factor such that a value greater than one increases heat losses and gains. The layers method assumes that all layers are completely homogeneous and that there are no thermal bridges or other features that would increase heat gain or loss.
Units	Unitless
Input Restrictions	Default is 1.2 (120%). Minimum value is 1.0 and maximum value is 3.0.
Baseline Rules	The baseline building shall use a derating factor of 1.0, e.g. no derating.

6.5.3 Roofs

Roof Name

Applicability	All roof surfaces
Definition	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.
Units	Text, unique
Input Restrictions	None
Baseline Rules	None

Roof Type

Applicability	All roof surfaces
Definition	One of three classifications of roofs defined in the baseline standard. These classifications are defined in ASHRAE Standard 90.1-2001 and ASHRAE Standard 90.1-2007 along with the associated User's Manuals. The prescriptive U-factor requirements for roofs depend on the type. For green building ratings and tax credits, it is not necessary to specify this information, as the PRM fixes the type for the baseline building to “insulation entirely above the deck.” This descriptor can be derived from other building descriptors and it may not be necessary for the software user to specify it directly.
Units	List: attic and other roofs; metal building roofs; and roofs with insulation entirely above deck.
Input Restrictions	This input is optional for the purposes covered by this manual.
Baseline Rules	All roofs in the baseline building are modeled as “insulation entirely above deck.”

Roof Geometry

Applicability	All roofs, required input
Definition	Roof geometry defines the position, orientation, azimuth, tilt, and dimensions of the

	roof surface. The details of how the coordinate system is implemented may vary between software programs. The data structure for surfaces is described in the reference section of this chapter.
Units	Data structure: surface
Input Restrictions	There are no restrictions other than that the surfaces defined must agree with the building being modeled, as represented on the construction drawings or as-built drawings.
Baseline Rules	Roof geometry will be identical in the proposed and baseline building designs.

Roof Construction

Applicability	All roofs, required input
Definition	A reference to a construction assembly for the proposed design. See the building descriptors above for construction assemblies.
Units	Dimensionless reference
Input Restrictions	All roof surfaces must reference a construction assembly.
Baseline Rules	Roofs in the baseline building are of the type “insulation entirely above deck.” The insulation requirement is determined by climate zone and baseline standard and is given in Table 44. The baseline building roof construction shall be modeled as layers as defined in Table 45. These tables reflect a construction that is available in the standard list of constructions.

Table 44 – Baseline Building R-value and U-factor Criteria for Roofs

			Standard Design	
Applicable Standard	Space Category	Climate Zone	Minimum Insulation	Maximum Assembly
90.1 – 2001	Nonresidential	1-7	R-15 c.i.	U-0.063
		8	R-20 c.i.	U-0.048
	Residential	1,2,3,4,5,6,7	R-15 c.i.	U-0.063
		8	R-20 c.i.	U-0.048
	Semi-Heated	1	NR	U-1.282
		2,3,4	R-3.8 c.i.	U-0.218
		5,6,7	R-5.0 c.i.	U-0.173
		8	R-10.0 c.i.	U-0.093
90.1 – 2007	Nonresidential	1	R-15 c.i.	U-0.063
		2-8	R-20 c.i.	U-0.048
	Residential	1-8	R-20 c.i.	U-0.048
	Semi-Heated	1, 2	R-3.8 c.i.	U-0.218
		3, 4	R-5.0 c.i.	U-0.173
		5	R-7.6 c.i	U-0.119
		6,7	R-10.0 c.i.	U-0.093
		8	R-15.0 c.i.	U-0.063

Table 45 – Baseline Building Roof Construction Assemblies

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft F)	Density (lb/ft²)	Specific Heat (Btu/lb F)	R-value (ft²·°F·h/Btu)	U-factor (Btu/h-ft²-F)
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	0.048
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	0.063
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	-
	Interior air film	-	-	-	-	0.61	-
	Total for assembly	-	-	-	-	10.78	0.093
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	0.119
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	0.173
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	0.218
NR.	Exterior air film	-	-	-	-	0.17	-
	Roofing membrane	-	-	-	-	0.00	-
	Steel deck	0.06	26	480	0.10	0.00	-
	Interior air film	-	-	-	-	0.61	-
	Total for assembly	-	-	-	-	5.78	1.282

Exterior Roof Surface Properties

Applicability	All roofs.
Definition	The exterior roof surface properties descriptor defines the characteristics of exterior surfaces. Exterior surface properties 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. The descriptor is a critical default structure input, applicable to all models. Critical defaults require documentation to change. Data structures are outlined in the reference data structures section of this chapter.
Units	Data structure: exterior surface properties
Input Restrictions	The default value is a reflectance of 0.30 and an emittance of 0.90. The default value may be overridden when roof materials are used that have been tested by the Cool Roof Rating Council (CRRC) and are called for in the construction documents. In cases where the default value is overridden, the user is required to submit documentation identifying the test procedure that was used to establish the non-default values.
Baseline Rules	The default values (see Input Restrictions above) shall be used for roofs for the baseline building.

6.5.4 Exterior Walls

Wall Name

Applicability	All walls, optional input
Definition	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.
Units	Text, unique
Input Restrictions	None
Baseline Rules	None

Wall Type

Applicability	All wall surfaces, optional
Definition	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: a) mass walls, b) metal building walls, c) metal framing walls, and d) wood framing and other walls. These wall types are defined in the baseline standards and the associated User's Manuals. The prescriptive criteria of the baseline standards depend on the wall type, but for green building ratings and tax deduction calculations, the PRM specifies that all baseline walls shall be "metal framed" so the input is not used for the purposes of this manual.
Units	List: mass walls, metal building walls, metal framing walls, and wood framing and other walls
Input Restrictions	This input is optional for the purposes covered by this manual. This input can often be derived from other inputs and may not need to be explicitly specified.
Baseline Rules	All walls in the baseline building are modeled as "metal framed."

Wall Geometry

Applicability	All walls, required input
Definition	Wall geometry defines the position, orientation, azimuth, and tilt of the wall surface. The details of how the coordinate system is implemented may vary between simulation engines. The data structure for surfaces is described in the reference section of this chapter.
Units	Data structure: surface
Input Restrictions	There are no restrictions other than that the surfaces defined must agree with the building being modeled, as represented on the construction drawings or as-built drawings.
Baseline Rules	Wall geometry in the baseline building is identical to the proposed design.

Wall Construction

Applicability	All walls, required input
Definition	A reference to a construction assembly for the proposed design. See the building descriptors above for *construction assemblies*.
Units	Dimensionless reference
Input Restrictions	All wall surfaces must reference a construction assembly that meets the mandatory requirements of the appropriate baseline standard.
Baseline Rules	Walls in the baseline building are all of the type "metal framed". The insulation requirement is determined by the baseline standard and climate zone and is given in Table 46. The baseline building construction shall be modeled as layers as defined in Table 47.

Table 46 – Baseline Building R-value and U-factor Criteria for Walls

			Standard Design	
Applicable Standard	Space Category	Climate Zone	Minimum Insulation	Maximum Assembly
90.1 - 2001	Nonresidential	1-4	R-13	U-0.124
		5,6	R-13 + R-3.8 c.i.	U-0.084
		7,8	R-13 + R-7.5 c.i.	U-0.064
	Residential	1,2	R-13	U-0.124
		3	R-13 + R-3.8 c.i.	U-0.084
		4- 7	R-13 + R-7.5 c.i.	U-0.064
		8	R-13 + 10.0 c.i.	U-0.055
	Semi-Heated	1- 3	NR	U-0.352
		4 - 8	R-13	U-0.124
90.1 - 2007	Nonresidential	1,2	R-13	U-0.124
		3	R-13 + R-3.8 c.i.	U-0.084
		4-8	R-13 + R-7.5 c.i.	U-0.064
	Residential	1	R-13	U-0.124
		2-6	R-13 + R-7.5 c.i.	U-0.064
		7	R-13 +15.6 c.i.	U-0.042
		8	R-13 + R-18.8 c.i.	U-0.037
	Semi-Heated	1	NR	U-0.352
		2-7	R-13	U-0.124
		8	R-13 + R-3.8 c.i.	U-0.084

Table 47 – Baseline Building Wall Construction Assemblies

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft F)	Density (lb/ft^2)	Specific Heat (Btu/lb F)	R-value (ft^2·°F·h/Btu)	U-factor (Btu/ft^2·°F·h)
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	-
	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	0.037
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	0.042
Wall R-13 + R-10.0	Air film	-	-	-	-	0.17	-
	Stucco	0.400	0.4167	116	0.2	0.08	-
	R-10.0continuous insulation	1.800	0.0200	1.8	0.29	10.0	-
	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	-	-	-	-	18.05	.055
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	0.64
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	0.84
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	-	-	-	-	199.95	0.124
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	-
	Cavity/steel framing	-	-	-	-	0.79	-
	Gypsum board	0.625	0.0930	50	0.2	0.56	-
	Interior air film	-	-	-	-	0.68	-
	Total for assembly	-	-	-	-	2.84	3.52

Exterior Wall Surface Properties

Applicability	All walls
Definition	The exterior wall surface properties descriptor describes the characteristics of exterior wall 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. The descriptor is a critical default structure input, applicable to all models. Critical defaults require documentation to change. Data structures are outlined in the reference data structures section of this chapter.
Units	Data structure: exterior surface properties
Input Restrictions	The default value for emittance is 0.90. The default value for reflectance is 0.30. There

	is no default for roughness. The default values may be overridden only in cases when the lower reflectance can be documented by manufacturers' literature or tests.
Baseline Rules	The baseline building shall use default values for emittance and reflectance. The roughness of the baseline building walls shall be identical to the proposed design.

6.5.5 Exterior Floors

Floor Name

Applicability	All floor surfaces
Definition	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.
Units	Text, unique
Input Restrictions	None
Baseline Rules	None

Floor Type

Applicability	All exterior floor surfaces, optional
Definition	One of three categories of exposed floor assemblies used to determine minimum prescriptive insulation requirements. The three floor type categories are: a) mass floor, b) steel joist floor, and c) wood and other floors. Definitions of these three exterior floor types are contained in Section 3.2, *Definitions,* of the baseline standard and associated User's Manuals. This building descriptor is not used for the purposes of this manual, since the type for the baseline building is fixed at "steel joist". This building descriptor can often be derived from other information in the model and may not be required as an explicit input.
Units	List: mass floor, metal joist floor, and wood and other floors
Input Restrictions	This building descriptor input is optional for the purposes of this manual.
Baseline Rules	The baseline building floors shall be of type "steel joist."

Floor Geometry

Applicability	All exterior floors, required input
Definition	Floor geometry defines the position, orientation, azimuth, and tilt of the floor surface. The details of how the coordinate system is implemented may vary between software programs. The data structure for surfaces is described in the reference section of this chapter.
Units	Data structure: surface
Input Restrictions	There are no restrictions other than that the surfaces defined must agree with the building being modeled, as represented on the construction documents or as-built drawings.
Baseline Rules	Baseline building floor geometry is identical to the proposed design.

Floor Construction

Applicability	All roofs, required input

Definition	A reference to a *construction assembly* for the proposed design
Units	Dimensionless reference
Input Restrictions	All floor surfaces must reference a construction assembly that meets the mandatory measures of the baseline standards.
Baseline Rules	Exterior floors in the baseline building are of type "steel joist." The insulation requirements depend on the baseline standard and the climate zone and are given in Table 48. The baseline building constructions shall be modeled as layers, which are defined in Table 49.

Table 48 – Baseline Building R-value and U-factor Criteria for Exposed Floors

			Standard Design	
Applicable Standard	Space Category	Climate Zone	Minimum Insulation	Maximum Assembly
90.1 - 2001	Nonresidential	1	NR	U-0.350
		2-5	R-19	U-0.052
		6-8	R-30	U-0.038
	Residential	1	NR	U-0.350
		2, 3	R-19	U-0.052
		4- 7	R-30	U-0.038
		8	R-38	U-0.032
	Semi-Heated	1, 2	NR	U-0.350
		3- 6	R-13	U-0.069
		7, 8	R-19	U-0.052
90.1 - 2007	Nonresidential	1	NR	U-0.350
		2,3	R-19	U-0.052
		4-7	R-30	U-0.038
		8	R-38	U-0.032
	Residential	1	NR	U-0.350
		2,3	R-19	U-0.052
		4,5	R-30	U-0.038
		6-8	R-38	U-0.032
	Semi-Heated	1	NR	U-0.350
		2-4	R-13	U-0.069
		5-8	R-19	U-0.052

Table 49 – Baseline Building Exposed Floor Construction Assemblies

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft F)	Density (lb/ft²)	Specific Heat (Btu/lb F)	R-value (ft²·°F·h/Btu)	U-factor (Btu/ft²·°F·h)
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	0.032
Floor R-30	Interior air film (flow down)	-	-	-	-	0.92	-
	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	0.038
Floor R-19	Interior air film (flow down)	-	-	-	-	0.92	-
	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	0.052
Floor R-13	Interior air film (flow down)	-	-	-	-	0.92	-
	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	0.069
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	0.350

6.5.6 Doors

Door Name

Applicability	All doors, optional input
Definition	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 entered by the user using the *windows* building descriptors.
Units	Text, unique
Input Restrictions	None
Baseline Rules	None

Door Type

Applicability	All doors, required input
Definition	The baseline standards classify doors as either: swinging or non-swinging. Non-swinging are generally roll-up doors. The prescriptive U-factor requirements depend on the door type so this input affects the baseline building criteria. The door types are described in greater detail in the baseline standards and the associated User's Manuals. This building descriptor may be derived from other building descriptors, in which case a specific input is not necessary.
Units	List: swinging or non-swinging
Input Restrictions	The door type shall be consistent with the type of door represented on the construction documents or as-built drawings.
Baseline Rules	The baseline building door type shall be the same as the proposed design.

Door Geometry

Applicability	All doors
Definition	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 is 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 in shape). The details of how the geometry of doors is specified may vary for each energy simulation program.
Units	Data structure: opening
Input Restrictions	No restrictions, other than that the inputs shall agree with the construction documents or as-built drawings.
Baseline Rules	Door geometry in the baseline building is identical to the proposed design.

Door U-factor

Applicability	All doors
Definition	The thermal transmittance of the door, including the frame.
Units	Btu/h·ft·°F
Input Restrictions	Door U-factors shall be taken from the default values in Appendix A of ASHRAE Standard 90.1-2001 or ASHRAE Standard 90.1-2007, or shall be obtained from NFRC test procedures.
Baseline Rules	The door U-factor in the baseline building depends on the baseline standard, the climate zone and the type of door (swinging or non-swinging). The user is required to input the door U-Factor, and the proposed design will be modeled as input by the user. The baseline building design will be modeled using the prescriptive U-Factor requirement in Tables 5-1 through 5-73 in the Standard. There are several independent variables used in the U-Factor look-up function: cooling degree days base 50°F (A.2.1), heating degree days base 65°F (A.2.1), tier of standard (A.3.1), electric resistance heating flag (A.5.1), occupancy type (B.1.4), and door type (B.11.5).

Table 50 – Baseline Building U-factor Criteria for Doors

			Space Category		
Applicable Standard	Swinging or Non-swinging	Climate Zone	Nonresidential	Residential	Semi-Heated
ASHRAE Standard 90.1 - 2001	Swinging	1- 5	0.700	0.700	0.700
		6, 7	0.700	0.500	0.700
		8	0.500	0.500	0.700
	Non-swinging	1, 2	1.450	1.450	1.450
		3- 5	1.450	0.500	1.450
		6- 8	0.500	0.500	1.450
ASHRAE Standard 90.1 - 2007	Swinging	1- 4	0.700	0.700	0.700
		5, 6	0.700	0.500	0.700
		7, 8	0.500	0.500	0.700
	Non-swinging	1	1.450	1.450	1.450
		2, 3	1.450	0.500	1.450
		4	1.500	0.500	1.450
		5- 7	0.500	0.500	1.450

6.5.7 Fenestration

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

Fenestration Name

Applicability	All fenestration, optional input
Definition	A unique name or code that relates the fenestration to the design documents and a parent surface.
Units	Text, unique
Input Restrictions	No restrictions
Baseline Rules	Not applicable

Fenestration Type (Vertical Fenestration)

Applicability	All vertical fenestration
Definition	This is a classification of vertical fenestration that determines the thermal performance and solar performance requirement for vertical fenestration.
Units:	List (ASHRAE Standard 90.1-2007): Nonmetal framing (all); metal framing (curtainwall/storefront); metal framing (entrance door); or metal framing (all other) List (ASHRAE Standard 90.1-2001): Fixed or Operable
Input Restrictions	No restrictions, other than that the vertical fenestration type must agree with the type specified on the construction documents or the as-built drawings.
Baseline Rules:	Same as the proposed design

Fenestration Type (Skylights)

Applicability	All skylights
Definition	This is a classification of skylights that determines the thermal performance and solar performance requirement for vertical fenestration.
Units:	List: Glass skylight with curb; plastic skylight with curb; or skylights with no curb
Input Restrictions	No restrictions, other than the skylight types specified must agree with the construction documents or the as-built drawings.
Baseline Rules:	Same as the proposed design

Fenestration Geometry

Applicability	All fenestration
Definition	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 is inherited from the parent surface. The details of how the coordinate system is implemented may vary between rating software programs.
Units	Data structure: opening
Input Restrictions	There are no restrictions, other than a match with the construction drawings or as-built drawings. Specification of the fenestration position within its parent surface is required for the following conditions: 1) exterior shading is modeled from buildings, vegetation, other objects; or 2) if daylighting is modeled within the adjacent space.

Baseline Rules	The geometry of the fenestration shall be identical to the proposed design with the following exceptions: • If the gross area of all windows in the building exceeds 40% of the gross above-grade exterior wall area in the building, the dimensions of each window in the baseline building shall be reduced in size such that the window area in the baseline building is equal to 40% of the above-grade exterior wall area. • If the gross area of skylights in the building exceeds 5% of the gross roof area, the dimensions of each skylight shall be reduced in size such that the skylight area in the proposed design is equal to 5% of the gross roof area.

Fenestration Construction

Applicability	All fenestration
Definition	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, SHGC and VT. Data may be specified in other ways, however, as long as the data are supported by appropriate tests.
Units	Data structure: fenestration construction
Input Restrictions	Performance information for fenestration shall be developed from NFRC test procedures or shall be taken from the default values in Appendix A of the baseline standard. Values entered shall be consistent with the specifications and the construction documents.
Baseline Rules	The requirements for vertical fenestration U factor, Solar Heat Gain Coefficient, and Visible light transmission by climate zone and framing type are found in Table 51 and for skylight inputs in Table 53. In cases where there is no requirement (NR) for SHGC or VT, the baseline building shall be equal to the proposed design.

Table 51 – Baseline Building Criteria for Vertical Glazing for 90.1 2001

			Standard Design					
			Assembly U-factor		Assembly SHGC		Assembly VT	
Building type	Climate Zone	Window to Wall Ratio	Fixed	Operable	All	North	All	North
Nonresidential	1	0-30.0%	1.22	1.27	0.25	0.61	0.25	0.61
		30.1-40.0%	1.22	1.27	0.25	0.44	0.25	0.44
	2	0-40.0%	1.22	1.27	0.25	0.61	0.25	0.61
	3(A,B)	0-10.0%	0.57	0.67	0.39	0.49	0.39	0.49
		10.1-20.0%	0.57	0.67	0.25	0.49	0.25	0.49
		20.1-40.0%	0.57	0.67	0.25	0.39	0.25	0.39
	3(C)	0-10.0%	1.22	1.27	0.61	0.82	0.61	0.82
		10.1-40.0%	1.22	1.27	0.39	0.61	0.39	0.61
	4	0-40.0%	0.57	0.67	0.39	0.49	0.50	0.62
	5	0-10.0%	0.57	0.67	0.49	0.49	0.62	0.62
		10.1-40.0%	0.57	0.67	0.39	0.49	0.50	0.62
	6	0-10.0%	0.57	0.67	0.49	0.49	0.62	0.62
		10.1-40.0%	0.57	0.67	0.39	0.49	0.50	0.62
	7	0-40.0%	0.57	0.67	0.49	0.64	0.49	0.64
	8	0-40.0%	0.46	0.47	NR	NR	NR	NR
Residential	1	0-30.0%	1.22	1.27	0.25	0.61	0.25	0.61
		30.1-40.0%	1.22	1.27	0.25	0.44	0.25	0.44
	2	0-10.0%	1.22	1.27	0.39	0.61	0.39	0.61
		10.1-40.0%	1.22	1.27	0.25	0.61	0.25	0.61
	3(A,B)	0-10.0%	0.57	0.67	0.39	0.49	0.39	0.49
		10.1-20.0%	0.57	0.67	0.25	0.49	0.25	0.49
		20.1-40.0%	0.57	0.67	0.25	0.39	0.25	0.39
	3(C)	0-10.0%	1.22	1.27	0.61	0.82	0.61	0.82
		10.1-20.0%	1.22	1.27	0.61	0.61	0.61	0.61
		20.1-30.0%	1.22	1.27	0.39	0.61	0.39	0.61
		30.1-40.0%	1.22	1.27	0.34	0.61	0.34	0.61
	4	0-40.0%	0.57	0.67	0.39	0.49	0.50	0.62
	5	0-10.0%	0.57	0.67	0.49	0.49	0.62	0.62
		10.1-40.0%	0.57	0.67	0.39	0.39	0.50	0.50
	6	0-10.0%	0.57	0.67	0.49	0.64	0.62	0.81
		10.1-40.0%	0.57	0.67	0.39	0.49	0.50	0.62
	7	0-40.0%	0.57	0.67	0.49	0.64	0.62	0.81
	8	0-40.0%	0.46	0.47	NR	NR	NR	NR
Semiheated	1-8	0-40.0%	1.22	1.27	NR	NR	NR	NR

Table 52 – Baseline Building Criteria for Vertical Glazing for 90.1 2007

			Standard Design		
Building type	Fenestration Type	Climate Zone	U-factor	SHGC	VT
Nonresidential	Non-Metal Framing	1	1.20	0.25	0.32
		2	0.75	0.25	0.32
		3	0.65	0.25	0.32
		4	0.40	0.40	0.51
		5,6	0.35	0.40	0.51

			Standard Design		
Building type	Fenestration Type	Climate Zone	U-factor	SHGC	VT
		7,8	0.35	0.45	0.57
	Metal Framing Curtainwall/ Storefront	1	1.20	0.25	0.32
		2	0.70	0.25	0.32
		3	0.60	0.25	0.32
		4	0.50	0.40	0.51
		5,6	0.45	0.40	0.51
		7,8	0.40	0.45	0.57
	Metal Framing Entrance Door	1	1.20	0.25	0.32
		2	1.10	0.25	0.32
		3	0.90	0.25	0.32
		4	0.85	0.40	0.51
		5,6	0.80	0.40	0.51
		7,8	0.80	0.45	0.57
Nonresidential (Continued)	Metal Framing All Other	1	1.20	0.25	0.32
		2	0.75	0.25	0.32
		3	0.65	0.25	0.32
		4	0.55	0.40	0.51
		5,6	0.55	0.40	0.51
		7,8	0.45	0.45	0.57
Residential	Non-Metal Framing	1	1.20	0.25	0.32
		2	0.75	0.25	0.32
		3	0.65	0.25	0.32
		4	0.40	0.40	0.51
		5,6	0.35	0.40	0.51
		7,8	0.35	NR	NR
	Metal Framing Curtainwall/ Storefront	1	1.20	0.25	0.32
		2	0.70	0.25	0.32
		3	0.60	0.25	0.32
		4	0.50	0.40	0.51
		5,6	0.45	0.40	0.51
		7,8	0.40	NR	NR
	Metal Framing Entrance Door	1	1.20	0.25	0.32
		2	1.10	0.25	0.32
		3	0.90	0.25	0.32
		4	0.85	0.40	0.51
		5,6	0.80	0.40	0.51
		7,8	0.80	NR	NR
	Metal Framing All Other	1	1.20	0.25	0.32
		2	0.75	0.25	0.32
		3	0.65	0.25	0.32
		4	0.55	0.40	0.51
		5,6	0.55	0.40	0.51
		7,8	0.45	NR	NR
Residential	Non-Metal Framing	1- 5	1.20	NR	NR
		6- 8	0.65	NR	NR

			Standard Design		
Building type	Fenestration Type	Climate Zone	U-factor	SHGC	VT
	Metal Framing Curtainwall/ Storefront	1- 5	1.20	NR	NR
		6- 8	0.60	NR	NR
	Metal Framing Entrance Door	1- 5	1.20	NR	NR
		6- 8	0.90	NR	NR
Residential (Continued)	Metal Framing All Other	1- 5	1.20	NR	NR
		6- 8	0.65	NR	NR

Applicable to all window to wall ratios (0-40.0%)

Table 53 – Baseline Building Criteria for Skylights

				Standard Design		
Proposed Design	Applicable Standard	Climate Zone	% of Roof	U-factor	SHGC	VT
Glass Skylight with Curb	90.1 – 2001 & 90.1 - 2007	1,2	0-2.0%	1.98	0.36	0.46
			2.1-5.0%	1.98	0.19	0.24
		3 (A,B) - (all climate zone 3 for 2007)	0-2.0%	1.17	0.39	0.50
			2.1-5.0%	1.17	0.19	0.24
		3 (C) (2001 only)	0-2.0%	1.98	0.61	0.77
			2.1-5.0%	1.98	0.39	0.50
		4,5	0-2.0%	1.17	0.49	0.62
			2.1-5.0%	1.17	0.39	0.50
		6	0-5.0%	1.17	0.49	0.62
		7	0-2.0%	1.17	0.68	0.68
			2.1-5.0%	1.17	0.64	0.64
		8	0-2.0%	0.98	0.55	0.63
Plastic Skylight with Curb	90.1 - 2001 & 90.1 - 2007	1	0-2.0%	1.90	0.34	0.41
			2.1-5.0%	1.90	0.27	0.32
		2	0-2.0%	1.90	0.39	0.47
			2.1-5.0%	1.90	0.34	0.41
		3,4	0-2.0%	1.30	0.65	0.78
			2.1-5.0%	1.30	0.34	0.41
		5	0-2.0%	1.10	0.77	0.92
			2.1-5.0%	1.10	0.62	0.74
		6	0-2.0%	0.87	0.71	0.85
			2.1-5.0%	0.87	0.58	0.70
		7	0-2.0%	0.87	0.77	0.92
			2.1-5.0%	0.87	0.71	0.85
		8	0-2.0%	0.61	0.59	0.64
Skylight without Curb	90.1 – 2001 & 90.1 – 2007	1,2	0-2.0%	1.36	0.36	0.46
			2.1-5.0%	1.36	0.19	0.24
		3 (A,B) - (all	0-2.0%	0.69	0.39	0.50

				Standard Design		
Proposed Design	Applicable Standard	Climate Zone	% of Roof	U-factor	SHGC	VT
		climate zone 3 for 2007)	2.1-5.0%	0.69	0.19	0.24
		3 (C) (2001 only)	0-2.0%	1.36	0.61	0.77
			2.1-5.0%	1.36	0.39	0.50
		4,5	0-2.0%	0.69	0.49	0.62
			2.1-5.0%	0.69	0.39	0.50
		6	0-5.0%	0.69	0.49	0.62
		7	0-2.0%	0.69	0.68	0.68
			2.1-5.0%	0.69	0.64	0.64
		8	0-5.0%	0.58	0.55	0.63

External Shading Devices

Applicability	All fenestration
Definition	Devices or building features, such as overhangs, fins, shading screens, and setbacks of windows from the exterior face of the wall, that are documented on the construction documents and shade the glazing. Objects that shade the building but that 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*.
Units	Data structure: opening shade
Input Restrictions	No restrictions other than that the inputs must match the construction documents
Baseline Rules	The baseline building is modeled without external shading devices.

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 or components or treatments of the glazing materials are addressed through the *Fenestration Construction* building descriptor.
Units	Data structure
Input Restrictions	Internal shading shall not be modeled in the proposed design, unless it is automatically controlled, based on input from an astronomical timeclock, an exterior pyronometer, or other sensors. The control algorithm shall be documented on the construction documents. Interior shades without automatic controls shall not be modeled.
Baseline Rules	The baseline building shall be modeled without interior shades.

6.5.8 Below Grade Walls

Below Grade Wall Name

Applicability	All projects, optional input

Definition	A unique name that keys the below grade wall to the construction documents
Units:	Text, unique
Input Restrictions	None
Baseline Rules:	Not applicable

Below Grade Wall Geometry

Applicability	All projects
Definition	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 take the depth below grade into account when estimating heat transfer, so the geometry may include height and width.
Units	Data structure: below grade wall geometry
Input Restrictions	There are no restrictions other than that the inputs shall be in agreement with the construction documents.
Baseline Rules	The geometry of below grade walls in the baseline building is identical to the below grade walls in the proposed design.

Below Grade Wall Construction

Applicability	All projects, required input
Definition	A description of the manner in which a below grade wall is constructed or a representation of the thermal performance of the below grade wall that can be used by the energy simulation software to estimate heat transfer. 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.
Units	Data structure: construction assembly
Input Restrictions	No restrictions other than that the inputs shall be in agreement with the construction documents.
Baseline Rules	See Table 54 and Table 55.

Table 54 – Baseline Building C-factor Criteria for Below-Grade Walls

			Standard Design	
Applicable Standard	Space Category	Climate Zone	Minimum Insulation	C-Factor
90.1 - 2001	Nonresidential	1- 6	NR	1.140
		7, 8	R-7.5 c.i.	0.119
	Residential	1-5	NR	1.140
		6- 8	R-7.5 c.i.	0.119
	Semi-Heated	1-8	NR	1.140
90.1 - 2007	Nonresidential	1- 4	NR	1.140
		5678	R-7.5 c.i.	0.119
	Residential	1-3	NR	1.140
		456	R-7.5 c.i.	0.119
		7	R-10 c.i.	0.092
		8	R-12.5 c.i.	0.075
	Semi-Heated	1- 8	NR	1.140

Table 55 – Baseline Building Below-Grade Wall Construction Assemblies

Construction	Layer	Thickness (inch)	Conductivity (Btu/h ft F)	Density (lb/ft^2)	Specific Heat (Btu/lb F)	R-value (ft^2·°F·h/Btu)	C-factor (Btu/ft^2·°F·h)
NR	115 lb/ft3 CMU, solid grout	8	0.45	115	0.20	0.87	1.140
R-7.5 c.i.	115 lb/ft3 CMU, solid grout	8	0.45	115	0.20	0.87	
	R-10 continuous insulation	1.8	0.02	1.8	0.29	7.50	
	Total assembly					8.37	0.119
R-10 c.i.	115 lb/ft3 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/ft3 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

6.5.9 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

Applicability	All slab floors, optional
Definition	A unique name or code that relates the exposed floor to the construction documents.
Units	Text, unique
Input Restrictions	None
Baseline Rules	Not applicable

Slab Floor Type

Applicability	All slab floors, required
Definition	One of two classes for floors in contact with ground. The classes are: 1) heated slab-

	on-grade floors and 2) unheated slab-on-grade floors. Heated slab-on-grade floors include all floors that are heated directly in order to provide heating to the space. Unheated slab-on-grade floors are all other floors in contact with ground. See the baseline standards and the associated User's Manuals for additional definition.
Units	List: heated or unheated
Input Restrictions	None
Baseline Rules	Not applicable

Slab Floor Geometry

Applicability	All slab floors, required
Definition	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.
Units:	Data structure: as appropriate for the simulation tool
Input Restrictions	No restrictions
Baseline Rules:	Not applicable

Slab Floor Construction

Applicability	All slab floors, required input
Definition	A description of how the slab is insulated (or not). How the construction is described will depend on the energy simulation model. 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. 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.
Units	Data structure: depends on the model that is used
Input Restrictions	If the perimeter method is used to model the slab, F-factors shall be taken from Appendix A of ASHRAE Standard 90.1-2001 or ASHRAE Standard 90.1-2007. For all methods, inputs shall be consistent with the construction documents.
Baseline Rules	Slab loss shall be modeled in the same manner in the baseline building as in the proposed design, e.g. if the perimeter method is used for the proposed design, the same method shall be used for the baseline building. The configuration of insulation and the F-factors for the baseline building are shown in Table 56. If the perimeter method is not used, then the F-factors from the table shall be used in the baseline building. If an alternative modeling method is used, then inputs to the method for the baseline building shall be consistent with the insulation configuration described in Table 56.

Table 56 – Baseline Building F-factor Criteria for Slab-on-Grade Floors

				Baseline Building	
Applicable Standard	Condition	Space Category	Climate Zone	Insulation Configuration	F-Factor
90.1 – 2001	Unheated	Nonresidential	1-7	NR	0.730
			8	R-10 for 24 in. vertical	0.540
		Residential	1-6	NR	0.730
			7	R-10 for 24 in. vertical	0.540
			8	R-15 for 24 in. vertical	0.520
		Semi-Heated	1- 8	NR	0.730
	Heated	Nonresidential	1- 4	R-7.5 for 12 in. vertical	1.020
			5- 7	R-10 for 36 in. vertical	0.840
			8	R-10 for 48 in. vertical	0.780
		Residential	1- 3	R-7.5 for 12 in. vertical	1.020
			4, 5	R-10 for 36 in. vertical	0.840
			6- 8	R-10 for 48 in. vertical	0.780
		Semi-Heated	1- 7	R-7.5 for 12 in. vertical	1.020
			8	R-7.5 for 24 in. vertical	.0950
90.1 – 2007	Unheated	Nonresidential	1-5	NR	0.730
			6	R-10 for 24 in. vertical	0.540
			7,8	R-15 for 24 in. vertical	0.520
		Residential	1- 3	NR	0.730
			4, 5	R-10 for 24 in. vertical	0.540
			6, 7	R-15 for 24 in. vertical	0.520
			8	R-20 for 24 in. vertical	0.510
		Semi-Heated	1- 8	NR	0.730
	Heated	Nonresidential	1, 2	R-7.5 for 12 in. vertical	1.020
			3	R-10 for 24 in. vertical	0.900
			4- 6	R-15 for 24 in. vertical	0.860
			7	R-20 for 24 in. vertical	0.843
			8	R-20 for 48 in. vertical	0.688
		Residential	1, 2	R-7.5 for 12 in. vertical	1.020
			3	R-10 for 24 in. vertical	0.900
			4, 5	R-15 for 24 in. vertical	0.860
			6- 8	R-20 for 48 in. vertical	0.688
		Semi-Heated	1- 6	R-7.5 for 12 in. vertical	1.020
			7, 8	R-10 for 24 in. vertical	0.900

6.5.10 Heat Transfer between Thermal Blocks

Partition Name

Applicability	All partitions, optional
Definition	A unique name or code that relates the partition to the construction documents.
Units	Text, unique
Input Restrictions	The text should provide a key to the construction documents.
Baseline Rules	Not applicable

Partition Geometry

Applicability	All partitions
Definition	A geometric construct that defines the position and size of partitions that separate one thermal block from another. The construct shall identify the thermal blocks 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 blocks on each side.
Units	Data structure: surface with additional information identifying the two thermal blocks that the partition separates.
Input Restrictions	No restrictions other than agreement with the construction documents
Baseline Rules	The geometry of partitions in the baseline building shall be identical to the proposed design.

Partition Construction

Applicability	All partitions
Definition	A description of the construction assembly for the partition
Units	Data structure: construction assembly
Input Restrictions	No restrictions other than the need for agreement with the construction documents
Baseline Rules	Partitions in the baseline building shall be steel framed walls with 5/8 in. gypsum board on each side.

6.6 HVAC Zone Level Systems

This group of building descriptors relate 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. The eight baseline building systems are shown as columns in Table 57. The building descriptors for zone level HVAC systems are shown as rows and the check marks "✓" indicate that the building descriptor applies for the baseline building system. Depending on the nature of the proposed design, any of the building descriptors could apply.

Table 57 – HVAC Zone Building Descriptors for Baseline Systems

	1 PTAC	2 PTHP	3 PSZ-AC	4 PSZ-HP	5 PVAV-DX-Blr	6 PVAV-DX-Elec	7 PVAV-CW-Blr	8 VAV-CW-Elec
HVAC ZONE INFORMATION								
Space Temperature Control								
Space Thermostat Throttling Range	✓	✓	✓	✓	✓	✓	✓	✓
Space Temperature Schedule	✓	✓	✓	✓	✓	✓	✓	✓
Terminal Device Data								
Terminal Type	✓	✓	✓	✓	✓	✓	✓	✓
Terminal Heating								
Terminal Heat Type					✓	✓	✓	✓
Terminal Heat Capacity					✓	✓	✓	✓
Reheat Delta T					✓	✓	✓	✓
Baseboard								
Baseboard Capacity								
Baseboard Heat Control								
VAV Air Flow								
Design Airflow					✓	✓	✓	✓
Terminal Minimum Stop					✓	✓	✓	✓
Fan Powered Boxes								
Fan Powered Box Type						✓		✓
Fan Power						✓		✓
Fan Powered Box Induced Air Zone						✓		✓
Parallel PIU Induction Ratio						✓		✓
Parallel Fan Box Thermostat Setpoint						✓		✓
Zone Exhaust								
Exhaust Fan Name								
Exhaust Air Flow Rate								
Exhaust Fan Schedule								
Outdoor Air Ventilation								
Ventilation Source	✓	✓	✓	✓	✓	✓	✓	✓
Design Ventilation Rate	✓	✓	✓	✓	✓	✓	✓	✓
Minimum Ventilation Rate	✓	✓	✓	✓	✓	✓	✓	✓
Ventilation Control Method	✓	✓	✓	✓	✓	✓	✓	✓

6.6.1 Space Temperature Control

Space Thermostat Throttling Range

Applicability	All HVAC zones
Definition	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.
Units	

	Degrees Fahrenheit (°F)
Input Restrictions	The prescribed value is 2°F. No input is needed and the prescribed value may not be overridden.
Baseline Rules	Same as the proposed design

Space Temperature Schedule

Applicability	All HVAC zones
Definition	An hourly space thermostat schedule
Units	Data structure: temperature schedule
Input Restrictions	The schedules specified in Appendix B, Table 7 and detailed in Appendix C shall be used as a default. When the default temperature schedule is overridden, the user must provide justification for use of nonstandard space temperature schedule assumptions.
Baseline Rules	Schedules in the baseline building shall be identical to the proposed design.

6.6.2 Terminal Device Data

Terminal Type

Applicability	All HVAC zones
Definition	A terminal unit includes any device serving a zone (or group of zones collected in a thermal block) that has the ability to reheat or recool in response to the zone thermostat. This includes: • None (the case for single zone units) • VAV box • Series Fan-Powered VAV box • Parallel Fan-Powered VAV box • Induction-type VAV box • Dual-duct mixing box (constant volume and VAV) • Two and three duct mixing dampers (multi-zone systems) • Reheat coil (constant volume systems) • Perimeter induction units
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Table 58 specifies the HVAC terminal device for each of the baseline building systems. See Figure 18 for a summary of the HVAC mapping.

Table 58 – Baseline Building HVAC Terminal Devices

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 – Packaged VAV with Reheat	VAV Box
System 6 – Packaged VAV with PFP boxes	Parallel Fan-Powered VAV Box
System 7 – VAV with Reheat	VAV Box
System 8 – VAV with PFP boxes	Parallel Fan-Powered VAV Box

6.6.3 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 through 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 Rules	Table 59 shows the terminal heat type for each baseline building system.

Table 59 – 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 – Packaged VAV with 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

Terminal Heat Capacity

Applicability	Systems that have reheat coils at the zone level
Definition	The heating capacity of the terminal heating source

Units	Btu/h
Input Restrictions	As designed. However, if the unmet load hours exceed 300, the energy analyst and design team may have to increase the size of the equipment so that the unmet load hours are less than 300. See Figure 18 and Figure 21.
Baseline Rules	The software shall automatically size the terminal heating capacity to be 25% greater than the design loads. However, the equipment may need to be reduced in size such that the unmet load hours of the proposed design does not exceed the baseline building by more than 50. See Figure 21.

Reheat Delta T

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

(8)

$$\Delta T_{reheat} = T_{reheat} - T_{cool\_supply}$$

$$\Delta T_{reheat} = Q_{coil} / (1.1 * CFM)$$

where

ΔT_{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	airflow (cfm)

Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed, but may need to be increased if unmet load hours are greater than 300
Baseline Rules	Method not used for baseline building. See Heat Capacity above.

6.6.4 Baseboard Heat

Baseboard Capacity

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

Baseboard Heat Control

Applicability	All HVAC zones
Definition	Defines the control scheme of base board heating as either:

- Reset by outdoor air temperature; or

	• Controlled by a space thermostat
Units	List (see above)
Input Restrictions	As designed. If the proposed design uses reset controls, the user must also input a reset schedule.
Baseline Rules	Not applicable for the baseline building

6.6.5 Zone Level Air Flow

VAV Air Flow

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

Applicability	Systems that vary the volume of air at the zone level
Definition	The air delivery rate at design conditions
Units	cfm
Input Restrictions	As designed. If the unmet load hours in the proposed design are greater than 300, the building descriptor may need to be modified to meet the criterion.
Baseline Rules	For systems 5 through 8, the software shall automatically size the airflow to meet the baseline building loads based on a supply-air-to-room-air temperature difference of 20°F or the required ventilation air or makeup air, whichever is greater

Terminal Minimum Stop

Applicability	Systems that vary the volume of air at the zone level
Definition	The minimum airflow that will be delivered by a terminal unit before reheating occurs
Units	Unitless fraction airflow (cfm) or specific airflow (cfm/ft^2)
Input Restrictions	This input must be greater than or equal to the outside air ventilation rate.
Baseline Rules	For systems 5 through 8, set the minimum airflow to be the greater of 0.4 cfm/ft^2 of conditioned floor area or the outside air ventilation rate.

Fan Powered Boxes

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; or • Parallel
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Applicable for baseline building systems 6 and 8 and the fan powered box type is

parallel.

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 Rules	For baseline building systems 6 and 8, power is prescribed at 0.35 W/cfm.

Fan Powered Box Induced Air Zone

Applicability	HVAC zones that have fan powered boxes
Definition	Zone from which a series or parallel fan-powered box draws its air
Units	List (of zones)
Input Restrictions	As designed
Baseline Rules	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 PIU Induction Ratio

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

Parallel Fan Box Thermostat Setpoint

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

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 block or multiple thermal blocks. Energy is summed for the exhaust system level, not the thermal block level.

Exhaust Fan Name

Applicability	All HVAC zones

Definition	A reference to an exhaust fan system that serves the thermal block
Units	Text or other unique reference to an exhaust fan system defined in the secondary systems section.
Input Restrictions	As designed
Baseline Rules	Same as the proposed design

Exhaust Air Flow Rate

Applicability	All HVAC zones
Definition	Rate of exhaust from a thermal block
Units	cfm
Input Restrictions	As designed
Baseline Rules	Same as the proposed design

Exhaust Fan Schedule

Applicability	All HVAC zones
Definition	Schedule indicating the pattern of use for exhaust air from the thermal block. 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.
Units	Data structure: schedule, fraction
Input Restrictions	As designed
Baseline Rules	Same as the proposed design

Outdoor Air Ventilation

Ventilation Source

Applicability	All HVAC zones
Definition	The source of ventilation for an HVAC system. The choices are: • Natural (by operable openings) • Forced (by fan)
Units	List: natural or forced
Input Restrictions	For residential units and hotel/motel guest rooms, as designed. For all other occupancies, set to forced.
Baseline Rules	For residential units, set to natural, for all other occupancies, set equal to the value for the proposed design.

Design Ventilation Rate

Applicability	All HVAC zones
Definition	The quantity of ventilation air that is provided to the space for the specified thermal block at maximum occupancy
Units	cfm or cfm/occupant

Input Restrictions	For the purpose of tax deduction calculations, the California ACM values from Table 4 of Appendix B shall be used. For green building ratings and energy labels, the COMNET values from Table 4 of Appendix B shall be used as a default. Other values may be used with appropriate documentation.
Baseline Rules	Same as the proposed design

Minimum Ventilation Rate

Applicability	All HVAC zones
Definition	The minimum quantity of ventilation air that must provided to the space when it is occupied
Units	cfm or cfm/ft²
Input Restrictions	As designed
Baseline Rules	Same as the proposed design

Ventilation Control Method

Applicability All HVAC zones

Definition 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:

- Occupant sensors: When the space is occupied, the outside air requirement is equal to the *design ventilation rate*, otherwise, the outside air requirement is the *minimum ventilation rate*.
- CO_2 sensors in the space: The outside air is determined to maintain a maximum CO_2 concentration in the space. This may be approximated by multiplying the ventilation rate per occupant times the number of occupants for that hour.
- Turnstiles to determine the number of occupants in the space (appropriate for theatres, etc.): The outside air requirement is modulated based on the number of occupants in the space, based on the turnstile counts.
- 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 Rules For the federal tax credit, if the design occupancy is greater than 100 persons per 1,000 ft² and the system design outside air flow rate is greater than 3,000 cfm, set control method to *CO_2 sensors in the space*, otherwise set to *fixed ventilation rate*.

For green building incentive programs, set to *CO_2 sensors in the space* if the design occupancy is greater than 40 people per 1,000 ft² and the system design outdoor air flow rate is greater than 1,200 cfm, otherwise set to *fixed ventilation rate*.

6.7 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. The eight baseline building systems are shown as columns in Table 60. The building descriptors are shown as rows and the check marks “✓” indicate that the building descriptor applies for the baseline building system. Depending on the nature of the proposed design, any of the building descriptors could apply.

Table 60 – HVAC Systems Building Descriptors for Baseline Systems

	1 PTAC	2 PTHP	3 PSZ-AC	4 PSZ-HP	5 PVAV-DX-Blr	6 PVAV-DX-Elec	7 PVAV-CW-Blr	8 VAV-CW-Elec
HVAC SECONDARY SYSTEMS								
Basic System Information								
HVAC System Name	✓	✓	✓	✓	✓	✓	✓	✓
System Type	✓	✓	✓	✓	✓	✓	✓	✓
Thermal Block List	✓	✓	✓	✓	✓	✓	✓	✓
Total Cooling Capacity	✓	✓	✓	✓	✓	✓	✓	✓
HVAC Unit Controls								
Cooling Schedule	✓	✓	✓	✓	✓	✓	✓	✓
Heating Schedule	✓	✓	✓	✓	✓	✓	✓	✓
Air-Handler Schedule	✓	✓	✓	✓	✓	✓	✓	✓
Air-Handler Fan Cycling	✓	✓	✓	✓	✓	✓	✓	✓
Optimum Start Control					✓	✓	✓	✓
Night-Cycle HVAC Fan Control								
Cooling Supply Air Temperature	✓	✓	✓	✓	✓	✓	✓	✓
Cooling Supply Air Temperature Control	✓	✓	✓	✓	✓	✓	✓	✓
Cooling Reset Schedule by OSA								
Preheat Setpoint								
Heating Supply Air Temperature	✓	✓	✓	✓	✓	✓	✓	✓
Heating Supply Air Temperature Control	✓	✓	✓	✓	✓	✓	✓	✓
Heating Reset Schedule by OSA								
Night Purge Availability Schedule								
Night Purge Control								
Night Purge Fan Ratio								
Baseline Building Fan Summary								
Supply Fan Ratio								
Return Fan Ratio								
Exhaust Fan Ratio								
Supply Fans								
Fan System Modeling Method					✓	✓	✓	✓
Supply Fan Design Air Rated Capacity					✓	✓	✓	✓
Fan Control Method					✓	✓	✓	✓
Supply Fan Brake Horsepower			✓	✓	✓	✓	✓	✓
Supply Fan Static Pressure								
Supply Fan Efficiency								
Supply Motor Efficiency								
Fan Position					✓	✓	✓	✓
Motor Position					✓	✓	✓	✓
Fan Part-Flow Power Curve					✓	✓	✓	✓
Supply Fan kW	✓	✓						
Return/Relief Fans								
Plenum Zone					✓	✓	✓	✓
Return Air Path					✓	✓	✓	✓
Return/Relief Air Rated Capacity					✓	✓	✓	✓

Return/Relief Fan Brake Horsepower								
Return/Relief Design Static Pressure								
Return/Relief Fan Efficiency								
Return/Relief Motor Efficiency								
Motor Position					✓	✓	✓	✓
Fan Part-Flow Power Curve					✓	✓	✓	✓
Return/Relief Fan kW					✓	✓	✓	✓
Exhaust Fan Systems								
Exhaust Fan Name								
Exhaust Fan System Modeling Method								
Exhaust Fan Rated Capacity								
Fan Control Method								
Exhaust Fan Schedule								
Exhaust Fan Brake Horsepower								
Exhaust Fan Design Static Pressure								
Exhaust Fan Efficiency								
Exhaust Fan Motor Efficiency								
Fan Part-Flow Power Curve					✓	✓	✓	✓
Exhaust Fan kW								
Outdoor Air Controls and Economizers								
Maximum Outside Air Ratio			✓	✓	✓	✓	✓	✓
Design Outside Air Flow			✓	✓	✓	✓	✓	✓
Outdoor Air Control Method			✓	✓	✓	✓	✓	✓
Economizer Control Type			✓	✓	✓	✓	✓	✓
Economizer High Temperature Lockout			✓	✓	✓	✓	✓	✓
Economizer Low Temperature Lockout			✓	✓	✓	✓	✓	✓
Economizer High Enthalpy Lockout			✓	✓	✓	✓	✓	✓
Cooling Coils								
Cooling Source					✓	✓	✓	✓
Total Cooling Capacity					✓	✓	✓	✓
Sensible Cooling Capacity					✓	✓	✓	✓
Cooling Capacity Adjustment Curve					✓	✓	✓	✓
Coil Bypass Factor					✓	✓	✓	✓
Coil Bypass Factor Adjustment Curve					✓	✓	✓	✓
Direct Expansion								
Direct Expansion Cooling Efficiency					✓	✓	✓	✓
Direct Expansion Cooling Efficiency Adjustment Curve					✓	✓	✓	✓
Minimum Unloading Ratio	✓	✓	✓	✓	✓	✓		
Minimum HGB Ratio	✓	✓	✓	✓	✓	✓		
Condenser Type	✓	✓	✓	✓	✓	✓		
Condenser Flow Type	✓	✓	✓	✓	✓	✓		
Evaporative Pre-Cooler								
Evaporative Cooling Type								
Direct Stage Effectiveness								
Indirect Stage Effectiveness								
Evaporative Cooling Performance Curves								
Auxiliary Evaporative Cooling Power								
Evaporative Cooling Scavenger Air Source								
Evaporative Condenser								

Evaporative Condenser Power	✓	✓	✓	✓	✓	✓		
Evaporative Condenser Effectiveness	✓	✓	✓	✓	✓	✓		
Evaporative Condenser Operation Range	✓	✓	✓	✓	✓	✓		
Heating Systems - General								
Heating Source					✓	✓	✓	✓
Preheat Coils								
Preheat Coil Capacity	✓	✓	✓	✓	✓	✓		
Heating Coils								
Heating Coil Capacity					✓	✓	✓	✓
Furnace								
Furnace Capacity	✓		✓					
Furnace Fuel Heating Efficiency	✓		✓					
Furnace Fuel Heating Part Load Efficiency Curve	✓		✓					
Furnace Fuel Heating Pilot	✓		✓					
Furnace Fuel Heating Fan/Auxiliary	✓		✓					
Electric Heat Pump								
Electric Heat Pump Heating Capacity		✓		✓				
Electric Heat Pump Supplemental Heating Source		✓		✓				
Electric Heat Pump Heating Efficiency		✓		✓				
Electric Heat Pump Heating Capacity Adjustment Curve(s)		✓		✓				
Electric Heat Pump Heating Efficiency Adjustment Curve(s)		✓		✓				
Electric Heat Pump Supplemental Heating Capacity		✓		✓				
Electric Supplemental Heating Control Temp		✓		✓				
Coil Defrost		✓		✓				
Coil Defrost kW		✓		✓				
Crank Case Heater kW		✓		✓				
Crank Case Heater Shutoff Temperature		✓		✓				
Heat Recovery								
Exhaust to Outside Heat Recovery Effectiveness								
Condenser Heat Recovery Effectiveness								
Heat Recovery Use								
Humidity Controls and Devices								
Humidifier Type			✓	✓	✓	✓	✓	✓
Humidistat Maximum Setting			✓	✓	✓	✓	✓	✓
Humidistat Minimum Setting			✓	✓	✓	✓	✓	✓
Desiccant Type								
Desiccant Control Mode								
Desiccant Air Fraction								
Desiccant Heat Source								
Liquid Desiccant Performance Curves								
Desiccant Dewpoint Temperature Setpoint								
Desiccant Heat Exchanger Effectiveness								
Desiccant Heat Exchanger Pressure Drop								

6.7.1 Basic System Information

HVAC System Name

Applicability	All system types
	A unique descriptor for each HVAC System
Units	Text, unique
Input Restrictions	When applicable, this input should match the tags that are used on the plans.
Baseline Rules	None

System Type

Applicability	All system types
Definition	A unique descriptor which identifies the following attributes of an HVAC System: • Number of air decks (one to three); • Constant or variable air flow; • Type of terminal device; and • Fan configuration for multiple deck systems.
Units	None
Input Restrictions	As designed
Baseline Rules	Based on the prescribed system type (see Figure 18). The baseline system types are shown in the table below.

Table 61 – Baseline Building System Type

Baseline Building System	System Type
System 1 – PTAC	Single Zone Heating and Cooling
System 2 – PTHP	Single Zone Heating and Cooling
System 3 – PSZ-AC	Single Zone Heating and Cooling
System 4 – PSZ-HP	Single Zone Heating and Cooling
System 5 – Packaged VAV with Reheat	Single Duct VAV
System 6 – Packaged VAV with PFP boxes	Single Duct VAV
System 7 – VAV with Reheat	Single Duct VAV
System 8 – VAV with PFP boxes	Single Duct VAV

Thermal Block List

Applicability	All system types
Definition	Comprehensive list of all thermal blocks served by a given HVAC system.
Units	None
Baseline Rules	Same as the proposed design
Input Restrictions	As designed

Total Cooling Capacity

Applicability	All system types
Definition	The installed cooling capacity of the project. This includes all: • Chillers; • Built-up DX; and, • Packaged cooling units.
Units	Cooling tons (12,000 Btu/h per ton)
Input Restrictions	As designed. This could be calculated by the program from the proposed design building description or a separate load calculation may be used. Unmet load hours for the simulation shall not exceed 300 annually. Weather conditions used in sizing runs shall be based on 1% dry-bulb and 1% wet-bulb cooling design temperatures.
Baseline Rules	Autosize. The cooling capacity shall be oversized by 15%. If the number of unmet load hours of the proposed design exceeds the number of unmet load hours of the baseline by more than 50, decrease the cooling capacity as indicated in Figure 2 and Figure 3.

6.7.2 System Controls

Schedules

Cooling Schedule

Applicability	All cooling systems
Definition	A schedule that represents the availability of cooling
Units	Data structure: schedule, on/off
Input Restrictions	For tax deduction calculations, the fan schedules from Tables 12 through 16 of Appendix C shall be used for cooling availability. For other purposes, the schedules in Appendix C shall be used as a default. The cooling availability schedule shall be consistent with the supply fan schedule and thermostat schedules to reduce the likelihood of unmet load hours.
Baseline Rules	Same as the proposed design

Heating Schedule

Applicability	All systems
Definition	A schedule that represents the availability of heating
Units	Data structure: schedule, on/off
Input Restrictions	For tax deduction calculations, the schedules from Tables 12 through 16 of Appendix C shall be used. For other purposes, the schedules in Appendix C shall be used as a default. The heating availability schedule shall be consistent with the supply fan schedule.
Baseline Rules	Same as the proposed design

Air-Handler Schedule

Applicability	All systems that do not cycle with loads

Definition	A schedule that indicates when the air handler operates continuously
Units	Data structure: schedule, on/off
Input Restrictions	For the purpose of tax deduction calculations, the fan schedule is prescribed. One of the schedules from Appendix C, Tables 12-16 shall be used. For green building ratings and energy labels, the schedules in Appendix C are defaults, but other schedules may be used when detailed information is known about the proposed design. When a fan system serves several occupancies, the fan schedule must remain ON to serve the operating hours of each occupancy.
Baseline Rules	Same as the proposed design

Air Handler Fan Cycling

Applicability	All fan systems
Definition	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.
Units	List: continuous or cycles with loads
Input Restrictions	Continuous fan operation during occupied periods is a prescribed input, except for hotel guest rooms and high-rise residential. For these building types, continuous operation is the default, however, the option to let the fan cycle with loads may be used when the following conditions are met and documented: • The spaces served by the system are located within 25 ft of an operable window. • The openable window area is at least 4% of the floor space. • Other requirements for natural ventilation specified in ASHRAE Standard 62.1-2007, Section 5.1 are satisfied. For natural ventilation systems, an air conditioner is modeled in the proposed design even though one is not specified for the proposed design. This fan in the simulated air conditioner is allowed to cycle with loads since the simulated air conditioner is assumed to operate only when natural ventilation is unable to satisfy thermal comfort.
Baseline Rules	Same as proposed design, except for natural ventilation, in which case the fans in the baseline building are assumed to operate continuously

Optimum Start Control

Applicability	Systems with the control capability for flexible scheduling of system start time based on building loads.
Definition	Optimum 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
Baseline Rules	The baseline building shall have optimum start controls when the baseline building design supply airflow is greater than 10,000 cfm.

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 blocks during periods when the heating, cooling and fan systems are scheduled to be off. The choices are: • Cycle on call from any zone • Cycle on call from the primary control zone • Stay off • Cycle zone fans only (for systems with fan-powered boxes) Restart fans below given ambient temperature.
Units	None
Input Restrictions	As designed. However, for purposes other than energy labels of existing buildings, night-cycle control shall be cycled on call from any zone for heating in climate zones 2 through 8, and for cooling in climate zones 1b, 2b, and 3b.
Baseline Rules	Cycle on call from any zone

Cooling Control

Cooling Supply Air Temperature

Applicability	Applicable to all systems
Definition	The supply air temperature setpoint at design cooling conditions
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	20°F lower than the design room air temperature

Cooling Supply Air Temperature Control

Applicability	Any system with multiple cooling stages or unloading
Definition	The method of controlling the supply air temperature. Choices are: • Fixed (constant) • Reset by warmest zone • Reset by outside air dry-bulb temperature • Scheduled setpoint
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	For baseline building systems 1 through 4, the SAT control is not applicable. For systems 5 through 8, the SAT control shall be reset by outside dry-bulb temperature.

Cooling Reset Schedule by OSA

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 21):

- The coldest cooling supply air temperature
- The corresponding (hot) outdoor air dry-bulb setpoint
- The warmest cooling supply air temperature
- The corresponding (cool) outdoor air dry-bulb setpoint

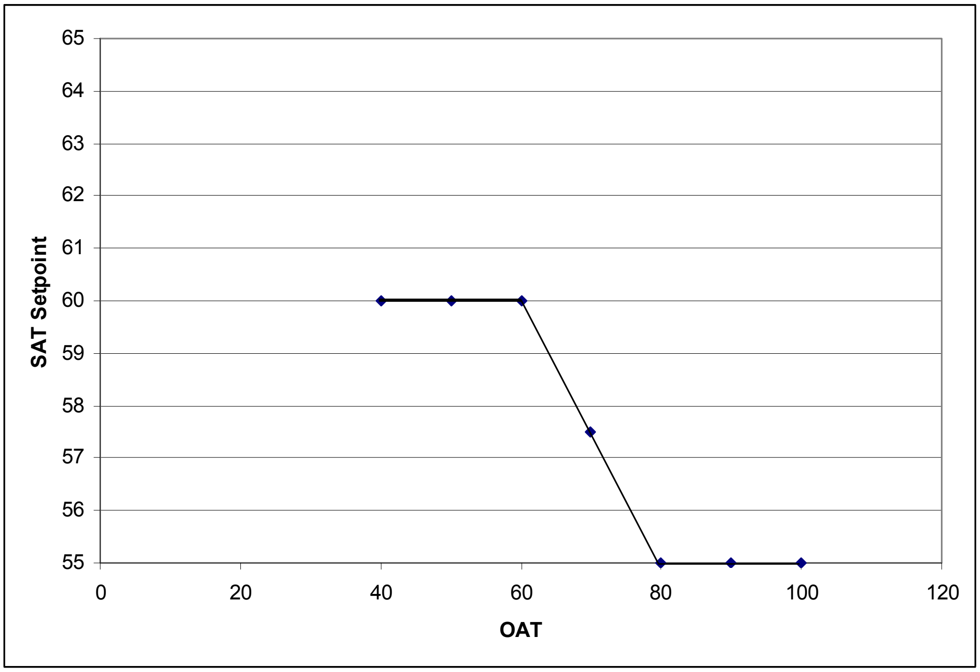


Figure 21 –SAT Cooling Setpoint Reset based on Outdoor Air Temperature (OAT) for Dry (B) and Marine (C) Climates

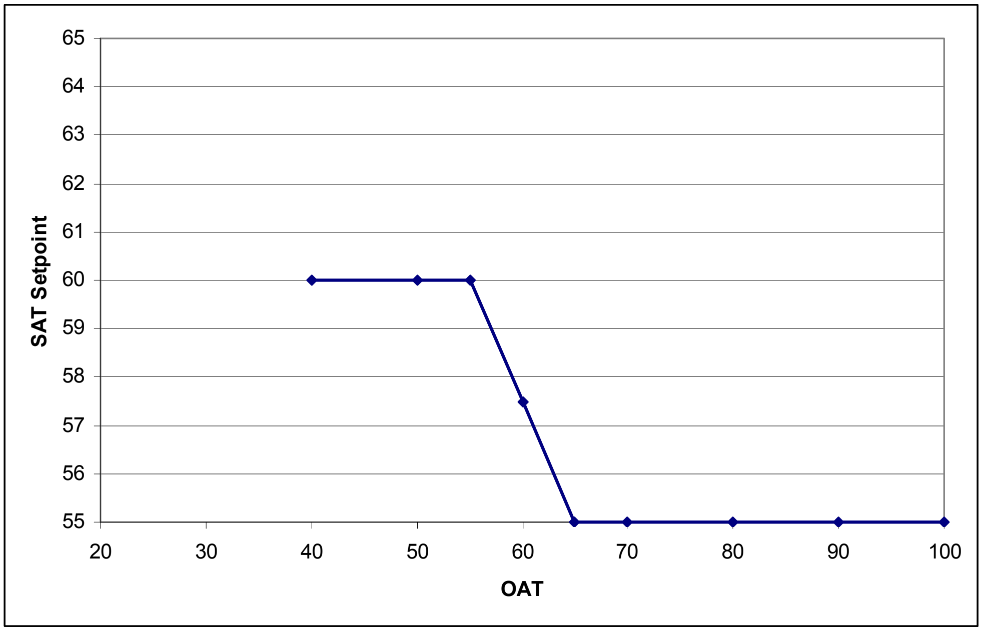


Figure 22 –SAT cooling setpoint reset based on outdoor air temperature for humid "A" climates

Units	Data structure (two matched pairs of SAT and OAT, see above)
Input Restrictions	As designed
Baseline Rules	Applicable for baseline building systems 5 through 8. For these systems, the minimum SAT shall be equal to the design conditions SAT when OAT is equal to or greater than 80 F. The maximum SAT shall be 5 F greater than the minimum when the OAT is 60 F or less.

Heating Control

Preheat Setpoint

Applicability	Systems with a preheat coil located in the outside air stream
Definition	The control temperature leaving the preheat coil
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	Same as the proposed design

Heating Supply Air Temperature

Applicability	All systems
Definition	The supply air temperature leaving the air handler when the system is in a heating mode (not the air temperature leaving the reheat coils in VAV boxes)
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	110°F for system types 1-4; 70°F for system types 5-8

Heading Supply Air Temperature Control

Applicability	Systems with the capability to vary heating SAT
Definition	The method of controlling heating SAT. Choices are: • Fixed (constant) • Reset by coldest zone • Reset by outside air dry-bulb temperature • Scheduled setpoint
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	Fixed (constant)

Heating Reset Schedule by OSA

Applicability	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)
Definition	A linear reset schedule that represents the heating supply air temperature or hot deck supply air temperature (for dual duct systems) as a function of outdoor air dry-bulb temperature. This schedule is defined by the following data points (see Figure 23): • The hottest heating supply air temperature • The corresponding (cold) outdoor air dry-bulb threshold • The coolest heating supply air temperature • The corresponding (mild) outdoor air dry-bulb threshold

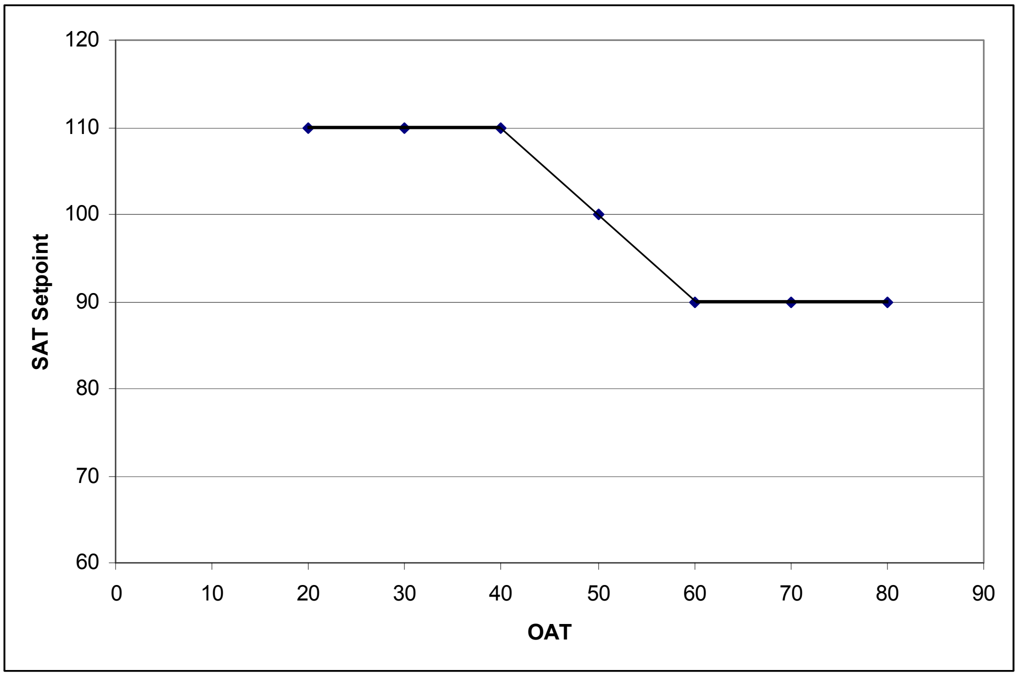


Figure 23 – Example of SAT heating setpoint reset based on outdoor air temperature (OAT).

Units

	Data structure (°F)
Input Restrictions	As designed
Baseline Rules	Not applicable

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 which 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 Rules	Not applicable

Night Purge Control

Applicability	Systems that operate the fans for nighttime purge of heat gains
Definition	The control strategy for operation of nighttime purge. The control strategy may take account of indoor temperature, season, indoor temperature and other factors.
Units	Data structure
Input Restrictions	As designed
Baseline Rules	Not applicable

Night Purge Fan Ratio

Applicability	Systems that operate the fans for nighttime purge of heat gains
Definition	The ratio of fan speed for a night purge cycle.
Units	Ratio
Input Restrictions	As designed. The default is 100% (or fans available at full speed).
Baseline Rules	Not applicable

6.7.3 Fan Systems

Baseline Building Fan System Summary

The baseline building fan system is summarized in this section. See Figure 18 for the HVAC baseline building system mapping.

Total baseline building fan system power for the baseline building fan systems is given in Table 62 for ASHRAE Standard 90.1-2007 and Table 63 for ASHRAE Standard 90.1-2001. In these tables, cfm_s is the supply fan air flow at peak design conditions. This is calculated for the baseline building with the sizing procedure described in Figure 2 and Figure 3. 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.

Table 62 – Baseline Building Fan System – ASHRAE Standard 90.1-2007

	System Types 1-2	System Types 3-4	System Types 5-8
Brake Horsepower (bhp)	Not applicable	0.00094 x cfm_s + A	0.0013 x cfm_s + A
Fan Motor Efficiency (ηm)	Not applicable	ASHRAE Standard 90.1-2007, Table 10.8	ASHRAE Standard 90.1-2007, Table 10.8
Fan Power (W)	0.3 x cfm_s	(bhp x 746)/η_m	(bhp x 746)/η_m
The term "A" for system types 3-8, is calculated based on equipment in the proposed design using the procedure in Table 6.5.3.1.1B of ASHRAE Standard 90.1-2007. This accounts for various additional fan pressure drops associated with special conditions.			

Table 63 – Baseline Building Fan System – ASHRAE Standard 90.1-2001

	Fan Size	System Types 1-4	System Types 5-8
Nameplate Horsepower (nhp)	< 20,000 cfm	0.0012 x cfm_s + P_{filter} + $P_{process}$ + P_{relief}	0.0017 x cfm_s + P_{filter} + $P_{process}$ + P_{relief}
	=> 20,000 cfm	0.0011 x cfm_s + P_{filter} + $P_{process}$ + P_{relief}	0.0015 x cfm_s + P_{filter} + $P_{process}$ + P_{relief}
Fan Motor Efficiency (η_m)		ASHRAE Standard 90.1-2001, Table 10.2	ASHRAE Standard 90.1-2001, Table 10.2
Brake Horsepower (bhp)		nhp x η_m	nhp x η_m
Fan Power (W)		(bhp x 746)/η_m	(bhp x 746)/η_m
The terms P_{filter}, $P_{process}$, and P_{relief} account for additional pressure drop. These are based on features in the proposed design such as special filtration, process fans, and relief or return fans. See Section 6.3.3.1 of ASHRAE Standard 90.1-2001 and the associated User's Manual for details on how to calculate these adders.			

When the proposed design has exhaust fans (toilets or kitchens), return fans, or fume hood exhaust systems, the baseline building has the same systems. The brake horsepower determined from Table 62 and Table 63 is allocated to these baseline building fan systems proportionally to the allocation in the proposed design. The allocation of brake horsepower to the supply fan, the return and any exhaust or fume hood fans is based on the ratios described below.

Table 64 – 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	✓	✓	✓

Supply Fan Ratio

Applicability	Systems that serve thermal blocks that have exhaust, fume hoods, kitchen exhaust or return fans
Definition	The ratio of supply fan brake horsepower in the proposed design to total fan system brake horsepower for the proposed design at design conditions
Units	Unitless ratio
Input Restrictions	Derived from other building descriptors
Baseline Rules	Same as proposed design

Return Fan Ratio

Applicability	Systems that serve thermal blocks that have exhaust, fume hoods, kitchen exhaust or return fans
Definition	The ratio of return fan brake horsepower in the proposed design to total fan system brake horsepower for the proposed design at design conditions
Units	Unitless ratio
Input Restrictions	Derived from other building descriptors
Baseline Rules	Same as proposed design

Exhaust Fan Ratio

Applicability	Systems that serve thermal blocks that have exhaust, fume hoods, kitchen exhaust or return fans
Definition	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. Fume hood exhaust is treated separately.
Units	Unitless ratio
Input Restrictions	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.
Baseline Rules	Same as proposed design

Supply Fans

Fan System Modeling Method

Applicability	All fan systems
Definition	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, part-load curve, 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. The latter two methods are commonly used for VAV and other larger fan systems.
Units	

List: power-per-unit-flow, static pressure or brake horsepower

Input Restrictions As designed. The power-per-unit-flow method shall be used when no fan performance data is available for the proposed design cooling system, e.g. only EER or SEER are available.

Baseline Rules 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 brake horsepower method.

Supply Fan Design Air Rated Capacity

Applicability All fan systems

Definition The design air flow rate of the supply fan(s) at design conditions. This building descriptor sets the 100% point for the fan part-load curve.

Units cfm

Input Restrictions As designed. This input should be at least as great as the sum of the design air flow specified for each of the thermal blocks that are served by the fan system. For multiple deck systems, a separate entry should be made for each deck.

Baseline Rules The program shall automatically size the air flow at each thermal block to meet the loads. The design air flow rate calculation shall be based on a 20 degree temperature differential between supply air and the room air. The supply fan design air flow rate shall be the sum of the calculated design air flow for the thermal blocks served by the fan system.

Fan Control Method

Applicability All fan systems

Definition A description of how the supply (and return/relief) fan(s) are controlled. The options include:

- Constant volume
- Variable-flow, inlet or discharge dampers
- Variable-flow, inlet guide vanes
- Variable-flow, variable speed drive (VSD)
- Variable-flow, variable pitch blades
- Variable-flow, other
- Two-speed
- Constant volume, cycling (fan cycles with heating and cooling)

Units List (see above)

Input Restrictions As designed

Baseline Rules Applicable to variable air volume systems

Based on the prescribed system type. Refer to the HVAC System Map in Figure 18.

Table 65 – Baseline Building Fan Control Method

Baseline building System	Fan Control Method
System 1 – PTAC	Constant volume
System 2 – PTHP	Constant volume
System 3 – PSZ-AC	Constant volume
System 4 – PSZ-HP	Constant volume
System 5 – Packaged VAV with Reheat	Variable-flow, variable speed drive (VSD)
System 6 – Packaged VAV with PFP boxes	Variable-flow, variable speed drive (VSD)
System 7 – VAV with Reheat	Variable-flow, variable speed drive (VSD)
System 8 – VAV with PFP boxes	Variable-flow, variable speed drive (VSD)

Supply Fan Brake Horsepower

Applicability	All fan systems, except those specified using the power-per-unit-flow method
Definition	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.
Units	Horsepower (hp)
Input Restrictions	As designed. If this building descriptor is specified for the proposed design, then the *Static Pressure* and *Fan Efficiency* are not.
Baseline Rules	See Table 62 for ASHRAE Standard 90.1-2007 and Table 63 for ASHRAE Standard 90.1-2001. These tables give 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_20)
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 Rules	Not applicable. When *Static Pressure* and *Fan Efficiency* are entered for the proposed design, the baseline building shall use *Brake Horsepower*.

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
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 Rules	Not applicable. When *Static Pressure* and *Fan Efficiency* are entered for the proposed design, the baseline building shall use *Brake Horsepower*.

Supply Motor Efficiency

Applicability	All supply fans, except those specified using the power-per-unit-flow method

Definition	The full-load efficiency of the motor serving the supply fan
Units	Unitless
Input Restrictions	As designed. Not applicable when the power-per-unit-flow method is used.
Baseline Rules	From Table 10.8 of ASHRAE Standard 90.1-2007 or Table 10.2 of ASHRAE Standard 90.1-2001

Fan Position

Applicability	All supply fans
Definition	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).
Units	List (see above)
Input Restrictions	As designed.
Baseline Rules	Draw through

Motor Position

Applicability	All supply fans
Definition	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.
Units	List (see above)
Input Restrictions	As designed.
Baseline Rules	In the air stream

Fan Part-Flow Power Curve

Applicability	All variable flow fan systems
Definition	A part-load power curve which represents the percentage full-load power draw of the supply fan as a function of the percentage full-load air flow. The curve is typically represented as a quadratic equation with an absolute minimum power draw specified.
Units	Unitless ratio
Input Restrictions	As designed. The default fan curve shall be selected from Equation (9) and Table 66 for the type of fan specified in the proposed design.

$$\begin{aligned} &Greater\ \ of \\ &PLR = a + b \cdot FanRatio + c \cdot FanRatio^{2} + d \cdot FanRatio^{3} \\ &PLR = PowerMin \end{aligned} \tag{9}$$

where

PLR	Ratio of fan power at part load conditions to full load fan power
PowerMin	Minimum fan power
FanRatio	Ratio of cfm at part-load to full-load cfm

a, b, c and d	Constants from Table 66 below

Table 66 – Fan Curve Default Values

Fan Type - Control Type	A	B	c	d	%Power$_{Min}$
AF or BI riding the curve[a]	0.1631	1.5901	-0.8817	0.1281	70%
AF or BI with inlet vanes[a]	0.9977	-0.659	0.9547	-0.2936	50%
FC riding the curve[a]	0.1224	0.612	0.5983	-0.3334	30%
FC with inlet vanes[a]	0.3038	-0.7608	2.2729	-0.8169	30%
Vane-axial with variable pitch blades[a]	0.1639	-0.4016	1.9909	-0.7541	20%
Any fan with VSD (use for baseline building)[b]	**0.0013**	**0.1470**	**0.9506**	**-0.0998**	**20%**
VSD with static pressure reset[c]	-0.0031	0.0991	1.0268	-0.1128	20%

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. Advanced VAV System Design Guide, California Energy Commission, CEC Publication 500,-03-082 A-11, April 2005, but adjusted to be relatively consistent with the curve specified in the PRM..

Baseline Rules Not applicable for baseline building systems 1-4. The curve for VSD fans shall be used for baseline building systems 5-8 with no adjustment for static pressure setpoint reset.

Supply Fan kW

Applicability Fan systems that use the power-per-unit-flow method

Definition The supply fan power per unit of flow.

Units kW/cfm

Input Restrictions As designed or specified in the manufacturers' literature. For units with rated total cooling capacities less than 120,000 Btu/h, the user may default to a value calculated as follows:

$$Fan_{kw} = 0.365 \times \frac{Q_{rated}}{30{,}000} \tag{10}$$

where

Fan_{kw}	The supply fan power (kW)
Q_{rated}	The rated total cooling capacity (Btu/h)

Baseline Rules Applicable when the baseline building uses the power-per-unit-flow method. Fan power is determined using Table 62 for ASHRAE Standard 90.1-2007 and Table 63 for ASHRAE Standard 90.1-2001. This power is then multiplied by the supply fan ratio.

Relief Fans

The baseline building has a return fan when the baseline building system is type 3 through 8 and the proposed design has a return fan.

Plenum Zone

Applicability Any system with return ducts or return air plenum

Definition A reference to the thermal block that serves as return plenum or where the return ducts are located

Units

	Text, unique
Input Restrictions	As designed
Baseline Rules	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

Applicability	Any system with return ducts or return air plenum
Definition	Describes the return path for air. This can be one of the following: ducted return; plenum return; or direct-to-unit.
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Applicable when the baseline building has a return fan. 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 same as proposed design.

Return/Relief Air Rated Capacity

Applicability	All systems with a return or relief fan
Definition	The design air flow fan capacity of the return or relief fan(s). This sets the 100% fan flow point for the part-load curve (see below).
Units	cfm
Input Restrictions	As designed
Baseline Rules	Applicable when the baseline building has a return fan. The return fan air *Rated Capacity* shall be equal to the baseline building supply fan capacity less exhaust air flow.

Return/Relief Fan Brake Horsepower

Applicability	Any system with return or relief fans that uses the brake horsepower method
Definition	The design shaft brake horsepower of the return/relief fan(s)
Units	Brake horsepower (bhp)
Input Restrictions	As designed
Baseline Rules	Applicable when the baseline building has a return fan. The bhp of the return fan shall be the fan system brake horsepower (see Table 62 and Table 63) times the return fan ratio. In other words, brake horsepower is allocated in proportion to the proposed design.

Return/Relief Design Static Pressure

Applicability	Any system with return or relief fans that uses the static pressure method
Definition	The design static pressure for return fan system. This is important for both fan electric energy usage and duct heat gain calculations.
Units	Inches of water column (in. H_20)
Input Restrictions	

	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.
Baseline Rules	Not applicable. When *Static Pressure* and *Fan Efficiency* are entered for the proposed design, the baseline building shall use *Brake Horsepower*.

Return/Relief Fan Efficiency

Applicability	Any system with return or relief fans that uses the static pressure method
Definition	The efficiency of the fan at design conditions
Units	Unitless
Input Restrictions	As designed. The return/relief fan efficiency does not need to be specified if the return fan brake horsepower (bhp) is specified.
Baseline Rules	Not applicable. When *Static Pressure* and *Fan Efficiency* are entered for the proposed design, the baseline building shall use *Brake Horsepower*.

Return/Relief Motor Efficiency

Applicability	All return fans, except those specified using the power-per-unit-flow method
Definition	The full-load efficiency of the motor serving the supply fan
Units	Unitless
Input Restrictions	As designed. Not applicable when the power-per-unit-flow method is used.
Baseline Rules	From Table 10.8 of ASHRAE Standard 90.1-2007 or Table 10.2 of ASHRAE Standard 90.1-2001

Motor Position

Applicability	All return fans
Definition	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.
Units	List (see above)
Input Restrictions	As designed.
Baseline Rules	In the air stream

Fan Part-Flow Power Curve

Applicability	All return fans for variable flow fan systems.
Definition	A part-load power curve which represents the percentage full-load power draw of the supply fan as a function of the percentage full-load air flow.
Units	Unitless ratio
Input Restrictions	As designed. The default fan curve shall be selected from Equation (9) and Table 66 for the type of fan specified in the proposed design.
Baseline Rules	Not applicable for baseline building systems 1-4. The curve for VSD fans shall be used for baseline building systems 5-8 that have a return/relief fan.

Return/Relief Fan kW

Applicability	Any system with a return fan

Definition	The supply fan power per unit of flow
Units	kW/cfm
Input Restrictions	As specified in the manufacturers' literature
Baseline Rules	Applicable when the baseline building uses the power-per-unit-flow method. Fan power is determined using Table 62 for ASHRAE Standard 90.1-2007 and Table 63 for ASHRAE Standard 90.1-2001. This power is then multiplied by the return fan ratio.

Exhaust Fan Systems

Exhaust fans include toilet exhaust, kitchen exhaust, as well as fume hoods in laboratories and other spaces. 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 block. An exhaust fan system may serve multiple thermal blocks. The baseline building has exhaust fans when the proposed design has exhaust fans. The exhaust air flow is the same for the baseline building and the proposed design.

Exhaust Fan Name

Applicability	All exhaust systems serving multiple thermal blocks
Definition	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 block level refer to this name.
Units	Text, unique
Input Restrictions	Where applicable, this should match the tags that are used on the plans.
Baseline Rules	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

Applicability	All exhaust fan systems
Definition	Software commonly models fans in three ways. See definition for supply system modeling method.
Units	List: power-per-unit-flow, static pressure or brake horsepower
Input Restrictions	As designed
Baseline Rules	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 brake horsepower method.

Exhaust Fan Rated Capacity

Applicability	All exhaust systems
Definition	The rated design air flow rate of the exhaust fan system. This building descriptor defines the 100% flow case for the part-flow curve. Actual air flow is the sum of the flow specified for each thermal block, as modified by the schedule for each thermal block.
Units	cfm
Input Restrictions	As designed

Baseline Rules	Same as proposed design

Fan Control Method

Applicability	All exhaust fan systems
Definition	A description of how the exhaust fan(s) are controlled. The options include: • Constant volume • Two-speed • Variable-flow, inlet or discharge dampers • Variable-flow, inlet guide vanes • Variable-flow, variable speed drive (VSD) • Variable-flow, variable pitch blades
Units	List (see above)
Input Restrictions	As designed, however, when exhaust fan flow at the thermal block level is varied through a schedule, one of the variable-flow options shall be specified.
Baseline Rules	The baseline building exhaust fan control shall generally be the same as the proposed design. For laboratories that have exhaust flow of 5,000 cfm or more, the baseline building exhaust flow shall vary in response to scheduled fume hood exhaust and lab zone airflow schedules. Fume hood exhaust flow control shall be the same as design, and general exhaust (relief) shall be VSD.

Exhaust Fan Schedule

Applicability	All exhaust fan systems
Definition	A schedule that indicates when the exhaust fan system is available for operation. Exhaust fan flow is specified at the thermal block level.
Units	Data structure: schedule, on/off
Input Restrictions	The exhaust fan system shall be available during all periods when one or more thermal blocks served by the system are scheduling exhaust.
Baseline Rules	Same as the proposed design

Exhaust Fan Brake Horsepower

Applicability	All exhaust fan systems
Definition	The design shaft brake horsepower of the exhaust fan(s).
Units	Brake horsepower (bhp)
Input Restrictions	As designed
Baseline Rules	The bhp for the baseline building is the total system fan horsepower from Table 62 or Table 63 times the exhaust fan ratio.

Exhaust Fan Design Static Pressure

Applicability	Any system with return or relief fans that uses the static pressure method
Definition	The design static pressure for exhaust fan system. This is important for both fan electric energy usage and duct heat gain calculations.
Units	

	Inches of water column (in. H_20)
Input Restrictions	As designed. The design static pressure for the exhaust fan does not need to be specified if the exhaust fan brake horsepower (bhp) is specified.
Baseline Rules	Not applicable. When static pressure and fan efficiency are entered for the proposed design, the baseline building shall use brake horsepower.

Exhaust Fan Efficiency

Applicability	Any exhaust fan system that uses the static pressure method
Definition	The efficiency of the exhaust fan at rated capacity
Units	Unitless
Input Restrictions	As designed. The exhaust fan efficiency does not need to be specified if the return fan brake horsepower (bhp) is specified.
Baseline Rules	Not applicable. When static pressure and fan efficiency are entered for the proposed design, the baseline building shall use brake horsepower.

Exhaust Fan Motor Efficiency

Applicability	All exhaust fan systems
Definition	The full-load efficiency of the motor serving the exhaust fan
Units	Unitless
Input Restrictions	As designed
Baseline Rules	From Table 10.8 of ASHRAE Standard 90.1-2007 or Table 10.2 of ASHRAE Standard 90.1-2001

Fan Part-Flow Power Curve

Applicability	All variable flow exhaust fan systems
Definition	A part-load power curve which represents the ratio full-load power draw of the exhaust fan as a function of the ratio full-load air flow.
Units	Unitless ratio
Input Restrictions	As designed. The default fan curve shall be selected from Equation (9) and Table 66 for the type of fan specified in the proposed design.
Baseline Rules	The baseline building fan curve shall be selected from Equation (9) and Table 66 for the type of fan specified in the proposed design.

Exhaust Fan KW

Applicability	All exhaust systems
Definition	The fan power of the exhaust fan per unit of flow. This building descriptor is applicable only with the power-per-unit-flow method.
Units	W/cfm
Input Restrictions	As designed.
Baseline Rules	The fan system power from Table 62 or Table 63

6.7.4 Outdoor Air Controls and Economizers

Outside Air Controls

Maximum Outside Air Ratio

Applicability	All systems with modulating outside air dampers
Definition	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.
Units	Ratio
Input Restrictions	As designed
Baseline Rules	1.0

Design Outside Air Flow

Applicability	All systems with outside air dampers
Definition	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 air flow for each of the zones served by the system.
Units	cfm
Input Restrictions	As designed
Baseline Rules	Same as proposed design. This input along with occupant density determines if the zones served by the system shall have demand control ventilation. See *ventilation control method* at the zone level.

Outdoor Air Control Method

Applicability	All HVAC systems that deliver outside air to zones
Definition	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 report their outside air requirements on an hourly basis. 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 on an hourly basis. Options include: • 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 fan. • 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 greater outside air than required. 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 which modulates the position of the outside air and return dampers to maintain the desired outside air flow. With the average flow, a CO_2 sensor in the return air duct is another way to control the position of the outside air and return dampers.

Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Same as proposed design

Air Side Economizers

Economizer Control Type

Applicability All systems with an air-side economizer

Definition An air-side economizer increases outside air ventilation during periods when refrigeration loads can be reduced from increased outside air flow. The control types include:

- No economizer
- Fixed dry-bulb. The system shifts to 100% outside air and shuts off the cooling when the temperature of the outside air is equal to or lower than the supply air temperature.
- Differential dry-bulb. The system shifts to 100% outside air when the temperature of the outside air is lower than the return air temperature but continues to operate the cooling system until the outside air temperature reaches the supply air temperature.
- Fixed enthalpy. The system shifts to 100% outside air and shuts off the cooling when the enthalpy of the outside air is equal to or lower than the supply air enthalpy.
- Differential enthalpy. The system shifts to 100% outside air when the enthalpy of the outside air is lower than the return air enthalpy but continues to operate the cooling system until the outside air enthalpy reaches the supply air enthalpy.

Units List (see above)

Input Restrictions As designed

Baseline Rules The control should be *no economizer* when the baseline building cooling capacity ≤ 50 tons AND the baseline building system total cooling capacity ≤ 95,000 Btu/h. Otherwise, the control should be based on the prescribed system type as shown in Table 67.

Table 67 – Baseline Economizer Control Type

Baseline building System	Economizer Control
System 1 – PTAC	None
System 2 – PTHP	None
System 3 – PSZ-AC	Differential dry-bulb None in climate zones 1a-4a and 1b
System 4 – PSZ-HP	Differential dry-bulb None in climate zones 1a-4a and 1b
System 5 – Packaged VAV with Reheat	Differential dry-bulb None in climate zones 1a-4a and 1b
System 6 – Packaged VAV with PFP boxes	Differential dry-bulb None in climate zones 1a-4a and 1b
System 7 – VAV with Reheat	Differential dry-bulb None in climate zones 1a-4a and 1b
System 8 – VAV with PFP boxes	Differential dry-bulb None in climate zones 1a-4a and 1b

Economizer High Temperature Lockout

Applicability	Systems with *fixed dry-bulb* economizer
Definition	It is the outside air setpoint temperature above which the economizer will return to minimum position.
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	Not applicable

Economizer Low Temperature Lockout

Applicability	Systems with air-side economizers
Definition	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.
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	Not used

Economizer High Enthalpy Lockout

Applicability	Systems with fixed enthalpy or differential enthalpy economizers
Definition	The outside air enthalpy above which the economizer will return to minimum position
Units	Btu/lb
Input Restrictions	As designed. The default is 25 Btu/lb.
Baseline Rules	No lockout limit

6.7.5 Cooling Systems

General

This group of building descriptors applies to all cooling systems.

Cooling Source

Applicability	All systems
Definition	The source of cooling for the system. The choices are: • Chilled water • Direct expansion (DX) • Other
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	The baseline building cooling source is shown in Table 68. See Figure 18 for HVAC system mapping.

Table 68 – Cooling Source for Baseline Building System

Baseline building System	Cooling Source
System 1 – PTAC	Direct expansion (DX)
System 2 – PTHP	Direct expansion (DX)
System 3 – PSZ-AC	Direct expansion (DX)
System 4 – PSZ-HP	Direct expansion (DX)
System 5 – Packaged VAV with Reheat	Direct expansion (DX)
System 6 – Packaged VAV with PFP boxes	Direct expansion (DX)
System 7 – VAV with Reheat	Chilled water
System 8 – VAV with PFP boxes	Chilled water

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 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.

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:

$$Q_{t,adj} = Q_{t,rated} + BHP_{supply} \times 2.545 \tag{11}$$

where

$Q_{t,adj}$	The adjusted total cooling capacity of a packaged unit (kBtu/h)

$Q_{t,rated}$	The ARI rated total cooling capacity of a packaged unit (kBtu/h) from manufacturers' literature
BHP_{supply}	The supply fan brake horsepower (bhp).

If the number of unmet load hours in the proposed design exceeds 300, the software shall warn the user to resize the equipment.

Baseline Rules The total cooling capacity of the baseline building is oversized by 15%. However, the cooling equipment may need to be subsequently downsized such that the difference in unmet load hours between the proposed design and the baseline building is less than 50 (see Chapter 2). Sizing calculations shall be based on 1% dry-bulb and 1% wet-bulb design conditions.

Sensible Cooling Capacity

Applicability All cooling systems

Definition The sensible heat 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.

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:

(12)

$$Q_{s,adj} = Q_{s,rated} + BHP_{supply} \times 2.545$$

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).

If the number of unmet load hours in the proposed design exceeds 300, the software shall warn the user to resize the equipment.

Baseline Rules The sensible cooling capacity of the baseline building is oversized by 15%. However, the cooling equipment may need to be subsequently downsized such that the difference in unmet load hours between the proposed design and the baseline building is less than 50 (see Chapter 2). Sizing calculations shall be based on 1% dry-bulb and 1% wet-bulb design conditions.

Cooling Capacity Adjustment Curves

Applicability All cooling systems

Definition A curve that represents the available total cooling capacity as a function of cooling coil and/or condenser conditions. The common form of these curves is given as follows:

(13)

$$Q_{t,available} = CAP\_FT \times Q_{t,adj}$$

For air cooled direct expansion

$$CAP\_FT = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{odb} + e \times t_{odb}^2 + f \times t_{wb} \times t_{odb} \tag{14}$$

For water cooled direct expansion

$$CAP\_FT = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{wt} + e \times t_{wt}^2 + f \times t_{wb} \times t_{wt} \tag{15}$$

For chilled water coils

$$CAP\_FT = a + b \times t_{wb} + c \times t_{wb}^2 + d \times t_{db} + e \times t_{db}^2 + f \times t_{wb} \times t_{db} \tag{16}$$

where

$Q_{t,available}$	Available cooling capacity at specified evaporator and/or condenser conditions (MBH)
$Q_{t,adj}$	Adjusted capacity at ARI conditions (Btu/h) (see Equation (11)
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 69 –Cooling Capacity Curve Coefficients

	Air Cooled Direct Expansion		Water Cooled Direct Expansion		Chilled Water Coils	
Coefficient	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.

Units Data structure

Input Restrictions As designed. The equations and coefficients given above are the default.

Baseline Rules Use the default curves or equivalent data for other models.

Coil Bypass Factor

Applicability All cooling systems

Definition The ratio of air that bypasses the cooling coil at design conditions to the total system airflow.

Units Ratio

Input Restrictions As designed. Default values are given in Table 70.

Table 70 – 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

Baseline Rules Defaults

Coil Bypass Factor Adjustment Curve

Applicability All cooling systems

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 Default to the simulation engine defaults based on HVAC system type. The following default values shall be used for the adjustment curves:

$$CBF_{adj} = CBF_{rated} \times COIL - BF - FFLOW \times COIL - BF - FT \times COIL - BF - FPLR \tag{17}$$

$$\text{COIL - BF - FFLOW} = a + b \times CFMR + c \times CFMR^2 + d \times CFMR^3 \tag{18}$$

$$\text{COIL - BF - FT} = a + b \times T_{wb} + c \times T_{wb}{}^2 + d \times T_{db} + e \times T_{db}{}^2 + f \times T_{wb} \times T_{db} \tag{19}$$

$$COIL - BF - FPLR = a + b \times PLR \tag{20}$$

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 air flow across the coil (take coefficients from Table 71)

COIL-BF-FT	A multiplier on the rated coil bypass factor to account for a variation in coil entering conditions (take coefficients from Table 72)
COIL-BF-FPLR	A multiplier on the rated coil bypass factor to account for the part load ratio (take coefficients from Table 73)
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 71 – 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 72 – 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 73 – Coil Bypass Factor Part Load Adjustment Factor

Coefficient	COIL-BF-FPLR (All Systems)
a	0.00
b	1.00

Baseline Rules Use defaults as described above.

Direct Expansion

Direct Expansion Cooling Efficiency

Applicability Packaged equipment

Definition The cooling efficiency of a direct expansion (DX) cooling system at ARI rated conditions as a ratio of output over input in Btu/h per W, excluding fan energy. The software must accommodate user input in terms of either the *Energy Efficiency Ratio (*EER) or the *Seasonal Energy Efficiency Ratio* (SEER). For equipment with SEER ratings, EER shall be taken from manufacturers' data when it is available. When it is not available it shall be calculated as follows:

(21)

$$\begin{aligned} EER &= 10 - (11.5 - SEER) \times 0.83 \text{ when } SEER<=11.5 \\ &= 10 \text{ when } SEER>=11.5 \end{aligned}$$

For all unitary and applied equipment where the fan energy is part of the equipment efficiency rating, the EER shall be adjusted as follows:

(22)

$$EER_{adj} = \frac{Q_{t,rated} + BHP_{supply} \times 2.545}{\frac{Q_{t,rated}}{EER} - BHP_{supply} \times 0.7457}$$

where

EER_{adj}	The adjusted *Energy Efficiency Ratio* for simulation purposes
EER	The rated Energy Efficiency Ratio
$Q_{t,rated}$	The ARI rated total cooling capacity of a packaged unit (kBtu/h)
BHP_{supply}	The supply fan brake horsepower (bhp) shall be taken from manufacturers' literature when available, otherwise use Equation (10).

Units	Btu/h-W
Input Restrictions	As designed. When possible, specify the SEER and EER for packaged equipment with cooling capacity less than 65,000 Btu/h. For equipment with capacity above 65,000 Btu/h, specify EER.
Baseline Rules	For the purpose of green building ratings, look up the requirement from Table 6.8.1A and Table 6.8.1B in ASHRAE Standard 90.1-2007. For the purpose of tax deduction calculations, look up the requirement from Table 6.2.1A and 6.2.1B in ASHRAE Standard 90.1-2001. Use the total cooling capacity of the proposed design to determine the size category.

Direct Expansion Cooling Efficiency Adjustment Curve

Applicability	Packaged DX equipment
Definition	A curve or group of curves that varies the cooling efficiency of a direct expansion (DX) coil as a function of evaporator conditions, condenser conditions and part-load ratio. The default curves are given as follows as adjustments to the energy input ratio (EIR)[20]:

(23)

$$PLR = \frac{Q_{operating}}{Q_{available}(t_{wb}, t_{odb/wt})}$$

(24)

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3$$

---

[20] 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).

(25)

For air-cooled DX systems:

$$EIR\_FT = a + b \times t_{wb} + c \times t_{wb}{}^2 + d \times t_{odb} + e \times t_{odb}{}^2 + f \times t_{wb} \times t_{odb}$$

(26)

For water-cooled DX systems:

$$EIR\_FT = a + b \times t_{wb} + c \times t_{wb}{}^2 + d \times t_{wt} + e \times t_{wt}{}^2 + f \times t_{wb} \times t_{wt}$$

(27)

$$P_{operating} = P_{rated} \times EIR\_FPLR \times EIR\_FT \times CAP\_FT$$

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
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 74 – Cooling System Coefficients for EIR-FPLR

Coefficient	Water-Source (Heat Pump)	Water-Source (Other)	Air-Source (PTAC)	Air-Source (Other)
a	0.1250000	0.2012301	0.1250000	0.2012301
b	0.8750000	-0.0312175	0.8750000	-0.0312175
c	0.0000000	1.9504979	0.0000000	1.9504979
d	0.0000000	-1.1205105	0.0000000	-1.1205105

Table 75 – 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

Units	Data structure
Input Restrictions	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 Rules	Use default curves.

Minimum Unloading Ratio

Applicability	Packaged systems which use hot-gas bypass during low load conditions
Definition	The upper end of the hot-gas bypass operating range. This is the percentage of peak cooling capacity below which hot-gas bypass will operate.
Units	Ratio
Input Restrictions	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. A maximum of 0.5 is allowed for units with a peak cooling capacity of 240 kBtu/h (20 tons) or less, and a maximum value of 0.25 is allowed for units with a peak cooling capacity greater than 240 kBtu/h.
Baseline Rules	Not applicable

Minimum HGB Ratio

Applicability	Packaged systems which use hot-gas bypass during low load conditions
Definition	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).
Units	Ratio
Input Restrictions	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.
Baseline Rules	Not applicable

Condenser Type

Applicability: All direct expansion systems including heat pumps

Definition The type of condenser for a direct expansion (DX) cooling system. The choices are:

- Air-Cooled
- Water-Cooled
- Air-Cooled with Evaporative Pre-cooler

Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Based on the prescribed system type. Refer to the HVAC System Map in Figure 18.

Table 76 – Baseline Building Condenser Type

Baseline building System	Condenser Type
System 1 – PTAC	Air-cooled
System 2 – PTHP	Air-cooled
System 3 – PSZ-AC	Air-cooled
System 4 – PSZ-HP	Air-Cooled
System 5 – Packaged VAV with Reheat	Air-cooled
System 6 – Packaged VAV with PFP boxes	Air-cooled
System 7 – VAV with Reheat	N/A
System 8 – VAV with PFP boxes	N/A

Condenser Flow Type

Applicability: All direct expansion systems including heat pumps

Definition Describes water flow control for a water-cooled condenser. The choices are:

- Fixed Flow
- Two-position
- Variable Flow

Units List (see above)

Input Restrictions Default to fixed flow. If the variable-flow is selected, the software must indicate that supporting documentation is required on the output forms.

Baseline Rules Always fixed flow

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.

Evaporative Cooling Type

Applicability Systems with evaporative pre-cooling

Definition The type of evaporative pre-cooler, including:

- None
- Non-Integrated Indirect
- Non-Integrated Direct/Indirect
- Integrated Indirect
- Integrated Direct/Indirect

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.

In all cases, the evaporative pre-cooler must be modeled with 100% of the outside air routed through the pre-cooler.

Units None

Input Restrictions As designed

Baseline Rules Not applicable

Direct Stage Effectiveness

Applicability Systems with evaporative pre-cooling

Definition The effectiveness of the direct stage of an evaporative cooling system. Effectiveness is defined as follows:

$$DirectEFF = \frac{Tdb - Tdirect}{Tdb - Twb} \tag{28}$$

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

Units Numeric

Input Restrictions As designed

Baseline Rules 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:

$$IndEFF = \frac{Tdb - Tind}{Tdb - Twb} \tag{29}$$

where

IndEFF	The indirect stage effectiveness
Tdb	The entering air dry-bulb temperature of the supply air
Twb	The entering air wet-bulb temperature of the “scavenger air”
Tind	The supply air leaving dry-bulb temperature

Units Numeric

Input Restrictions As designed

Baseline Rules 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:

(30)

$$PLR = \frac{CFM_{operating}}{CFM_{design}}$$

$$EFF\_FFLOW = a + b \times PLR + c \times PLR^2$$

where

PLR	Part load ratio of airflow based on design airflow
$EFF\text{-}FFLOW$	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 77 – 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

Units Data structure

Input Restrictions 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 Rules Not used.

Auxiliary Evaporative Cooling Power

Applicability Systems with evaporative cooling

Definition The auxiliary energy of the indirect evaporative cooler fan, and the pumps for both direct and indirect stages

Units kW/cfm

Input Restrictions As designed

Baseline Rules Not applicable

Evaporative Cooling Scavenger Air Source

Applicability Systems with evaporative cooling

Definition The source of scavenger air for an indirect section of an evaporative cooler. Options include:

- Return Air
- Outside Air

Units List (see above)

Input Restrictions	As designed
Baseline Rules	Not applicable

Evaporative Condenser

Evaporative Condenser Power

Applicability	Direct expansion systems with an evaporatively cooled condenser
Definition	The power of the evaporative precooling unit. This includes any pump(s) and/or fans that are part of the precooling unit.
Units	Kilowatts (kW)
Input Restrictions	As designed
Baseline Rules	Not applicable

Evaporative Condenser Effectiveness

Applicability Direct expansion systems with an evaporatively cooled condenser

Definition The effectiveness of the evaporative precooling unit for a condenser. Effectiveness is defined as follows:

$$DirectEFF = \frac{Tdb - Tdirect}{Tdb - Twb} \tag{31}$$

where

DirectEFF	The direct stage effectiveness
Tdb	The entering air dry-bulb temperature
Twb	The entering air wet-bulb temperature
Tdirect	The direct stage leaving dry-bulb temperature

Units	Ratio
Input Restrictions	As designed
Baseline Rules	Not applicable

Evaporative Condenser Operation Range

Applicability Direct expansion systems with an evaporatively cooled condenser.

Definition The temperature range within which the evaporative condenser operates. Two values are provided:

$T_{maximum}$	The threshold outside air dry-bulb temperature below which evaporative condenser operates.
$T_{minimum}$	The threshold outside air dry-bulb temperature above which evaporative condenser operates.

Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	Not applicable

6.7.6 Heating Systems

General

Heating Source

Applicability	All systems that provide heating
Definition	The source of heating for the heating and preheat coils. The choices are: • Hot water • Steam • Electric resistance • Electric heat pump • 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 Rules	Based on the prescribed system type. Refer to the HVAC System Map in Figure 18.

Table 78 – Heating Source for Baseline Building

Baseline Building System	Heating Source
System 1 – PTAC	Gas Furnace
System 2 – PTHP	Heat pump
System 3 – PSZ-AC	Gas or Oil Furnace
System 4 – PSZ-HP	Heat pump
System 5 – Packaged VAV with 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

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

Applicability	Systems with a preheat coil located in the outside air stream
Definition	The heating capacity of a preheating coil at design conditions.
Units	Btu/h
Input Restrictions	As designed
Baseline Rules	The baseline building has a pre-heat coil when the proposed design has one. Autosize

to maintain the preheat coil temperature of the proposed design.

Heating Coils

Systems with boilers have heating coils, including baseline building systems 1, 5 and 7.

Heating Coil Capacity

Applicability	All systems with a heating coil
Definition	The heating capacity of a heating coil at ARI conditions
Units	Btu/h
Input Restrictions	As designed. Adjust the capacity if the number of unmet load hours exceeds 300.
Baseline Rules	Autosize with a heating oversizing factor of 25%. If the number of unmet load hours for the proposed design exceeds the number of unmet load hours for the baseline building by more than 50, reduce the heating coil capacity as indicated in Figure 3.

Furnace

Furnace Capacity

Applicability	Systems with a furnace
Definition	The full load heating capacity of the unit
Units	Btu/h
Input Restrictions	As designed. Adjust the capacity if the number of unmet load hours exceeds 300.
Baseline Rules	Autosize with an oversizing factor of 25% (let the software determine heating capacity based on the building loads). If the number of unmet load hours for the proposed design exceeds the number of unmet load hours for the baseline building by more than 50, reduce the furnace capacity as indicated in Figure 2 and Figure 3.

Furnace Fuel Heating Efficiency

Applicability Systems with a furnace

Definition The full load thermal efficiency of either a gas or oil furnace at design conditions. The software must accommodate input in either *Thermal Efficiency* (E_t) or *Annual Fuel Utilization Efficiency* (AFUE). Where AFUE is provided, E_t shall be calculated as follows:

$$\begin{aligned}&\text{1) All Single Package Equipment}\\&E_t = 0.005163 \times AFUE + 0.4033\\&\text{2) Split Systems, AFUE} \le 83.5\\&E_t = 0.002907 \times AFUE + 0.5787\\&\text{3) Split Systems, AFUE} > 83.5\\&E_t = 0.011116 \times AFUE - 0.098185\end{aligned} \tag{32}$$

where

AFUE	The annual fuel utilization efficiency (%)
Et	The thermal efficiency (fraction)

Units	Fraction
Input Restrictions	As designed
Baseline Rules	Look up the requirement from the equipment efficiency tables in Table 6.8.1E of the Standard. Use the heating input of the proposed design system to determine the size category.

Furnace Fuel Heating Part Load Efficiency Curve

Applicability Systems with furnaces

Definition 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:

$$Fuel_{partload} = Fuel_{rated} \times FHeatPLC \tag{33}$$

$$FHeatPLC = \left(a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left(\frac{Q_{partload}}{Q_{rated}} \right)^2 \right) \tag{34}$$

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 79 – Furnace Efficiency Curve Coefficients

Coefficient	Furnace
a	0.0186100
b	1.0942090
c	-0.1128190

Units	Data structure
Input Restrictions	Fixed
Baseline Rules	Fixed

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 Rules	Zero (pilotless ignition)

Furnace Fuel Heating Fan/Auxiliary

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)
Input Restrictions	As designed
Baseline Rules	Not applicable

Electric Heat Pump

Electric Heat Pump Heating Capacity

Applicability	All heat pumps
Definition	The full load heating capacity of the unit, excluding supplemental heating capacity at ARI rated conditions
Units	Btu/h
Input Restrictions	As designed
Baseline Rules	Autosize and use an oversizing factor of 25% (let the software determine heating capacity based on the building loads). The autosized equipment may need to be downsized to achieve a maximum difference in unmet load hours between the proposed design and the baseline building of 50.

Electric Heat Pump Supplemental Heating Source

Applicability	All heat pumps
Definition	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: • Electric resistance • Gas furnace • Oil furnace • Hot water • Other
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	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 *Coefficient of Performance* (COP) or the *Heating Season Performance Factor* (HSPF). Where HSPF is provided, COP shall be calculated as follows:

(35)

1)All Single Package Equipment

$$COP = 0.2778 \times HSPF + 0.9667$$

2)All Split Systems

$$COP = 0.4813 \times HSPF - 0.2606$$

For all unitary and applied equipment where the fan energy is part of the equipment efficiency rating, the COP shall be adjusted as follows to remove the fan energy:

(36)

$$COP_{adj} = \frac{\frac{HCAP_{rated}}{3.413} - BHP_{supply} \times 0.7457}{\frac{HCAP_{rated}}{COP \times 3.413} - BHP_{supply} \times 0.7457}$$

where

COP_{adj}	The adjusted coefficient of performance for simulation purposes
COP	The ARI rated coefficient of performance
$HCAP_{rated}$	The ARI rated heating capacity of a packaged unit (kBtu/h)
BHP_{supply}	The supply fan brake horsepower (bhp).

Refer to building descriptor *Supply Fan BHP*.

Units	Unitless
Input Restrictions	As designed
Baseline Rules	For the purpose of green building ratings, look up the requirement from the equipment efficiency Table 6.8.1B and Table 6.8.1D in ASHRAE Standard 90.1-2007. For the purpose of tax deduction calculations, find the equipment efficiency from Table 6.2.1B and 6.2.1D in ASHRAE Standard 90.1-2001. 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:

(37)

$$Q_{available} = CAP\_FT \times Q_{rated}$$

(38)

For air-cooled heat pumps:

$$CAP\_FT = a + b \times t_{odb} + c \times t_{odb}^{2} + d \times t_{odb}^{3}$$

(39)

For water-cooled heat pumps:

$$CAP\_FT = a + b \times t_{db} + d \times t_{wt}$$

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 80 – 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

Units	Data structure
Input Restrictions	User may input curves or use default curves. If defaults are overridden, supporting documentation shall be provided.
Baseline Rules	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:

(40)

$$PLR = \frac{Q_{operating}}{Q_{available}\left(t_{db}, t_{odb/wt}\right)}$$

(41)

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3$$

Air Source Heat Pumps:

(42)

$$EIR\_FT = a + b \times \left(\frac{t_{odb}}{t_{db}}\right) + c \times \left(\frac{t_{odb}}{t_{db}}\right)^2 + d \times \left(\frac{t_{odb}}{t_{db}}\right)^3$$

Water Source Heat Pumps:

(43)

$$EIR\_FT = a + b \times t_{wt} + d \times t_{db}$$

(44)

$$P_{operating} = P_{rated} \times EIR\_FPLR \times EIR\_FT \times CAP\_FT$$

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 81 – 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

Units	None
Input Restrictions	User may input curves or use default curves. If defaults are overridden, documentation shall be provided.
Baseline Rules	Use default curves

Electric Heat Pump Supplemental Heating Capacity

Applicability	All heat pumps
Definition	The design heating capacity of a heat pump supplemental heating coil at ARI conditions
Units	Btu/h
Input Restrictions	As designed
Baseline Rules	Autosize

Electric Supplemental Heating Control Temp

Applicability	All heat pumps
Definition	The outside dry-bulb temperature below which the heat pump supplemental heating is allowed to operate
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed. Default to 40°F
Baseline Rules	

40°F

Coil Defrost

Applicability	Air-cooled electric heat pump
Definition	The defrost control mechanism for an air-cooled heat pump. The choices are: • Hot-gas defrost, on-demand • Hot-gas defrost, timed 3.5 minute cycle • Electric resistance defrost, on-demand • Electric resistance defrost, timed 3.5 minute cycle Defrost shall be enabled whenever the outside air dry-bulb temperature drops below 40°F.
Units	List (see above)
Input Restrictions	Default to use hot-gas defrost, timed 3.5 minute cycle. User may select any of the above.
Baseline Rules	The baseline building uses the default.

Coil Defrost kW

Applicability	Heat pumps with electric resistance defrost
Definition	The capacity of the electric resistance defrost heater
Units	Kilowatts (kW)
Input Restrictions	As designed. This descriptor defaults to 0 if nothing is entered.
Baseline Rules	Not applicable. Baseline building systems 2 and 4 use hot-gas, timed 3.5 minute cycle.

Crank Case Heater kW

Applicability	All heat pumps
Definition	The capacity of the electric resistance heater in the crank case of a direct expansion (DX) compressor. The crank case heater operates only when the compressor is off.
Units	Kilowatts (kW)
Input Restrictions	As designed. This descriptor defaults to 0 if nothing is entered.
Baseline Rules	Zero (0)

Crank Case Heater Shutoff Temperature

Applicability	All heat pumps
Definition	The outdoor air dry-bulb temperature above which the crank case heater is not permitted to operate.
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed. This descriptor defaults to 50°F.
Baseline Rules	50°F

Heat Recovery

Exhaust to Outside Heat Recovery Effectiveness

Applicability	Any system with outside air heat recovery
Definition	The effectiveness of an air-to-air heat exchanger between the building exhaust and entering outside air streams. Effectiveness is defined as follows:

(45)

$$HREFF = \frac{(EEAdb - ELAdb)}{(EEAdb - OSAdb)}$$

where

HREFF	The air-to-air heat exchanger effectiveness
EEAdb	The exhaust air dry-bulb temperature entering the heat exchanger
ELAdb	The exhaust air dry-bulb temperature leaving the heat exchanger
OSAdb	The outside air dry-bulb temperature

Units	Ratio
Input Restrictions	As designed
Baseline Rules	Required for fan systems with a design supply air flow rate of 5,000 cfm or greater if the minimum outside air quantity is 70% of the design air flow rate. If required, the energy recovery system should have at least 50% effectiveness. Energy recovery is not required for heating systems in climate zones 1 through 3 or for cooling systems in climate zones 3c, 4c, 5b, 5c, 6b, 7 and 8.

Condenser Heat Recovery Effectiveness

Applicability	Systems that use recover heat from a condenser
Definition	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.
Units	Percent (%)
Input Restrictions	As designed. The software must indicate that supporting documentation is required on the output forms if heat recovery is specified.
Baseline Rules	Not applicable for most conditions. Condenser heat recovery is required for 24-hour facilities when the heat rejection exceeds 6,000,000 Btu/h and the design service water heating load exceeds 1,000,000 Btu/h. When required, the effectiveness will be 60%.

Heat Recovery Use

Applicability	Systems that use heat recovery
Definition	The end use of the heat recovered from a DX or heat pump unit. The choices are: • Reheat coils • Water heating
Units	List (see above)
Input Restrictions	As designed. The software must indicate that supporting documentation is required on

	the output forms if heat recovery is specified.
Baseline Rules	Not applicable for most conditions. The end use will be water heating if required for 24-hour facility operation.

6.7.7 Humidity Controls and Devices

General

Humidifier Type

Applicability	Optional humidifier
Definition	The type of humidifier employed. Choices include: • Hot-Water • Steam • Electric • Evaporative Humidification
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Same as the proposed design

Humidistat Maximum Setting

Applicability	Systems with humidity control
Definition	The control setpoint for dehumidification
Units	Percent (%)
Input Restrictions	As designed
Baseline Rules	Same as the proposed design

Humidistat Minimum Setting

Applicability	Systems with humidity control
Definition	The control setpoint for humidification
Units	Percent (%)
Input Restrictions	As designed
Baseline Rules	Same as proposed design

Desiccant

Desiccant Type

Applicability	Systems with desiccant dehumidification
Definition	Describes the configuration of desiccant cooling equipment The following configurations for desiccant systems are allowed:

- LIQ-VENT-AIR1 – a liquid desiccant dehumidifying unit
- LIQ-VENT-AIR2 – a liquid desiccant dehumidifying unit combined with a gas-fired absorption chiller
- SOL-VENT-AIR1 – a solid desiccant dehumidifying unit
- NO-DESICCANT – the default, which indicates that no desiccant system is present

Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Not applicable

Desiccant Control Mode

Applicability Systems with desiccant dehumidification

Definition The method of controlling the operation of the desiccant unit. For liquid-based systems this can be either:

- Dry-bulb – the desiccant unit is turned on whenever the outside air dry-bulb exceeds a set limit.
- Evaporative cooling– cycles the desiccant unit on when an evaporative cooler is on to maintain a dewpoint setpoint.
- Dewpoint – cycles the desiccant unit on and off to maintain the dewpoint temperature of the supply air.

For solid-based systems the following configurations are possible:

- Dehumidification only – the desiccant unit cycles on and off to maintain indoor humidity levels
- 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
- 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

Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Not applicable

Desiccant Air Fraction

Applicability	Systems with desiccant dehumidification
Definition	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.
Units	Ratio
Input Restrictions	As designed
Baseline Rules	Not applicable

Desiccant Heat Source

Applicability

Systems with desiccant dehumidification

Definition The source of heat that is used to dry out the desiccant. This can be either:

- Gas – Hydronic – the regeneration heat load is met with a gas-fired heater
- Hot water – the heat load is met with hot water from the plant

Units List (see above)

Input Restrictions As designed

Baseline Rules Not applicable

Liquid Desiccant Performance Curves

Applicability Systems with liquid-based desiccant dehumidification

Definition A set of performance curves that apply to liquid desiccant systems.

(46)

- $DESC - T - FTW = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w$

(47)

- $DESC - W - FTW = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w$

(48)

- $DESC - Gas - FTW = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w$

(49)

- $DESC - kW - FTW = a + b \times T + c \times T^2 + d \times w + e \times w^2 + f \times T \times w$

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 82 – 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

Units Data structure

Input Restrictions As designed, default to values in Table 82

Baseline Rules 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 Rules	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	Ratio
Input Restrictions	As designed
Baseline Rules	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_2O
Input Restrictions	As designed. Defaults to 1.0 in. H_2O
Baseline Rules	Not applicable

6.8 HVAC Primary Systems

Table 83 – Primary Systems Building Descriptors for Baseline Systems

	1 PTAC	2 PTHP	3 PSZ-AC	4 PSZ-HP	5 PVAV-DX-Blr	6 PVAV-DX-Elec	7 PVAV-CW-Blr	8 VAV-CW-Elec
HVAC Primary Systems								
Boilers								
Boiler Name	✓				✓		✓	
Boiler Fuel	✓				✓		✓	
Boiler Type	✓				✓		✓	
Boiler Draft Type	✓				✓		✓	
Number of Identical Boiler Units	✓				✓		✓	
Boiler Heat Loss	✓				✓		✓	
Boiler Design Capacity	✓				✓		✓	
Boiler Efficiency Type	✓				✓		✓	
Boiler Efficiency	✓				✓		✓	
Boiler Part-Load Performance Curve	✓				✓		✓	
Boiler Minimum Unloading Ratio	✓				✓		✓	
Hot Water Supply Temperature	✓				✓		✓	
Hot Water Return Temperature	✓				✓		✓	
Hot Water Supply Temperature Reset	✓				✓		✓	
Chillers								
Chiller Name							✓	✓
Chiller Type							✓	✓
Number of Identical Chiller Units							✓	✓
Chiller Fuel							✓	✓
Chiller Rated Capacity							✓	✓
Chiller Rated Efficiency							✓	✓
Chiller Minimum Unloading Ratio							✓	✓
Chiller Cooling Capacity Adjustment Curve							✓	✓
Electric Chiller Cooling Efficiency Adjustment Curves							✓	✓
Fuel and Steam Chiller Cooling Efficiency Adjustment Curves							✓	✓
Chilled Water Supply Temperature							✓	✓
Chilled Water Return Temperature							✓	✓
Chilled Water Supply Temperature Reset							✓	✓
Condenser Type							✓	✓
Air-Cooled Condenser Power							✓	✓
Cooling Towers								
Cooling Tower Name							✓	✓
Cooling Tower Type							✓	✓
Cooling Tower Capacity							✓	✓
Cooling Tower Number of Cells							✓	✓
Cooling Tower Total Fan Horsepower							✓	✓
Cooling Tower Design Wet-Bulb							✓	✓
Cooling Tower Design Entering Water Temperature							✓	✓
Cooling Tower Design Return Water Temperature							✓	✓

Cooling Tower Capacity Adjustment Curve							✓	✓
Cooling Tower Set Point Control							✓	✓
Cooling Tower Capacity Control							✓	✓
Cooling Tower Low-Speed Airflow Ratio							✓	✓
Cooling Tower Low-Speed kW Ratio							✓	✓
Cooling Tower Power Adjustment Curve							✓	✓
Cooling Tower Minimum Speed							✓	✓
Water-side Economizer								
Water-Side Economizer Name								
Water-Side Economizer Control Temperature Difference								
Water-Side Economizer HX Effectiveness								
Water-Side Economizer Mode								
Water-Side Economizer Maximum Tdb								
Water-Side Economizer Maximum CWS								
Water-Side Economizer CWS Setpoint								
Water-Side Economizer Availability Schedule								
Water-Side Economizer Auxiliary kW								
Pumps								
Pump Name	✓				✓		✓	
Pump Service	✓				✓		✓	
Number of Pumps	✓				✓		✓	
Water Loop Design	✓				✓		✓	
Pump Motor Modeling Method	✓				✓		✓	
Pump Motor Power-Per-Unit-Flow	✓				✓		✓	
Impeller Efficiency	✓				✓		✓	
Motor Efficiency	✓				✓		✓	
Pump Design Head	✓				✓		✓	
Pump Minimum Speed	✓				✓		✓	
Pump Design Flow (GPM)	✓				✓		✓	
Pump Control Type	✓				✓		✓	
Pump Operation	✓				✓		✓	
Pump Part Load Curve	✓				✓		✓	
Heat Recovery Equipment								
Heat Recovery Name								
Heat Recovery Device Type								
Heat Recovery Loads								
Plant Management								
Equipment Type Managed	✓				✓		✓	✓
Equipment Schedule	✓				✓		✓	✓
Equipment Operation	✓				✓		✓	✓

6.8.1 Boilers

Boiler Name

Applicability All boilers

Definition

A unique descriptor for each boiler, heat pump, central heating heat-exchanger or heat recovery device.

Units None

Input Restrictions User entry. Where applicable, this should match the tags that are used on the plans for the proposed design.

Baseline Rules 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).

Boiler Fuel

Applicability All boilers

Definition The fuel source for the central heating equipment. The choices are:

- Gas
- Oil
- Electricity

Units List (see above)

Input Restrictions As designed

Baseline Rules Same fuel as the proposed design

Boiler Type

Applicability All boilers

Definition The boiler type. Choices include:

- Steam Boiler
- Hot Water Boiler
- Heat-Pump Water Heater

Units List (see above)

Input Restrictions As designed

Baseline Rules The boiler type will be a hot water boiler for baseline systems 1, 5 and 7, according to the baseline system descriptions from Table G3.1.1B. All other system types do not have a boiler.

Boiler Draft Type

Applicability All boilers

Definition How combustion airflow is drawn through the boiler. Choices are:

- Natural (sometimes called atmospheric)
- Mechanical

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.

Mechanical draft boilers enhance the air flow in one of three ways: 1) Induced draft, which uses ambient air, a steam jet, or a fan to induce a negative pressure which 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, and 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.
Units	List (see above)
Input Restrictions	As designed. Default is natural draft.
Baseline Rules	The baseline boiler is always assumed to be a natural draft boiler. (G3.1.3.2)

Number of Identical Boiler Units

Applicability	All boilers
Definition	The number of identical units for staging
Units	Numeric: integer
Input Restrictions	As designed. Default is 1.
Baseline Rules	The number of boilers in the baseline case is set as follows (G3.1.3.2). The baseline building has one boiler when it serves an area less than or equal to 15,000 ft^2. For larger service areas, the baseline building shall have two equally sized boilers.

Boiler Heat Loss

Applicability	All boilers
Definition	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.
Units	Percent (%)
Input Restrictions	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.
Baseline Rules	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, combustion efficiency or AFUE of the boiler.

Boiler Design Capacity

Applicability	All boilers
Definition	The heating capacity at design conditions
Units	Btu/h
Input Restrictions	Unmet load hours 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.
Baseline Rules	The boiler is sized to be 25% larger than the peak loads of the baseline building. Baseline boilers shall be sized using weather files containing 99.6% heating design temperatures and 1% dry-bulb and 1% wet-bulb cooling design temperatures. The unmet load hours of the proposed case shall also not exceed the unmet load hours of the baseline design by more than 50 hours. If they do, then the capacity of the baseline boiler shall be decreased incrementally until this difference is less than 50 hours.

Boiler Efficiency Type

Applicability	All boilers
Definition	

The full load efficiency of a boiler is expressed as one of the following:

- *Annual Fuel Utilization Efficiency* (AFUE) is a measure of the boiler's efficiency over a predefined heating season.
- *Thermal Efficiency* (E_t) is the ratio of the heat transferred to the water divided by the heat input of the fuel.
- *Combustion Efficiency* (E_c) 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.

Units List (see above)

Input Restrictions *Annual Fuel Utilization Efficiency* (AFUE), for all gas and oil-fired boilers with less than 300,000 Btu/h capacity.

Thermal Efficiency (E_t), for all gas and oil-fired boilers with capacities between 300,000 and 2,500,000 Btu/h.

Combustion Efficiency (E_c), for all gas and oil-fired boilers with capacities above 2,500,000 Btu/h.

Baseline Rules Same as 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* (E_t) or *Annual Fuel Utilization Efficiency* (AFUE). Where AFUE is provided, E_t shall be calculated as follows:

$$\begin{aligned}
&1)\, 75\% \le \text{AFUE} < 80\% \\
&E_t = 0.1 \times AFUE + 72.5\% \\
&2)\, 80\% \le \text{AFUE} \le 100\% \\
&E_t = 0.875 \times AFUE + 10.5\%
\end{aligned} \tag{50}$$

All electric boilers will have an efficiency of 100%.

Units Ratio

Input Restrictions As designed

Baseline Rules Boilers for the baseline design are assumed to have the minimum efficiency as listed in Table 6.8.1F from ASHRAE Standard 90.1-2007 or Table 6.2.1F from ASHRAE Standard 90.1-2001.

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:

(51)

$$Fuel_{partload} = Fuel_{design} \times FHeatPLC\left(Q_{partload}, Q_{rated}\right)$$

$$FHeatPLC = \left(a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left(\frac{Q_{partload}}{Q_{rated}} \right)^2 \right)$$

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. If the user does not use the default curve, supporting documentation is required. The software may auto-generate curves for other boiler types from descriptive type information such as boiler type, core, full or partial condensing, combustion air control, minimum unloading or staging, and return water temperature.

Baseline Rules The baseline building uses the default

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 84 – 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%

Units Percent (%)

Input Restrictions As designed. If the user does not use the default curve the software must indicate that supporting documentation is required on the output forms.

Baseline Rules Use defaults.

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 Rules	Use 180°F for baseline boiler (G3.1.3.3).

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 Rules	Use 130°F for baseline boiler design.

Hot Water Supply Temperature Reset

Applicability	All boilers
Definition	Variation of the hot water supply temperature with outdoor air temperature.
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	The hot water supply temperature should vary according to the following: • 180°F when outside air is ≤ 20°F • ramp linearly between 180°F & 150°F when outdoor air is between 20°F and 50°F • 150°F when outdoor air is ≥ 50°F

6.8.2 Chillers

Chiller Name

Applicability	All chillers
Definition	A unique descriptor for each chiller
Units	Text, unique
Input Restrictions	User entry. Where applicable, this should match the tags that are used on the plans.
Baseline Rules	Chillers are only designated when the baseline system is of type 7 (VAV with reheat) or 8 (VAV with PFP Boxes) (see Table G3.1.1B).

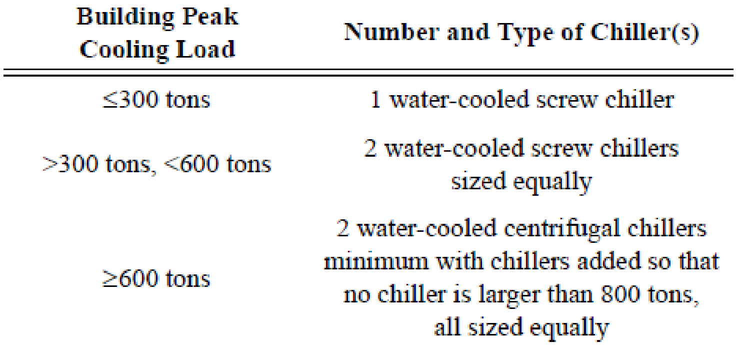
Chiller Type

Applicability	All chillers
Definition	The type of chiller, either a vapor-compression chiller or an absorption chiller. Vapor compression chillers operate on the reverse-Rankine cycle, using mechanical energy to compress the refrigerant, and include: • Reciprocating – uses pistons for compression • Screw – uses two counter rotating screws for compression • Scroll – uses two interlocking spirals or scrolls to perform the compression

- Centrifugal – uses rotating impeller blades to compress the air
- Absorption chillers – use heat to vaporize a working fluid (usually either ammonia or lithium bromide)
- Single Effect Absorption – use a single generator & condenser
- Double Effect Absorption – use 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.

Units	List (see above)
Input Restrictions	As designed
Baseline Rules	The baseline building chiller is based on the design capacity of the proposed design as follows from ASHRAE 90.1 Appendix G:

Table 85 – 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	2 water-cooled centrifugal chillers minimum with chillers added so that no chiller is larger than 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 Rules	From Table 85 above, there is one chiller if the cooling load is 300 tons or less and two equally sized chillers for 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.
Baseline Rules	Electricity

Chiller Rated Capacity

Applicability	All chillers
Definition	The cooling capacity of a piece of heating equipment at rated conditions.
Units	Btu/h or tons
Input Restrictions	As designed. If unmet load hours are greater than 300, the chiller may have to be made larger.
Baseline Rules	Determine loads for baseline building and oversize by 15%.

Chiller Rated Efficiency

Applicability	All chillers
Definition	The Coefficient of Performance (COP) at ARI rated conditions.
Units	Ratio
Input Restrictions	As designed
Baseline Rules	With the ASHRAE Standard 90.1-2007 baseline, use the minimum values of efficiency from either Table 6.8.1C for various types of chillers or the values from Tables 6.8.1H, 6.8.1I or 6.8.1J for centrifugal chillers. With the ASHRAE Standard 90.1-2001 baseline, use the minimum values of efficiency from either Table 6.2.1C for various types of chillers, or the values from Tables 6.2.1H, 6. 2.1I or 6. 2.1J for centrifugal chillers.

Chiller Minimum Unloading Ratio

Applicability	All chillers
Definition	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 86 – 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%

Units	Percent (%)
Input Restrictions	As designed. If the user does not employ the default values, supporting documentation is required.
Baseline Rules	Use defaults listed above.

Chiller Cooling Capacity Adjustment Curve

Applicability	All chillers
Definition	

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:

(52)

$$Q_{available} = CAP\_FT \times Q_{rated}$$

For air-cooled chillers:

(53)

$$CAP\_FT = a + b \times t_{chws} + c \times t_{chws}{}^{2} + d \times t_{odb} + e \times t_{odb}{}^{2} + f \times t_{chws} \times t_{odb}$$

For water-cooled chillers:

(54)

$$CAP\_FT = a + b \times t_{chws} + c \times t_{chws}{}^{2} + d \times t_{cws} + e \times t_{cws}{}^{2} + f \times t_{chws} \times t_{cws}$$

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.

Table 87 – 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

Table 88 – 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

Table 89 – Default Capacity Coefficients – Fuel- & 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

Units	Data structure
Input Restrictions	User may input curves, other appropriate functions, or use default curves. If the default curves are overridden, supporting documentation is required.
Baseline Rules	Use default curves.

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. The default curves are given as follows:

(55)

$$PLR = \frac{Q_{operating}}{Q_{available}\left(t_{chws}, t_{cws/odb}\right)}$$

$$EIR\_FPLR = a + b \times PLR + c \times PLR^2$$

$$\text{air-cooled} \quad EIR\_FT = a + b \times t_{chws} + c \times t_{chws}{}^2 + d \times t_{odb} + e \times t_{odb}{}^2 + f \times t_{chws} \times t_{odb}$$

$$\text{water-cooled} \quad EIR\_FT = a + b \times t_{chws} + c \times t_{chws}{}^2 + d \times t_{cws} + e \times t_{cws}{}^2 + f \times t_{chws} \times t_{cws}$$

$$P_{operating} = P_{rated} \times EIR\_FPLR \times EIR\_FT \times CAP\_FT$$

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 90 – 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

Table 91 – 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 92 – 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 93 – 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

Units	Data structure
Input Restrictions	User may input curves or use default curves. If defaults are overridden, supporting documentation is required.
Baseline Rules	Use default curves.

Fuel and Steam Chiller Cooling Efficiency Adjustment Curves

Applicability All chillers

Definition A curve or group of curves that varies the cooling efficiency of a fuel-fired or steam chiller as a function of evaporator conditions, condenser conditions, and part-load ratio. The default curves are given as follows:

Default Curves for Steam-Driven Single and Double Effect Absorption Chillers

(56)

$$PLR = \frac{Q_{operating}}{Q_{available}\left(t_{chws}, t_{cws/odb}\right)}$$

$$FIR\_FPLR = a + b \times PLR + c \times PLR^2$$

$$FIR\_FT = a + b \times t_{chws} + c \times t_{chws}^2 + d \times t_{cws} + e \times t_{cws}^2 + f \times t_{chws} \times t_{cws}$$

$$Fuel_{partload} = Fuel_{rated} \times FIR\_FPLR \times FIR\_FT \times CAP\_FT$$

Default Curves for Direct-Fired Double Effect Absorption Chillers

(57)

$$PLR = \frac{Q_{operating}}{Q_{available}\left(t_{chws}, t_{cws/odb}\right)}$$

$$FIR\_FPLR = a + b \times PLR + c \times PLR^2$$

$$FIR\_FT1 = a + b \times t_{chws} + c \times t_{chws}^2$$

$$FIR\_FT2 = d + e \times t_{cws} + f \times t_{cws}^2$$

$$Fuel_{partload} = Fuel_{rated} \times FIR\_FPLR \times FIR\_FT1 \times FIR\_FT2 \times CAP\_FT$$

The default curves for engine driven chillers are the same format as those for the Steam-Driven Single and Double Effect Absorption Chillers but there are three sets of curves for different ranges of operation based on the engine speed.

where

PLR	Part load ratio based on available capacity (not rated capacity)
FIR-FPLR	A multiplier on the fuel input ratio (FIR) to account for part load conditions
FIR-FT	A multiplier on the fuel input ratio (FIR) to account for the chiller water supply temperature and the condenser water temperature
FIR-FT1	A multiplier on the fuel input ratio (FIR) to account for chilled water supply temperature
FIR-FT2	A multiplier on the fuel input ratio (FIR) to account for condenser water supply temperature
CAP-FT	A multiplier on the capacity of the chiller (see Equation (53))
$Q_{operating}$	Present load on chiller (in Btu/h)
$Q_{available}$	Chiller available capacity at present evaporator and condenser conditions (in Btu/h)
t_{chws}	The chilled water supply temperature (in °F)
t_{cws}	The condenser water supply temperature (in °F)
t_{odb}	The outside air dry-bulb temperature (°F)

$Fuel_{rated}$	Rated fuel consumption at ARI conditions (in Btu/h)
$Fuel_{partload}$	Fuel consumption at specified operating conditions (in Btu/h)

Table 94 – Default FIR-FPLR coefficients – Fuel- & Steam-Source Water-Cooled Absorption Chillers

Coefficient	Single Stage Absorption	Double Stage Absorption	Direct-Fired Absorption
a	0.098585	0.013994	0.13551150
b	0.583850	1.240449	0.61798084
c	0.560658	-0.914883	0.24651277
d	-0.243093	0.660441	0.00000000

Table 95 – Default FIR-FPLR coefficients – Engine Driven Chillers

Coefficient	%Speed≤Min.	%Speed>Min. %Speed<60%	%Speed>60%
a	0.3802	1.14336	1.38861
b	2.3609	0.022889	-0.388614
c	0.0000	0.0000	0.0000
d	0.0000	0.0000	0.0000

Table 96 – Default FIR-FT coefficients – Fuel- & Steam-Source Water-Cooled Absorption Chillers

Coefficient	Single Stage Absorption	Double Stage Absorption	Direct-Fired Absorption
a	0.652273	1.658750	4.42871284
b	0.000000	0.000000	-0.13298607
c	0.000000	0.000000	0.00125331
d	-0.000545	-0.290000	0.86173749
e	0.000055	0.000250	-0.00708917
f	0.000000	0.000000	0.0010251

Table 97 – Default FIR-FT coefficients – Engine Driven Chillers

Coefficient	%Speed≤Min.	%Speed>Min. %Speed<60%	%Speed>60%
A	1.0881500	1.2362400	1.2362400
B	0.0141064	0.0168923	0.0168923
C	0.0000000	0.0000000	0.0000000
D	-0.00833912	-0.0115235	-0.0115235
E	0.0000000	0.0000000	0.0000000
F	0.0000000	0.0000000	0.0000000

Units	Data structure
Input Restrictions	User may input curves or use default curves. If defaults are overridden, supporting documentation is required.
Baseline Rules	Use default curves.

Chilled Water Supply Temperature

Applicability	All chillers
Definition	The chilled water supply temperature of the chiller at design conditions
Units	

	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	The baseline chilled water supply temperature is set to 44°F.

Chilled Water Return Temperature

Applicability	All chillers
Definition	The chilled water return temperature setpoint
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed
Baseline Rules	The baseline chilled water return temperature is set to 56°F.

Chilled Water Supply Temperature Reset

Applicability	All chillers
Definition	The reset schedule for the chilled water supply temperature. The chilled water setpoint may be reset based on demand or outdoor air temperature.
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed. The default is Figure 24.
Baseline Rules	The baseline chilled water supply temperature is reset from 44°F to 54°F based on outdoor air temperature as shown in the figure below.

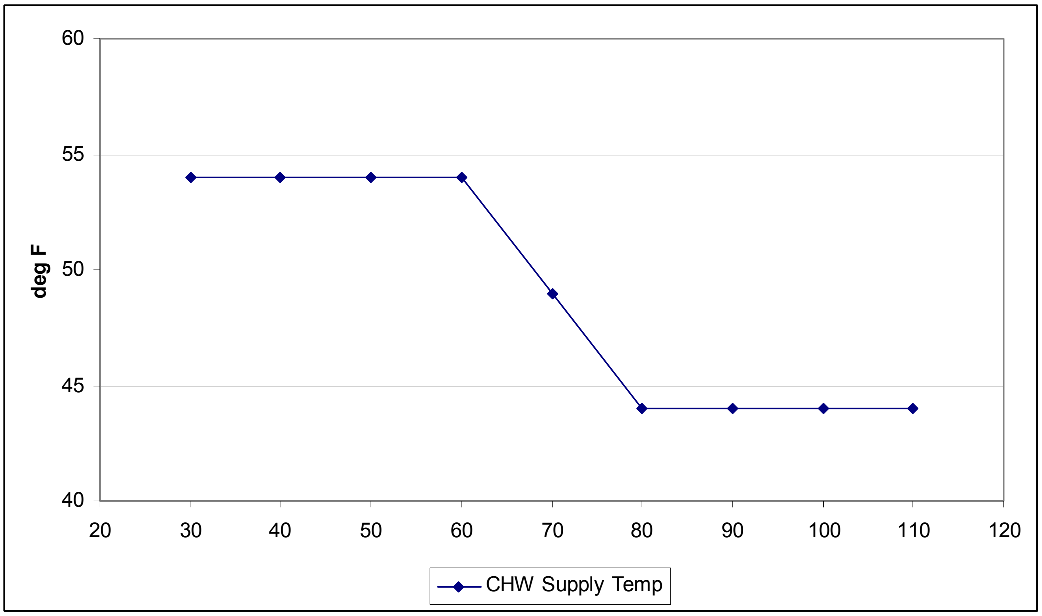


Figure 24 – Chilled Water Supply Temperature Reset Schedule

Condenser Type

Applicability	All chillers
Definition	The type of condenser for a chiller. The choices are:

- Air-Cooled

- Water-Cooled
- Evaporatively-Cooled

Air-cooled chillers use air to cool the condenser coils. Water-cooled chillers use cold water to cool the condenser and additionally need either a cooling tower or a local source of cold water. Evaporatively-cooled chillers are similar to air-cooled chillers, except they use a water mist to cool the condenser coil which makes them more efficient.

Units	List (see above)
Input Restrictions	As designed
Baseline Rules	The baseline chiller is always assumed to have a water-cooled condenser, although the chiller type will change depending on the design capacity. If the chiller size is less than 600 tons, the baseline chiller is a water-cooled screw; if the capacity is greater than or equal to 600 tons, the baseline chiller is a water-cooled centrifugal chiller.

Air-Cooled Condenser Power

Applicability	All chillers
Definition	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.
Units	Kilowatts (kW)
Input Restrictions	As designed. The user must enter data for remote air-cooled condensing units.
Baseline Rules	Not applicable, since all baseline chillers have water-cooled condensers.

6.8.3 Cooling Towers

Baseline Building Summary. Baseline building systems 7 and 8 have one or more cooling towers. One tower is assumed to be matched to each baseline building chiller. The number of baseline building chillers is determined in 6.8.2. 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 the condenser water flow is a constant 2.5 gpm per cooling ton[21] when the chiller is in service. 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 of 70 F when weather permits. The tower fan cycles to one-speed or off to maintain a CWS of 70 F at low wetbulb conditions. Under cooling conditions closer to design conditions, the CWS floats up to a maximum of 85 F (the design condition).

Cooling Tower Name

Applicability	All cooling towers
Definition	A unique descriptor for each cooling tower
Units	Text, unique
Input Restrictions	User entry. Where applicable, this should match the tags that are used on the plans.
Baseline Rules	Descriptive name that keys the baseline building plant

---

[21] 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 Type

Applicability	All cooling towers
Definition	The type of cooling tower employed. The choices are: • Open tower, centrifugal fan • Open tower, axial fan • Closed tower, centrifugal fan • Closed tower, axial fan 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.
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	The baseline cooling tower is an open tower axial fan device with a two-speed fan (See PRM G3.1.3.11)

Cooling Tower Capacity

Applicability	All cooling towers
Definition	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 wetbulb with a 3 gpm/nominal ton water flow. The default cooling tower curves below are at unity at these conditions.
Units	Btu/h
Input Restrictions	As designed
Baseline Rules	The baseline building chiller is autosized and increased by 15%. The tower is sized to deliver 85 F condenser water supply at design conditions for the oversized chiller.

Cooling Tower Number of Cells

Applicability	All cooling towers
Definition	The number of cells in the cooling tower. Each cell will be modeled as equal size. Cells are subdivisions in cooling towers into individual cells, each with their own fan and water flow, and allow the cooling system to respond more efficiently to lower load conditions.
Units	Numeric: integer
Input Restrictions	As designed
Baseline Rules	One cell per tower and one tower per chiller.

Cooling Tower Total Fan Horse Power

Applicability	All cooling towers
Definition	The sum of the nameplate rated horsepower (hp) of all fan motors on the cooling tower. Pony motors should not be included.
Units	Horsepower (hp)
Input Restrictions	As designed. For minimum compliance with ASHRAE Standard 90.1-2007, must be at

	least 38.2 gpm/hp for an axial fan cooling tower and at least 20.0 gpm/hp for a centrifugal fan cooling tower. (Table 6.8.1G)
Baseline Rules	Not applicable since pump power is specified as 19 watts/gpm.

Cooling Tower Design Wet-Bulb

Applicability	All cooling towers
Definition	The design wet-bulb temperature that was used for selection and sizing of the cooling tower.
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed.
Baseline Rules	Same as proposed design

Cooling Tower Design Entering Water Temperature

Applicability	All cooling towers
Definition	The design condenser water supply temperature (leaving tower) that was used for selection and sizing of the cooling tower.
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed. Default to 85°F.
Baseline Rules	85°F or 10°F above the design wet-bulb temperature, whichever is lower (Table 6.8.1G)

Cooling Tower Design Return Water Temperature

Applicability	All cooling towers
Definition	The design condenser water return temperature (entering tower) that was used for selection and sizing of the cooling tower.
Units	Degrees Fahrenheit (°F)
Input Restrictions	As designed. Default to 95°F.
Baseline Rules	Set to 95°F for a range of 10 F. (Table 6.8.1G)

Cooling Tower Capacity Adjustment Curve(s)

Applicability	All cooling towers
Definition	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:

$$
\begin{aligned}
t_R &= t_{cwr} - t_{cws} \\
t_A &= t_{cws} - t_{owb} \\
t_A &= a + b \times t_R + c \times t_R^{\,2} + d \times FRA + e \times FRA^2 + f \times t_R \times FRA \\
FRA &= \frac{-d - f \times t_R + \sqrt{(d + f \times t_R)^2 - 4 \times e \times \left(a + b \times t_R + c \times t_R^{\,2} - t_A\right)}}{2 \times e} \\
FWB &= a + b \times FRA + c \times FRA^2 + d \times t_{owb} + e \times t_{owb}^{\,2} + f \times FRA \times t_{owb} \\
Q_{available} &= Q_{rated} \times FWB \times \left(\frac{t_R}{10}\right)
\end{aligned}
\tag{58}
$$

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 98 – 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

Units	Data structure
Input Restrictions	User may input curves or use default curves. If defaults are overridden, the rating software must indicate that supporting documentation is required on the output forms.
Baseline Rules	Use 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 to provide the design supply water temperature at all times. A wet-bulb reset control will reset according to the following control scheme:

$$t_{cws} = t_{owb} + t_A + RR \times (t_{dwb} - t_{owb}) \tag{59}$$

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. A reset ratio (RR) of 1 will cause the system to perform as if it had fixed condenser water controls.

Units List (see above)

Input Restrictions As designed. If the user does not use the default curve, supporting documentation is required.

Baseline Rules Fixed at 70°F

Cooling Tower Capacity Control

Applicability All cooling towers

Definition Describes the modulation control employed in the cooling tower. Choices include:

- **Fluid Bypass** provides a parallel path to divert some of the condenser water around the cooling tower at part-load conditions
- **Fan Cycling** is a simple method of capacity control where the tower fan is cycled on and off. This is and is often used on multiple-cell installations.
- **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 buildling descriptors are triggered when this method of capacity control is selected.
- **Variable Speed Fan.** A variable frequency drive is installed for the tower fan so that the speed can be modulated.

Units List (see above)

Input Restrictions As designed.

Baseline Rules Two-speed fan

Cooling Tower Low-Speed Airflow Ratio

Applicability All cooling towers with two-speed or pony motors

Definition 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.

Units

	Ratio
Input Restrictions	As designed.
Baseline Rules	0.50

Cooling Tower Low-Speed kW Ratio

Applicability	All cooling towers
Definition	The percentage full load power that the tower fans draw at low speed or with the pony motor operating
Units	Ratio
Input Restrictions	As designed.
Baseline Rules	0.30

Cooling Tower Power Adjustment Curve

Applicability All cooling towers with VSD control

Definition 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:

(60)

$$PLR = \frac{Q_{operating}}{Q_{available}(t_R, t_A, t_{OWB})}$$

$$TWR\_FAN\_FPLR = a + b \times PLR + c \times PLR^2$$

$$P_{operating} = P_{rated} \times TWR\_FAN\_FPLR$$

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 99 – Default Efficiency TWR-FAN-FPLR Coefficients – VSD on Cooling Tower Fan

Coefficient	TWR-FAN-FPLR
a	0.33162901
b	-0.88567609
c	0.60556507

Units	Data structure
Input Restrictions	

	User may input curves or use default curves. If defaults are overridden, supporting documentation is required.
Baseline Rules	Use default curves from DOE 2, given above.

Cooling Tower Minimum Speed

Applicability	All cooling towers with a VSD control
Definition	The minimum fan speed setting of a VSD controlling a cooling tower fan expressed as a ratio of full load speed.
Units	Ratio
Input Restrictions	As designed. The default is 0.40.
Baseline Rules	Not applicable

6.8.4 Water-side Economizers

Baseline Building Summary. None of the baseline building systems use a water-side economizer.

Water-Side Economizer Name

Applicability	All water-side economizers
Definition	The name of a water-side economizer for a cooling system
Units	Text, unique
Input Restrictions	Descriptive reference to the construction documents. The default is no water-side economizer.
Baseline Rules	No water economizer

Water Economizer Type

Applicability All water-side economizers

Definition The type of water-side economizer. Choices include:

- None
- Heat exchanger in parallel with chillers. This would be used with an open cooling tower is often referred to as a non-integrated economizer, because the chillers are locked out when the plant is in economizer mode.
- Heat exchanger in series with chillers. This would be used with an open cooling tower and is often referred to as an integrated, because the chillers can operate simultaneously with water economizer operation.
- 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.
- Thermo-cycle (also known as refrigerant migration). With thermo-cycle, bypass valves allow for the flow to 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.

Units	List (see above)
Input Restrictions	As designed
Baseline Rules	No water economizer

Water-Side Economizer HX Effectiveness

Applicability	Water-side economizers with an open cooling tower
Definition	The effectiveness of a water-side heat exchanger at design conditions. This is defined as:

$$WSE_{eff} = \frac{t_{ea} - t_{la}}{t_{ea} - t_{ew}} \tag{61}$$

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_{ea}	The entering coil water temperature (°F)

Units	Ratio
Input Restrictions	As designed. The default is 60%.
Baseline Rules	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 Rules	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 Rules	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.”
Baseline Rules	No water economizer

Water-Side Economizer Availability Schedule

Applicability	All water-side economizers
Definition	A schedule which represents the availability of the water-side economizer
Units	Data structure: schedule, on/off
Input Restrictions	As designed
Baseline Rules	No water economizer

Water-Side Economizer Auxiliary kW

Applicability	Water-side economizers with an open tower
Definition	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.
Units	KW or kW/ton
Input Restrictions	As designed
Baseline Rules	No water economizer

6.8.5 Pumps

Baseline Building Summary. Hot water pumping in the baseline building (systems 1, 5, and 7) shall be modeled as a variable flow primary only system. When the spaces served by the hot water system are greater than or equal to 120,000 ft², 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.

Chilled water pumping in the baseline building (systems 7 and 8) is a primary/secondary system. Each chiller has its own primary and condenser water pumps that operate when the chiller is activated. All primary and secondary pumps shall be assumed to be 22 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.

General Notes. 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

Applicability	All pumps
Definition	A unique descriptor for each pump
Units	Text, unique
Input Restrictions	

	User entry. Where applicable, this should match the tags that are used on the plans.
Baseline Rules	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

Applicability	All pumps
Definition	The service for each pump. Choices include: • Chilled water • Chilled water (primary) • Chilled water (secondary) • Heating water • Heating water (primary) • Heating water (secondary) • Service hot water • Condenser water • Loop water (for hydronic heat pumps)
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	As needed by the baseline building system

Number of Pumps

Applicability	All pumps
Definition	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
Units	Numeric: integer
Input Restrictions	As designed
Baseline Rules	There will be one heating hot water pump for each boiler, one chilled water pump, and one condenser water pump for each chiller.

Water Loop Design

Applicability	All pumps
Definition	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.
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Assume primary loops only for heating hot water. For chilled water loops, a primary-secondary loop design is assumed.

Pump Motor Modeling Method

Applicability	All pumps
Definition	Software commonly models fans 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
Units	List: Power-Per-Unit-Flow or Detailed
Input Restrictions	Either method may be used, as appropriate.
Baseline Rules	Power-Per-Unit-Flow

Pump Motor Power-Per-Unit-Flow

Applicability	All baseline building pumps and proposed design pumps that use the Power-Per-Unit-Flow method.
Definition	The electric power of the pump divided by the flow at design conditions.
Units	W/gpm
Input Restrictions	As designed
Baseline Rules	Prescribed to be 19 W/gpm for condenser and heating hot water pumps and 22 W/gpm for primary and secondary chilled water pumps.

Impeller Efficiency

Applicability	All pumps in proposed design that use the detailed modeling method
Definition	The full load efficiency of the impeller
Units	Ratio
Input Restrictions	As designed
Baseline Rules	Not applicable

Motor Efficiency

Applicability	All pumps in proposed design that use the detailed modeling method
Definition	The full load efficiency of the pump motor
Units	Ratio
Input Restrictions	As designed
Baseline Rules	Not applicable

Pump Design Head

Applicability	All pumps in proposed design that use the detailed modeling method
Definition	The design pressure for the pump
Units	Feet of water (or feet of head)
Input Restrictions	As designed
Baseline Rules	Not applicable

Pump Minimum Speed

Applicability	

	All two-speed or variable-speed pumps
Definition	The minimum pump speed for a two-speed for variable-speed pump. 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.
Units	Ratio
Input Restrictions	As designed
Baseline Rules	The secondary chilled water pumps for baseline building systems 7 and 8 have variable speed drives when the size of the cooling plant is greater than 300 tons. In these cases the Pump Minimum Speed shall be 0.10.

Pump Design Flow (GPM)

Applicability	All pumps
Definition	The flow rate of the pump at design conditions. This is derived from the load, and the design supply and return temperatures.
Units	gpm or gpm/ton for condenser and primary chilled water pumps
Input Restrictions	Not a user input
Baseline Rules	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. The temperature change on the condenser side of the chillers is 10 F, which equates to a flow of 2.5 gpm/ton. The flow for secondary chilled water pumps 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. A VSD is required for heating pumps when the service area is greater than or equal to 120,000 ft².

Pump Control Type

Applicability	All pumps
Definition	The type of control for the pump. Choices are: • Fixed speed, fixed flow • Fixed speed, variable flow (the default, with flow control via a valve) • Two-speed • Variable speed, variable flow
Units	None
Input Restrictions	As designed. The default is "Fixed Speed, Variable Flow" which models the action of a constant speed pump riding the curve against 2-way control valves.
Baseline Rules	The hot water and condenser water loops shall be primary loops only. When the hot water system serves less than 120,000 ft², the hot water pump shall be modeled as a fixed speed, variable flow pump (riding the pump curve). When the hot water system serves more than 120,000 ft², the hot water pump shall be modeled as a variable speed pump on a primary loop. The chilled water pumping for systems 7 and 8 is primary/secondary with variable flow. When the chilled water system has a capacity of less than 300 tons, the secondary system pumps shall ride the pump curve. When the chilled water system has a capacity of more than 300 tons, the secondary chilled water pumps shall be variable speed. Chilled water pumps used in the primary loop shall be fixed speed, fixed flow. Condenser water pumps shall be modeled as fixed speed, fixed flow.

Pump Operation

Applicability	All pumps
Definition	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 3-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.
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	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

Applicability All pumps

Definition A part-load power curve for the pump

$$CIRC - PUMP - FPLR = a + b \times PLR + c \times PLR^2 + d \times PLR^3 \tag{62}$$

$$P_{pump} = P_{design} \times CIRC - PUMP - FPLR \tag{63}$$

where

PLR	Part load ratio (the ratio of operating flow rate in gpm to design flow rate in gpm)
P_{pump}	Pump power draw at part-load conditions (W)
P_{design}	Pump power draw at design conditions (W)

Table 100 – Default Part-Load CIRC-PUMP-FPLR Coefficients – VSD on Circulation Pump

Coefficient	CIRC-PUMP-FPLR
a	0.0015303
b	0.0052081
c	1.1086242
d	-0.1163556

Units	Data structure
Input Restrictions	As designed. Default is curve above.
Baseline Rules	

Use the defaults described above.

6.8.6 Thermal Storage

There are multiple ways to model thermal storage in the proposed design. The baseline building does not have thermal storage.

6.8.7 Heat Recovery Equipment

Heat Recovery Name

Applicability	All heat recovery systems
Definition	A name assigned to a heat recovery system. This would provide a link to the construction documents.
Units	Text, unique
Input Restrictions	As designed
Baseline Rules	No heat recovery systems

Heat Recovery Device Type

Applicability	All heat recovery systems
Definition	The type of heat recovery equipment. Choices include: • Double-Bundled Chiller • Generator • Engine-Driven Chiller • Air Conditioning Unit • Refrigerated Casework
Units	List (see above)
Input Restrictions	As designed
Baseline Rules	Heat recovery systems are not included in the baseline system.

Heat Recovery Loads

Applicability	All heat recovery systems
Definition	The loads met by the heat recovery system. Choices include: • Service water heating • Space heating • Process heating More than one load may be selected.
Units	List (see above)
Input Restrictions	As designed

Baseline Rules	Not required in the baseline system.

6.8.8 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

Applicability	All plant systems
Definition	The type of equipment under a plant management control scheme. Choices include: • Chilled water cooling • Hot water space heating • Condenser water heat rejection • Service water heating • Electrical generation
Units	None
Input Restrictions	As designed
Baseline Rules	Same as the proposed design

Equipment Schedule

Applicability	All plant equipment
Definition	A schedule which identifies when the equipment is in service.
Units	Data structure
Input Restrictions	As designed
Baseline Rules	Where multiple equipment is used, they shall be staged in operation.

Equipment Operation

Applicability	All plant equipment
Definition	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 it scheduled to be in service.
Units	None
Input Restrictions	As designed; the default is On-Demand.
Baseline Rules	Assume On-Demand operation

6.9 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 blocks or the HVAC systems that serve them.

6.9.1 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.

System Loads and Configuration

Water Heating System Name	
Applicability	All water heating systems
Definition	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.
Units	Text, unique
Input Restrictions	Where applicable, this should match the tags that are used on the plans such that a plan reviewer can make a connection.
Baseline Rules	The naming convention for the baseline building system shall be similar to the proposed design.

Water Heating Peak Use	
Applicability	All water heating systems, required
Definition	An indication of the peak hot water usage (e.g. service to sinks, showers, and kitchen appliances, etc.). 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 which are used in the simulation. 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. 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.
Units	Btu/h or gallons/h
Input Restrictions	For the purpose of federal tax deductions, peak use shall be specified as a thermal

	load using the California 2005 ACM values from Appendix B, Table 5. For the purpose of green building ratings and energy labels, the inputs from Appendix B are default values, but other values may be used with justification.
Baseline Rules	Hot water consumption or load in 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. Examples of such measures include: low-flow terminal devices or controls, alternative sanitizing technologies, or heat recovery laundry or showers drains.

Water Heating Schedule

Applicability	All water heating systems, required
Definition	A fractional schedule reflecting the time pattern of water heating use. This input modifies the water heating peak use, described above.
Units	Data structure: schedule, fractional
Input Restrictions	For the purpose of federal tax deductions, the schedules for the California 2005 ACM from Appendix B, Table 7 shall be used. For the purpose of green building ratings and energy labels, the inputs from Appendix B, Table 7 are default values, but other values may be used with justification.
Baseline Rules	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

Applicability	All water heating systems, required
Definition	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.
Units	Data structure
Input Restrictions	None
Baseline Rules	The baseline building shall have the same configuration and layout as the proposed design.

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

Applicability	All water heaters
Definition	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.
Units	

Text, unique

Input Restrictions Where applicable, this should match the tags that are used on the plans such that a plan reviewer can make a connection.

Baseline Rules The naming convention for the baseline building system shall be similar to the proposed design.

Water Heater Type and Size

Applicability All water heaters

Definition This building descriptor includes information needed to determine the criteria from baseline standards. The choices are listed below. See Table 7.2.2 of ASHRAE Standard 90.1-2001 or Table 7.8 of ASHRAE Standard 90.1-2007 for more detail.

- Electric water heaters (storage and instantaneous)
  - Small (≤ 12 kW)
  - Large (> 12 kW)
  - Heat pump
- Gas storage water heaters
  - Small (≤ 75,000 Btu/h)
  - Medium (> 75,000 and ≤ 155,000 Btu/h)
  - Large (> 155,000 Btu/h)
- Gas instantaneous water heaters
  - Small (> 50,000 and < 200,000 Btu/h)
  - Large (≥ 200,000 Btu/h)
- Oil storage water heaters
  - Small (≤ 105,000 Btu/h)
  - Medium (> 105,000 and ≤ 155,000 Btu/h)
  - Large (> 155,000 Btu/h)
- Oil instantaneous water heaters
  - Small (≤ 210,000 Btu/h)
  - Large (> 210,000 Btu/h)
- Gas hot water supply boiler
- Oil hot water supply boiler

Units List (see above)

Input Restrictions The water heater type shall agree with equipment specified in the construction documents.

Baseline Rules Water heaters in the baseline system shall be the same as those in the proposed design, 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.

Rated Capacity

Applicability All water heaters

Definition	The heating capacity of a water heater at the rated conditions specified in Table 7.8 of ASHRAE Standard 90.1-2007 or Table 7.2.2 of ASHRAE Standard 90.1-2001
Units	Thousands of British Thermal Units per hour (MBH)
Input Restrictions	As designed. If the loads are not met, autosize.
Baseline Rules	Autosize

Energy Factor

Applicability	Equipment covered by NAECA, which includes small storage and instantaneous water heaters
Definition	The energy factor (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.
Units	Unitless ratio
Input Restrictions	Building descriptors for the proposed design should be consistent with equipment specified on the construction documents or observed in the candidate building.
Baseline Rules	The EF for the baseline building system shall be determined from Table 7.2.2 of ASHRAE Standard 90.1-2001 or Table 7.8 of ASHRAE Standard 90.1-2007, depending on the purpose of the simulations.

Thermal Efficiency

Applicability	Oil and gas fired water heaters not covered by NAECA
Definition	The full load efficiency of a water heater at rated conditions expressed as a dimensionless ratio of output over input
Units	Unitless ratio
Input Restrictions	Building descriptors for the proposed design should be consistent with equipment specified on the construction documents or observed in the candidate building.
Baseline Rules	The thermal efficiency for the baseline building system shall be determined from Table 7.2.2 of ASHRAE Standard 90.1-2001 or Table 7.8 of ASHRAE Standard 90.1-2007, depending on the purpose of the simulations.

Tank Standby Loss

Applicability	Water heaters not covered by NAECA
Definition	The tank standby loss for storage tanks, which includes the effect of recovery efficiency.
Units	Btu/h for the entire tank
Input Restrictions	As specified in manufacturer data and documented on the construction documents
Baseline Rules	The tank standby loss for the baseline building system shall be determined from Table 7.2.2 of ASHRAE Standard 90.1-2001 or Table 7.8 of ASHRAE Standard 90.1-2007.

Fuel Water Heater Part Load Efficiency Curve

Applicability	Equipment not covered by NAECA for which a thermal efficiency, as opposed to an EF

	is specified
Definition	A set of factors that adjust the full-load thermal efficiency for part load conditions. Typically, the factor is set as a curve.
Units	Percent (%)
Input Restrictions	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:

(64)

$$Fuel_{partload} = Fuel_{design} \times FHeatPLC$$

$$FHeatPLC = \left(a + b \times \frac{Q_{partload}}{Q_{rated}} + c \times \left(\frac{Q_{partload}}{Q_{rated}} \right)^2 \right)$$

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 Rules	The baseline building equipment shall use the default curve

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

Applicability	All recirculation systems
Definition	A unique descriptor for each water heating recirculation system
Units	Text, unique
Input Restrictions	Where applicable, this should match the tags or descriptions that are used on the plans such that a plan reviewer can make a connection.
Baseline Rules	The naming convention for the baseline building system shall be similar to the proposed design.

Pumping Power

Applicability	All recirculation systems
Definition	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.
Units	Watts (W)
Input Restrictions	Pumping power shall be consistent with the piping configuration, flow rate, and equipment specified on the construction documents.
Baseline Rules	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

Applicability	All recirculation systems
Definition	An on/off or fraction schedule that indicates when the recirculation system is expected to be operated
Units	Data structure: schedule, on/off or fraction
Input Restrictions	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.
Baseline Rules	Recirculation schedules for the baseline building shall be the same as the proposed design.

Piping

Applicability	All recirculation systems
Definition	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).
Units	Btu/h-°F specified separately for outdoor, indoor, or buried locations
Input Restrictions	All piping in the recirculation system should be included. Heat loss for each of the three conditions should be consistent with piping runs, sizes, and insulation as shown on the construction documents.
Baseline Rules	The length and size of piping in the baseline building shall be the same as the proposed design. Insulation in the baseline building shall be as prescribed in Table 6.8.3 for ASHRAE Standard 90.1-2007 and Table 6.2.4.1.3 of ASHRAE Standard 90.1-2001.

Water Heating Auxiliaries

External Storage Tanks

Applicability	All water heating systems that have an external storage tank
Definition	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). The heat loss shall account for the surface area and U-factor tank, as well as the average temperature conditions where the tank is located. Some software may allow these factors to be separately specified.
Units	Btu/h for the entire tank
Input Restrictions	As specified in manufacturer data and documented on the construction documents
Baseline Rules	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.

Heat Recovery

Applicability	Water heating systems that are coupled to heat recovery equipment
Definition	Building equipment such as air conditioners, chillers, gas fired generators, etc. 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 on an hourly basis so that the schedule of heat production and heating needs can be aligned and evaluated in the water heating model.
Units	Data structure: depends on the equipment producing the heat
Input Restrictions	There are no restrictions, other than agreement with the construction documents.
Baseline Rules	The baseline building has heat recovery when the baseline standard is ASHRAE Standard 90.1-2007 and the conditions of Section 6.5.6.2 of that standard are satisfied. The baseline building is modeled with heat recovery when all of the following conditions are true: • The building operates 24 hours per day. • The building has water cooled chillers with a heat rejection capacity greater than 6 million Btu/h. This equates to about 400 tons of electric chiller capacity. • The water heating peak use is greater than 1,000,000 Btu/h. See the User's Manual for ASHRAE Standard 90.1-2007, page 6-82 for details on the requirements for the heat recovery system and exceptions to the requirement.

Solar Thermal

Applicability	Water heating systems with a solar thermal system
Definition	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. 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.

	Heat produced by solar thermal systems will generally not align perfectly with the need for heating, so the model needs to account for the temporal mismatch in some manner.
Units	Data structure: will vary with the software and system details
Input Restrictions	There are no restrictions, other than agreement with the construction documents.
Baseline Rules	The baseline building has no solar auxiliary system.

Combined Space Heating and Water Heating

Applicability	Projects that use a boiler to provide both space heat and water heating
Definition	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.
Units	Data structure
Input Restrictions	The proposed design may have a combined space and water heating system.
Baseline Rules	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.

6.9.2 Exterior Lighting

All exterior lighting applications shall be included in the model when the purpose is for green building ratings or energy labels. Exterior lighting is an optional input for the purpose of tax deductions. If an exterior lighting application is not connected to the building electricity meter, then it should not be included, e.g. street lighting or common area lighting.

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, etc. 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.

With ASHRAE Standard 90.1-2007, exterior lighting applications are grouped 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 lighting power density 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, guardhouses, loading for law enforcement, drive through windows, or parking near retail. The allotment 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 lighting power density for these applications and the area/length of these applications.

Exterior Lighting Name

Applicability	All exterior lighting systems

Definition	A name for the lighting system
Units	Text, unique
Input Restrictions	The name should be descriptive and provide a link to the construction documents.
Baseline Rules	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 Category

Applicability	All exterior lighting systems
Definition	A classification of each exterior lighting system from Table 9.4.5 in ASHRAE Standard 90.1-2007 or Table 9.3.2 in ASHRAE Standard 90.1-2001. This classification will determine the lighting power for the baseline building (see below). The lighting category establishes if the exterior lighting application is tradable or non-tradable under ASHRAE Standard 90.1-2007. Credit is offered for power reductions for tradable lighting applications, but not for non-tradable lighting applications. The baseline standard and the associated User's Manual should be consulted for how to classify exterior lighting applications, however main entries shall provide access to the general public and shall not be used exclusively for staff or service personnel."[22] A couple of other clarifications are as follows: • Bikeways – treated as walkways • Outdoor dining – treated as plaza areas One of the categories offered by the software should be "Lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation." This lighting is specifically excluded by the baseline standards such that the baseline building lighting power is the same as the proposed design.
Units	List (from Table 9.4.5 of ASHRAE Standard 90.1-2007)
Input Restrictions	The classification should accurately match the exterior lighting application in the rated building.
Baseline Rules	Same as the proposed design

Exterior Lighting Area or Length

Applicability	All exterior lighting systems
Definition	Each exterior lighting system application (see above) has an area or length associated with it. This area or length is a factor in determining the baseline building lighting power (see below). 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 door linear footage exceeds 25% of building perimeter, the software shall produce a warning. • Uncovered parking shall be calculated according to the rules for the parking portion of "Illuminated hardscape" from Title 24-2005. 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

---

[22] From CA T-24-2008 Table 147B

	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."[23].
Units	ft² or ft
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 Rules	Same as the proposed design

Exterior Lighting Power

Applicability	All exterior lighting systems
Definition	The power used for the exterior lighting application. This power should include the lamp as well as the ballast.
Units	W or W/ft²
Input Restrictions	The lighting power should match the construction documents or the existing building being rated.
Baseline Rules	The exterior lighting power for the baseline building is determined from the product of the *exterior lighting area or length* and the allowed power for the exterior *lighting category*. The allowed power is determined from Table 9.4.5 in ASHRAE Standard 90.1-2007 or Table 9.3.2 in ASHRAE Standard 90.1-2001. For non-tradable exterior lighting applications, the baseline building lighting power is the lesser of the lighting power for the proposed design application or the allowed power determined above.

Exterior Lighting Control

Applicability	All exterior lighting systems
Definition	The means of controlling exterior lighting systems. The baseline standards required both daylight control and scheduling (e.g. a photocell and a standard time clock or an astronomical time clock). Additional controls could include: • Standard (as required by baseline standards) • Bi-level motion sensing controls[24] • On/off motion sensing controls • Bi-level scheduling controls[25]
Units	List (see above) along with an associated power adjustment factor (PAF) or schedule adjustment
Input Restrictions	As designed. Documentation should be provided for lighting controls other than

---

[23] 2005 T-24 T-24-2005 §147(c)1A

[24] A PG&E study of bi-level motion sensing lighting controls for an outdoor parking lot found that the lights operated at low output for 45% of the evening hours. Pacific Gas and Electric Company Bi-Level LED Parking Lot Lighting: Raley's Supermarket West Sacramento, CA: February 2009 Emerging Technologies Program Application Assessment Report #0815 http://www.etcc-ca.com/images/stories/final20emerging20technology20report20for20led20parking20lot20lighting1.pdf

[25] For bi-level scheduling controls, one could turn off a fraction of the lights after interior lighting schedule dropped below 50% to indicate reduced lighting for after normal business hours or if parking lot lighting is within scope, reduced parking area that is illuminated during stocking, and other reduced activity periods.

	standard and evidence should be provided to support the reduction in lighting power (PAF) or the modification to the schedule.
Baseline Rules	The baseline building shall have standard lighting controls, e.g. a photocell and standard time clock. No adjustment is made to either the baseline building exterior lighting power or the schedule.

Exterior Lighting Schedule

Applicability	All exterior lighting systems
Definition	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.
Units	Data structure: schedule, fractional.
Input Restrictions	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. The schedule may be modified when qualifying lighting controls are installed (see above).
Baseline Rules	The schedule for the baseline building shall be the same as the proposed design unless the proposed design schedule is adjusted for qualifying lighting controls, in which case the unadjusted schedule is used for the baseline building.

Swimming Pools

Configuration and Design Requirements

Pool Name

Applicability	All pools
Definition	A unique identifier that keys the pool to the construction documents
Units	Text, unique
Input Restrictions	None
Baseline Rules	The name for the baseline building pool should be similar to the proposed design.

Volume

Applicability	All pools
Definition	The volume of the pool
Units	Cubic feet (ft^3)
Input Restrictions	None
Baseline Rules	Same as the proposed design

Surface Area

Applicability	All pools

Definition	The surface area of the pool affects heat loss and evaporation.
Units	Square feet (ft²)
Input Restrictions	None
Baseline Rules	Same as the proposed design

Cover

Applicability	All pools
Definition	An indication
Units	Boolean (Yes/No)
Input Restrictions	None
Baseline Rules	The baseline building shall have a pool cover per Section 7.4.5.2 of ASHRAE Standard 90.1-2007.

Cover Schedule

Applicability	All pools
Definition	A schedule indicating when the pool cover is in place
Units	Data structure: schedule, on/off or fractional
Input Restrictions	None
Baseline Rules	Same as the proposed design

Filtration Rate

Applicability	All pools
Definition	The rate at which the pool water is passed through the filtering system when the filtration system is operating
Units	Hours per pool change
Input Restrictions	None
Baseline Rules	Same as the proposed design

Filtration Schedule

Applicability	All pools
Definition	A schedule indicating when the pool filtration system is in operation.
Units	Data structure: schedule, on/off or fractional
Input Restrictions	None
Baseline Rules	Same as the proposed design

Temperature

Applicability	All pools
Definition	The temperature at which the pool is maintained
Units	Degrees Fahrenheit (°F)
Input Restrictions	

	None
Baseline Rules	Same as the proposed design

Temperature Schedule

Applicability	All pools
Definition	A schedule indicating variation in the pool temperature, either seasonally or monthly
Units	Data structure: schedule, temperature
Input Restrictions	None
Baseline Rules	Same as the proposed design

Pumping and Filtration

Pumping Power

Applicability	All pools
Definition	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.
Units	Watts (W)
Input Restrictions	None
Baseline Rules	Same as the proposed design unless the proposed design uses special low head filters and premium efficiency motors

Heating Equipment

Heater Type

Applicability	All pools
Definition	The type of equipment that is used to maintain the pool temperature
Units	List: solar, heat pump, gas, oil, or electric resistance
Input Restrictions	None
Baseline Rules	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 for ASHRAE Standard 90.1-2007 and Table 7.2.2 for ASHRAE Standard 90.1-2001. 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 for ASHRAE Standard 90.1-2007 and Table 7.2.2 for ASHRAE Standard 90.1-2001.

Heater Efficiency

Applicability	All pools with pool heaters
Definition	The thermal efficiency of the pool heater
Units	Unitless, thermal efficiency
Input Restrictions	

	None
Baseline Rules	See the baseline building rules for heater type.

Solar System Features

Applicability	All pools with solar pool heaters
Definition	The collector area, size, efficiency, and pumping characteristics of the solar pool system
Units	Data structure
Input Restrictions	None
Baseline Rules	Not applicable. The baseline building has a pool cover, not solar.

6.9.3 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 block.

Miscellaneous Electric Power

Applicability	All buildings with miscellaneous electric equipment located on the building site
Definition	The power for miscellaneous equipment.
Units	Watts (W)
Input Restrictions	As designed. All miscellaneous power shall be accounted for when the purpose is a green building rating or an energy label.
Baseline Rules	Same as the proposed design

Miscellaneous Electric Schedule

Applicability	All buildings with miscellaneous electric equipment located on the building site
Definition	The schedule of operation for miscellaneous electric equipment. This is used to convert electric power to energy use.
Units	Data structure: schedule, fractional
Input Restrictions	The schedule specified for the building should match the operation patterns of the system.
Baseline Rules	Same as the proposed design

6.9.4 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 block.

Other Gas Power

Applicability	All buildings that have commercial gas equipment
Definition	

	Gas power is the peak power which is modified by the schedule (see below).
Units	Btu/h-ft²
Input Restrictions	As designed
Baseline Rules	Same as the proposed design

Other Gas Schedule

Applicability	All buildings that have commercial gas equipment
Definition	The schedule of operation for commercial gas equipment. This is used to convert gas power to energy use.
Units	Data structure: schedule, fractional
Input Restrictions	Continuous operation is prescribed.
Baseline Rules	Same as the proposed design

6.10 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 described 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 CHP), on-site power generation can be modeled in a separate process, otherwise, it needs to be linked to the building simulation.

6.10.1 Photovoltaic Systems

Candidate buildings may have photovoltaic (PV) systems and the energy generated by these systems may offset the power used by HVAC, lighting, and other building systems. Since most PV systems work under a net metering arrangement whereby the utility grid is used as a storage battery, accepting excess energy when it is available and providing power back to the building at night and other times when the PV system is not generating, the simulation of PV systems need to be on an hourly time step so that it can be aligned with the building loads and the utility rate structure.

This section describes one set of building descriptors for specifying a PV system. This set of building descriptors is based on the five-parameter model[26]. Other models may be used for PV systems. The inputs apply only to the proposed design, as the baseline building is modeled without a PV system.

Configuration

This set of building descriptors addresses the overall layout and design of the PV system, including the orientation and slope of the collectors, how they are wired together, and how they are linked to an inverter that converts DC power to AC and synchronizes it with the grid.

PV System Name

Applicability	All PV systems
Definition	

---

[26] De Soto, W., S.A. Klein, and W.A. Beckman, “Improvement and validation of a model for photovoltaic array performance”, Solar Energy, Volume 80, Issue 1, January 2006, Pages 78-88

	A unique identifier that can be used to reference the PV system and associate it with the construction documents
Units	Text, unique
Input Restrictions	The name should provide a link to the construction documents.
Baseline Rules	None (PV not modeled for the baseline building)

Number of Modules in a String

Applicability	All PV systems
Definition	This is the number of modules in a series string. Modules in series increase voltage which is often needed in order to match output voltage with the inverter requirements; modules in parallel increase current.
Units	Numeric: integer
Input Restrictions	As designed
Baseline Rules	None (PV not modeled for the baseline building)

Number of Strings

Applicability	All PV systems
Definition	This is the number of strings of modules in parallel. Modules in series increase voltage; modules in parallel increase current.
Units	Numeric: integer
Input Restrictions	As designed
Baseline Rules	None (PV not modeled for the baseline building)

Collector Area

Applicability	All PV systems
Definition	The area of the collector module.
Units	Square feet (ft^2)
Input Restrictions	From manufacturer's specification
Baseline Rules	None (PV not modeled for the baseline building)

Slope

Applicability	All PV systems
Definition	The slope of the collector modules relative to the horizontal.
Units	Degrees (°)
Input Restrictions	As designed
Baseline Rules	None (PV not modeled for the baseline building)

Azimuth

Applicability	All PV systems
Definition	The orientation of the collector modules relative to due North. An azimuth of 180°

	faces due south; 90° faces east, etc.
Units	Degrees (°)
Input Restrictions	As designed
Baseline Rules	None (PV not modeled for the baseline building)

PV Mounting Height

Applicability	All PV systems
Definition	The height of the collectors above the ground.
Units	Feet (ft)
Input Restrictions	As designed.
Baseline Rules	None (PV not modeled for the baseline building)

Shading

Shading of PV systems results in significant reduction of production and must be accounted for in an acceptable manner. A method is implied in the following building descriptors that is consistent with the NSHP Calculator[27]. With this method, the area around the solar system is divided into 22.5° cones and the height and distance to shading objects is entered for each quadrant. Other methods may be used, including use of the building shade inputs (see *building site characteristics* under *project data*)

Shading Azimuth

Applicability	All PV systems
Definition	A quadrant where the height and distance of shading objects is specified.
Units	List: ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW
Input Restrictions	As estimated from existing surrounding buildings and shading structures
Baseline Rules	None (PV not modeled for the baseline building)

Shading Object Height

Applicability	All PV systems
Definition	The height of the building or shading object in the 22.5° cone
Units	Feet (ft)
Input Restrictions	As estimated from existing surrounding buildings and shading structures
Baseline Rules	None (PV not modeled for the baseline building)

Shading Object Distance

Applicability	All PV systems
Definition	The horizontal distance from the shading object to the collectors
Units	Feet (ft)
Input Restrictions	As estimated from existing surrounding buildings and shading structures
Baseline Rules	

---

[27] More information is available at http://www.gosolarcalifornia.ca.gov/nshp/.

None (PV not modeled for the baseline building)

Collector Performance

The collector performance can be characterized by the following five variables that are available from PV array manufacturers: the open-circuit voltage, the short-circuit current, the voltage and current at the maximum power-point, and the temperature coefficient of the open-circuit voltage. These are described below.

Short-circuit current

Applicability	All PV systems
Definition	I_{sc} - current measured with zero voltage
Units	Amps
Input Restrictions	From manufacturer's specification
Baseline Rules	None (PV not modeled for the baseline building)

Open-circuit voltage

Applicability	All PV systems
Definition	V_{oc} - voltage measured with an open circuit
Units	Volts
Input Restrictions	From manufacturer's specification
Baseline Rules	None (PV not modeled for the baseline building)

Maximum Power-Point Voltage and Current

Applicability	All PV systems
Definition	I_{mp}, V_{mp} - current and voltage at the maximum power-point condition. These parameters are typically reported at Standard Test Conditions of 1000 W/m^2 and a cell temperature of 25°C.
Units	Amps and Volts
Input Restrictions	From manufacturer's specification
Baseline Rules	None (PV not modeled for the baseline building)

Open-circuit Temperature Coefficient

Applicability	All PV systems
Definition	B_{Voc} - temperature coefficient at open-circuit voltage
Units	I/C
Input Restrictions	From manufacturer's specification
Baseline Rules	None (PV not modeled for the baseline building)

Short-circuit Temperature Coefficient

Applicability	All PV systems
Definition	α_{Voc} - temperature coefficient at short-circuit current. This is supplied the manufacturer.

Units	V/C
Input Restrictions	From manufacturer's specification
Baseline Rules	None (PV not modeled for the baseline building)

Normal Operating Cell Temperature (NOCT)

Applicability	All PV systems
Definition	The normal operating cell temperature, typically between 45°C and 55°C
Units	Degrees Celsius (°C)
Input Restrictions	From manufacturer's specification
Baseline Rules	None (PV not modeled for the baseline building)

6.10.2 Wind Systems

Wind systems produce electricity and their output depends on the availability of wind at the project site. Wind speed and direction is contained on the climate file used for the building simulation. The building descriptors below assume that the wind turbine is free to pivot to face the wind.

System Name

Applicability	All wind systems
Definition	A unique identifier that makes a link to the construction documents
Units	Text, unique
Input Restrictions	None
Baseline Rules	None (Wind not modeled for the baseline building)

Rated Output

Applicability	All wind systems
Definition	The rated output of the wind turbine at a given design condition, e.g. wind speed
Units	Kilowatts (kW)
Input Restrictions	As specified by the manufacturer
Baseline Rules	None (Wind not modeled for the baseline building)

Rated Wind Speed

Applicability	All wind systems
Definition	The wind speed at which the rated output is measured
Units	Miles per hour (mph)
Input Restrictions	As specified by the manufacturer
Baseline Rules	None (Wind not modeled for the baseline building)

Cut-In Wind Speed

Applicability	All wind systems
Definition	

	The wind speed above which the system will produce useful power
Units	Miles per hour (mph)
Input Restrictions	As specified by the manufacturer
Baseline Rules	None (Wind not modeled for the baseline building)

Part Load Performance

Applicability	All wind systems
Definition	The rated capacity gives the power production at one wind speed. The part load performance will generally be a curve that gives the output for wind speeds that are greater or lower than the rated wind speed.
Units	Data structure
Input Restrictions	As specified by the manufacturer
Baseline Rules	None (Wind not modeled for the baseline building)

6.10.3 Cogeneration and Fuel Cells

System Name

Applicability	All cogeneration systems
Definition	A unique identifier that makes a link to the construction documents
Units	Text, unique
Input Restrictions	None
Baseline Rules	Not applicable

Rated Output

Applicability	All cogeneration systems
Definition	The rated electric power that the cogenerator can produce
Units	Kilowatts (kW)
Input Restrictions	None
Baseline Rules	Not applicable

Rated Efficiency

Applicability	All cogeneration systems
Definition	The efficiency of converting a fuel to electricity
Units	Unitless
Input Restrictions	None
Baseline Rules	Not applicable

Heat Production Rate

Applicability	

	All cogeneration systems
Definition	The rate of heat production at the rated output
Units	Btu/h
Input Restrictions	None
Baseline Rules	Not applicable

Heat Temperature

Applicability	All cogeneration systems
Definition	The temperature of the water produced
Units	Degrees Fahrenheit (°F)
Input Restrictions	None
Baseline Rules	Not applicable

Modulation

Applicability	All cogeneration systems
Definition	The capability of the cogeneration system to modulate output with corresponding modulation of input energy and waste heat
Units	Data structure
Input Restrictions	None
Baseline Rules	Not applicable

Schedule

Applicability	All cogeneration systems
Definition	A schedule that indicates when the cogeneration system will operate and perhaps at what capacity (if there is a means for modulation)
Units	Data structure: schedule, on/off or fractional
Input Restrictions	None
Baseline Rules	Not applicable

6.11 Common Data Structures

This section describes common data structures referenced in this chapter and in Appendix A. 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. However, other parameters or data constructs are acceptable. It is not the intent of COMNET to impose a single format for a data structure when alternative structures could be equally acceptable.

6.11.1 Schedule

This data structure provides information on how equipment, people, lights, or other items are operated on an hourly basis. The ultimate construct of a schedule is an hourly time series for the simulation period, typically 8,760 hours (365 days time 24 hours/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:

- **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.
- **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.
- **On/off** schedules specify when equipment is operating or when infiltration is occurring.
- **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.

Software may accommodate any appropriate user specification of the schedule as long as the schedules listed in Appendix C are supported.

6.11.2 Holidays

A series of dates defining holidays for the simulation period. Dates identified are operated for the schedule specified for holidays.

6.11.3 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.

6.11.4 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.

6.11.5 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 commonly specified in terms of the projection distance, height above the opening, and extension distance on each side of the opening. Side fins may be described in a similar manner. Any geometric construct is acceptable as long as it accounts for the physical and geometric relationship between the opening and the objects around it that provide shading.

6.11.6 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. A construction assembly may also be defined in terms of its U-factor and the time pattern of heat transmission related to the thermal mass.

6.11.7 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.

6.11.8 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.

6.11.9 Slab Construction

This data structure describes the composition of a slab-on-grade. There are many acceptable ways to represent slabs in energy simulation models. Some models have building descriptors for the perimeter length and the F-factor, which represents the heat loss per lineal foot. Other models require that the slab surface area within two feet of the building perimeter be specified along with the interior slab area. In the latter case, coefficients of heat loss either to the air temperature, the ground temperature, or both are linked to insulation configurations.

6.11.10 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.

6.11.11 Building Shade

This data structure describes trees, adjacent buildings, terrain, and other objects near the proposed building that would shade the building for a significant portion of the year. Exterior shading objects typically have the same properties as surfaces, e.g. the coordinates of the origin, height, width, azimuth, and tilt. They may also have transparency in terms of both SHGC and VT, and the transparency may be varied according to a schedule or algorithm.

6.11.12 Utility Rate

This data structure describes how energy costs are calculated for the consumption of a particular fuel such as electricity, gas, chilled water, or steam. A utility rate typically references a Time Period Schedule (see above). For each period, an energy cost, a peak demand charge, or other costs may be assigned.

6.11.13 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 typically specified in Btu/h.

6.11.14 Furniture and Contents

This data structure represents the thermal mass effect of furniture and other building contents. This is sometimes expressed in terms of lb/ft^2 for the space in question.

6.11.15 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.

6.11.16 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.

6.11.17 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.

6.11.18 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 is supply air temperature. In this case, a common schedule would be to set the supply air temperature 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 supply air temperature scaling between 55°F and 62°F when the outside air temperature is between 80°F and 58°F. Temperature reset schedules can be specified in various ways.

6.11.19 Photovoltaic (PV) Panel

This data structure describes the power produced by a PV panel as a function of the solar insolation, incident angle, temperature, and other parameters.

7 Advanced Modeling Tips

7.1 Challenging Building Types

Modeling tips and advice is offered in this section for laboratories, healthcare and data centers. Each of these building types presents unique challenges to energy modelers. The guidance here supplements the information in Chapter 6. Information provided in this chapter supersedes information in Chapter 6 when there is a conflict.

7.1.1 Laboratories

Many aspects of laboratory energy usage are not directly regulated by the baseline standards. However, these energy uses must be accounted for in order to obtain an accurate simulation of the building energy usage and properly calculate percent savings for green building ratings (tax deduction calculations only require consideration of regulated energy use, e.g. heating, cooling, fans, hot water and interior lighting). In addition, it is also important to note that the non-regulated energy components of the laboratory will impose loads on the regulated portions, such as chillers and boilers, increasing the importance of capturing this energy usage.

Laboratory HVAC Systems

Laboratories tend to be large buildings so the basic HVAC mapping rules presented in Chapter 6 will typically map to baseline building systems 5 through 8, which are variable air volume systems with one air handler per floor. There are three exceptions to this rule, however, that could affect the baseline building systems for laboratories:

- The first exception is specific for laboratories. This exception applies when a laboratory or group of laboratories have an exhaust system designed for 5,000 cfm or more of air movement. The baseline building system serving the laboratory spaces shall be either system 5 (PVAV with hot water reheat) or system 6 (PVAV with parallel fan-powered boxes and electric reheat), depending on the heating source in the building. The PVAV system must be capable of reducing the exhaust and makeup air volume to 50% of design values during unoccupied periods. This exception essentially requires VAV for both the supply fan and the exhaust system. (See the PRM, G3.1.1, Exception c.)
- When the above exception for laboratories does not apply, a separate laboratory system may still be required to be modeled in the baseline building. Either system 3 (PSZ-AC) or system 4 (PSZ-HP) shall serve laboratories in the baseline building (depending on the heating source for the building) when one of the following conditions apply:
    - Spaces on a floor have significantly different schedules or internal heat loads: heat gain differences of more than 10 Btu/h or operation schedule differences of more than 40 hours/week. (See the PRM, G3.1.1, Exception b.)
    - Spaces on a floor have "special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates." Many laboratory spaces with fume hoods would likely trigger this exception. (See the PRM, G3.1.1, Exception c.)

These special systems apply to the spaces that trigger one or more of the exceptions. The rest of the building/floor would be served by the baseline building HVAC system and air handlers.

Equipment Loads

The amount of internal load in a laboratory from equipment will vary greatly based upon function, and also will vary based upon time, with night-time loads typically much lower. The topic of diversity is addressed under the topic of schedules; however the peak load should be input based upon the actual equipment selection. In most cases, the equipment power will be the same for both the baseline and proposed design, except when the proposed design employs explicit strategies to reduce energy use and reduce internal loads, in which case, more efficient equipment or lower internal loads may be assumed in the proposed design. As an example, localized refrigeration equipment in the lab space might be replaced by a central chilled water system, thus reducing the heat rejection load that occurs in the space and increasing the efficiency of cooling the equipment. In this case, it would be acceptable to have different internal loads in the baseline and proposed buildings. When equipment power or internal loads are different between the proposed design and the baseline building, special documentation shall be provided. Some common laboratory equipment is discussed in greater detail in subsequent sections.

Redundancy

In some cases it is standard practice to provide redundant equipment in laboratories because of the risk involved in equipment failure. If additional equipment is installed for pure redundancy, then this equipment shall be ignored in the modeling of the proposed design and the baseline building. For a more complex situation, a laboratory with a 100 ton load might be designed with two 75 ton chillers with the idea that should one chiller fail, the remaining chiller will be able to satisfy the critical load. If this design intent can be documented, then it is acceptable to model the proposed design in this fashion. The baseline building equipment will be autosized according to the rules in Chapter 2 and Chapter 6 and the number of chillers or boilers will be determined based on the rules in Chapter 6.

Design Conditions

Space dry-bulb temperature setpoints should generally be based upon actual design requirements, but for laboratories will generally be around 70°F for heating, 72°F for cooling. Humidification to at least 30% RH is common in most areas of the country. Dehumidification, when required, is accomplished by keeping coil leaving air temperatures around 53 F during humid ambient conditions.

Air Delivery

For systems serving laboratory spaces, use a supply-air-to-room-air temperature difference of 17°F for the baseline building and the proposed design (Chapter 6 specifies 20°F for other building types). If return or relief fans are specified in the proposed design, the baseline building design shall also be modeled with fans serving the same functions (this is the general Chapter 6 modeling rule). The baseline building return/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. See the discussion above on *laboratory HVAC systems* for more detail on exhaust systems serving fume hoods.

Outside Air

Due to the presence of hazardous materials in laboratory environments, it is common practice to use 100% outside air. The codes do not explicitly forbid lab air recirculation within individual lab zones, but code requirements are most easily met by a 100% outside air system. The Chapter 6 modeling rules apply in this case, as the outside air for the baseline building is the same as the outside air for the proposed design.

In some cases, labs are part of a mixed-use building that includes both office spaces as well as laboratories served by the same air handling system. In most cases, the baseline building system serving laboratories will be separate from the main building system (see *laboratory HVAC systems* above).

Outside air delivered by these dedicated systems would be the same as the air delivered by the proposed design systems, unless the assignment of thermal blocks to systems is modified.

Schedules

Appendix C has schedules for laboratories that shall be used as a default. The schedules assume heavier loads during more typical working hours. Fans are assumed to be on 24 hours throughout the day. If the laboratory operates on a seasonal schedule, such as a school schedule, and has lower usage during one season, adjust the schedules as needed.

Animal Cages

Open animal cages that do not include their own dedicated ventilation system are commonly used in laboratories. These shall be the same in the proposed design and the baseline building.

Autoclaves

These systems use high pressure steam for sterilization. Typically efficiency measures accounted for here would be on the steam side.

Compressed Dry Air

Some laboratories require a supply of compressed dry air for drying and other purposes. When these systems exist in the proposed design, they shall also exist in the baseline building. In the baseline building, the supply air pressure setpoint is constant and the systems do not employ heat recovery. The air dryers are regenerated with compressed air, on a regular time-based interval. Energy efficiency measures may be documented for the proposed design with proper documentation.

De-Ionized Water

These systems remove minerals and ions from the water to reduce the electrical conductivity of the water and would typically be the same in the baseline and proposed buildings.

Environmental Chambers

Heat pumps typically heat or cool the interior of the chamber to provide a controlled test environment. For the baseline building, heat rejection (or absorption) from the heat pumps is assumed to occur directly into the space in which the heat pump is installed. The proposed design may employ energy efficiency measures, including high efficiency heat pump units, as well as remote heat rejection through a condenser water system.

Fume Hoods

Fume hoods generally do not contain local fans, but rather have an exhaust system serving multiple hoods. The energy use of a fume hood is reflected in the amount of air moving through the hood and the efficiency of the exhaust system that serves it.

Fume hood exhaust systems in the proposed design can be operated as constant air volume (CAV) or variable air volume (VAV). The baseline building exhaust system shall be VAV for laboratory exhaust systems that are designed for 5,000 cfm or more. See *laboratory HVAC systems* above. Otherwise, the baseline building exhaust fan system and operation shall the same as the proposed design. The modeling assumption for the sash opening face velocity is a constant 100 ft/min for both the proposed design and the baseline building, regardless of space occupancy and regardless of whether an occupant is standing in front of the hood. However the baseline hood exhaust schedule assumes the hoods are closed and airflow reduced during unoccupied periods.

Biosafety cabinets can also be operated as CAV or VAV. However, biosafety cabinets have a more demanding tolerance (+/-5%) on variations in air flow than fume hoods. The air flow variation in a typical VAV system is on the order of +/-10%, so the necessary control may be difficult to achieve. The baseline for biosafety cabinets is CAV.

Glass Washers

These machines will wash and sterilize lab glassware. The equipment will typically be the same in the baseline and proposed buildings. This equipment has high but intermittent heat and moisture gains to the containing spaces.

Vacuum Systems

Process vacuum pumps create a negative-pressure distribution system needed for certain types of lab equipment. Not to be confused with the “house” vacuum system, used for janitorial purposes. In most cases, the baseline and proposed vacuum pumps will be the same, although more efficient vacuum pumps could be substituted in the proposed design with suitable documentation of what is considered a typical base case condition.

Reverse Osmosis Water

These systems are similar to the de-ionized water systems except that the process involves pumping the water through a semi-permeable membrane. These systems would typically be the same in the baseline and proposed buildings. Average loads should be far below design electrical capacities.

7.1.2 Health Care

Many health care projects are designated as occupancy group "I", which subjects them to specialized code requirements necessary based upon health and safety requirements. Typically, the envelope components of health care projects are not that different from conventional occupancies. However, lighting, HVAC and domestic hot water systems can be significantly different and will present some challenges in the modeling process. In addition, these facilities can have many other energy consuming systems that will require attention.

Lighting

Health care projects typically have a wide range of space uses. A typical hospital could have 50 or 60 different space functions occurring in the facility. In modeling the facility, there are two possible choices for lighting. The easiest choice is to use the *building classification* method for all spaces that occur in the building. The second choice is to break the building out into each space function and use the *space-by-space* method, which will entail a significantly larger amount of work. Choosing the approach can be difficult, as a facility with a large amount of space functions requiring large amounts of light would benefit from the more granular approach of using the space functions. Given the fact that a hospital might require HVAC zoning of several hundred zones, the additional work of layering in space function lighting can result in models with zones numbering 600 to 1000. In either case, the baseline and proposed buildings will have the same thermal blocks, zoning and space functions.

An additional consideration is that many spaces in the proposed design may use task/ambient lighting systems. For example, patient rooms will typically have an ambient lighting system that provides minimal illumination, and a second lighting system that will only be activated by staff during brief examination periods. Other areas, such as surgery rooms, will have surgical lights that are only used during active surgery, so it is important that the lighting systems include appropriate schedules for the task lighting that accounts for the intermittent use. Note that in modeling the baseline building, the baseline lighting power density allowance will be modeled, using the ambient lighting schedule from the proposed design. An alternative schedule may be used for task lighting in the proposed design. For exempt lighting uses, this alternative schedule shall be used for both the baseline building and the proposed design.

HVAC

The basic HVAC system mapping rules described in Chapter 6 apply to health care facilities. Most are large buildings so the baseline building systems will tend to be system 7 (VAV with hydronic reheat) or system 8 (VAV with parallel fan-powered boxes and electric reheat). However, many spaces in healthcare facilities trigger the exceptions to the HVAC mapping rules:

- The laboratory exception applies when a laboratory or group of laboratories have an exhaust system designed for 5,000 cfm or more of air movement. The baseline building system serving the laboratory spaces shall be either system 5 (PVAV with hot water reheat) or system 6 (PVAV with parallel fan-powered boxes and electric reheat), depending on the heating source in the building. The PVAV system must be capable of reducing the exhaust and makeup air volume to 50% of design values during unoccupied periods. This exception essentially requires VAV for both the supply fan and the exhaust system. (See the PRM, G3.1.1, Exception c.)
- When the above exception for laboratories does not apply, a separate system may still be required to be modeled in the baseline building. Either system 3 (PSZ-AC) or system 4 (PSZ-HP) shall serve healthcare spaces in the baseline building (depending on the heating source for the building) when one of the following conditions apply:
  - Spaces have significantly different schedules or internal heat loads. Heat gain differences or more than 10 Btu/h or operation schedule differences of more than 40 hours/week trigger this exception. (See the PRM, G3.1.1, Exception b.)
  - Spaces on a floor have "special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates". Surgical suites and other healthcare spaces would likely trigger this exception. (See the PRM, G3.1.1, Exception c.)

The HVAC systems in many healthcare facilities are in operation 24 hours per day and consume very large amounts of energy. In many cases, the decision of a certain type of mechanical system in these facilities is made for health and safety code compliance, and in many cases they will be 100% outside air systems. It is not unusual to see very large static pressure requirements due to HEPA filtration and sound attenuators. In the case of 100% outside air systems, exhaust fans are also an important aspect of the design. Given the large diversity of space uses, and the fact that each may have specialized ventilation requirements, it is important to model the building with a sufficient number of zones to account for these uses. In modeling the baseline building, the same zones are used with the same ventilation rates used in the proposed building. These conditions will likely trigger one of the exceptions to the HVAC mapping rules and require that the spaces be served by a separate system.

Some healthcare facilities will have areas that are used continuously, such as patient rooms, mixed in with areas that are only in use during normal daytime hours, such as medical offices. In some cases an entire wing or floor of a facility will be on a normal 8-5 operation and will have a dedicated HVAC system to allow night-time shutdown. In this case, the proposed building modeling should include appropriate HVAC operating schedules to account for the night-time operation. The baseline building will typically have separate systems for spaces with a different schedule (see discussion above).

Most areas of hospitals have relatively high airflow minimums and require continuous operation even when unoccupied. Some areas do not allow VAV operation or require return air VAV valves to assure pressurization. Some areas of the building will have very large air change rates, such as surgical suites. However, in many applications, these suites are only used during daytime hours. One strategy is to have a night setback in these spaces, reducing the air change rate from 20 in the daytime, for example, down to 6 at night. This will require the proposed building to include schedules to account for this, but in the case of the baseline building, operation would be assumed to be at the 20 air change rate for all hours.

Surgical suites may also require low SATs and special dehumidification. Most hospitals require winter humidification, varying among systems and zones.

Domestic Hot Water

Domestic hot water usage will vary greatly depending upon the type of facility, as well as functions that occur in the facility. Some hospitals have on-site laundry facilities, while many others out-source this activity to offsite providers. Facilities such as medical office buildings will have dramatically lower hot water usage than a multi-bed facility with many patient rooms. Once again, accurate schedules that reflect this usage will need to be developed. In most cases, the baseline and proposed buildings will include the same hot water usage and schedules, unless a reduction in hot water usage can be demonstrated due to a proposed design feature that is not required by or typical of the baseline building. An example might be a laundry facility that uses water saving equipment. Other energy savings in the proposed building could come from the boiler efficiency and possibly the recirculation pumping system.

Internal Loads

A wide range of internal loads exist in healthcare facilities, ranging from television sets in patient rooms to radiology equipment in labs, all running during different hours of the day. Most internal loads are reduced to a minimum at night while a facility is fully staffed in the daytime. There will be a need to develop equipment operation schedules to reflect this operation. In addition, given the fact that some equipment will only run a few minutes out of the hour, such as an MRI machine, it is important not to overestimate the loads attributed to the equipment. In most cases, the baseline and proposed building models will include the same equipment loads and operating schedules, unless the modeler can clearly demonstrate a more efficient piece of equipment is being used compared to standard practice or code minimum.

7.1.3 Data Centers

Data centers are spaces specifically designed to accommodate dense arrangements of computer equipment. This currently includes telephone company “central offices” (“telcos”) and computer labs. Any space where dedicated HVAC is installed to handle computing equipment load is likely to be considered a data center.

Data Center HVAC Systems

Data centers in the baseline building will typically be served by a separate system because they trigger the exception to the HVAC mapping requirements having to do with abnormal internal heat gain and schedules of operation. When heat gain differences of more than 10 Btu/h or operation schedule differences of more than 40 hours/week trigger this exception, a separate system is required to serve the data center. Either system 3 (PSZ-AC) or system 4 (PSZ-HP) shall serve the data center (depending on the heating source for the building). See the PRM, G3.1.1, Exception b.

Loads

Loads in a data center could range from anywhere as low as 20 W/ ft^2 up to 400 W/ ft^2 Load densities above 400 W/ ft^2 would not typically be handled by an air based cooling system. As a rule of thumb: the initial actual energy use of a new data center is 50% of the design capacity of the cooling system serving the data center, so the equipment is initially oversized by a significant margin. In many cases, the data center load will increase each year, as additional equipment is added, reaching full load after a five year period. However, if there is more precise information on the expected load, this should be used. In most cases, the load for the baseline and proposed buildings should be the same, unless documentation of equipment that is more efficient than standard practice can be provided.

Redundancy

Given the uptime requirements of data center equipment, redundant equipment is a necessity. Purely redundant equipment is ignored in the modeling of the proposed building and the baseline building. This might simply be additional CRAC (computer room air conditioning) units, or might be more complicated to include additional chillers and supporting pumps.

Ventilation

In mixed-use facilities, ventilation for the data center is often provided by the “house air” system, i.e. the system that serves the office or other commercial space, with a separate system providing cooling. In dedicated data center systems, the ventilation air is typically provided by a dedicated outside air system and should be modeled accordingly. Outside air in the proposed and baseline system will be the same, but the baseline building system will typically be modeled with its own supply of outside air.

Humidity Control Systems

The ASHRAE document “Thermal Guidelines for Data Processing Environments” describes the “Recommended” relative humidity (RH) range for Class 1 and Class 2 computing environments as 40% to 55%, and the “Allowable” range for these same environments as 20% to 80%. These RH values apply to the air entering the computer equipment.

CRAC units with on-board humidity control systems typically have the temperature and humidity sensors factory-mounted in the return air opening of the CRAC. For open aisle data centers, the sensors are typically left in this position, and the humidity of the return air is controlled to the ASHRAE recommended range of 40% to 55%.

For ducted return and fully enclosed data center aisles, the practice is to relocate the CRAC temperature and humidity sensors to a cold aisle, or to install additional temperature and humidity sensors in the cold aisles and disable the original CRAC sensors. The aisle-mounted sensors will control the CRAC humidity system to provide the ASHRAE recommended range of 40% to 55% in the cold aisles.

The baseline building system shall be modeled with the same temperature and humidity conditions as the proposed design.

Uninterruptible Power Supply (UPS)

Data centers typically include some type of battery-based system to address power failures. Depending upon the size, configuration and amount of load, the efficiency of these systems will range from 86% to 93%. In determining the data center power usage, this must be accounted for in the building modeling. In addition, there will be additional cooling requirements for the UPS systems that will need to be modeled. Both the baseline and proposed buildings should be modeled with the same UPS configuration and power, unless supporting documentation of a more efficient technology or arrangement can be documented.

7.2 Design Features

7.2.1 Automatically Controlled Window Shades

Some advanced buildings include either interior or exterior shading systems that include automatic controls to optimize the shade position for energy savings. In some cases, this may be as simple as a time based control system that operates the shades based upon time of day. More sophisticated systems may include sensors designed to detect solar gains on the fenestration, and determine the optimum shade position.

Most simulation programs include a variety of commands to facilitate modeling the various scenarios that will be found in buildings. In the case of the simple time of day based control system, a straightforward hourly/daily/monthly schedule command can be utilized that will adjust the solar gain through the fenestration using a multiplier that is applied to the hourly solar gain.

For the more sophisticated case, a solar gain or glare threshold should be input that will result in the shades being closed. In some software, this may include hourly pairs of values that describe the solar gain threshold and corresponding solar gain multiplier resulting from the shade.

7.2.2 Active Chilled Beams

An active chilled beam is a device that is located in or above the conditioned space to provide heating, cooling and ventilation. The system consists of a coil box that is recessed in or hung from the ceiling with chilled water flowing through the coil. Ventilation air is introduced by a remote air handler into the diffuser box through small air jets, which induces room air to flow through the coils. Because the active introduction of ventilation air magnifies the natural induction effect, active chilled beams are commonly referred to as induction diffusers.

Depending upon the modeling software, active chilled beams may be modeled directly in the software or by using the more commonly available induction unit selection. Since each zone in a building will typically have its own chilled beam system (multiple units) with thermostatic control, a decision will need to be made as to how to properly zone the building to account for the individual chilled beam units. In most cases, conventional zoning of the building will be sufficient, such that thermally similar zones would be combined together. In combining zones, however, the source of ventilation air will need to be taken into account. Thus, two thermally similar chilled beam zones that are supplied by different ventilation air handlers would need to be separated out for modeling purposes.

Once the thermal zoning has been determined, each zone will then be modeled with a chilled beam induction system; inputs would include the system cooling capacity and the induction ratio. In addition, the source of heat, whether electric or hot water, would need to be specified. Since one or more dedicated ventilation fan systems will provide the outside air to the chilled beams, this would be modeled in the same fashion as the dedicated outside air system described below, with each chilled beam system coupled to this dedicated outdoor air system.

7.2.3 Dedicated Outside Air Systems (DOAS)

Dedicated outdoor air systems are provided to pre-condition the outside air which is then supplied to the main HVAC systems in the building. In most cases, the purpose of a DOAS is to address the large loads associated with the introduction of outside air, whether due to low ambient conditions, high ambient conditions or high humidity of the outside air. Depending upon the configuration, the DOAS may include heating coils, cooling coils and possibly a heat recovery component, in addition to the supply and optional exhaust fans associated with the unit. The main HVAC system fed by the DOAS could be any number of HVAC system types but typically will be smaller zonal systems such as water source heat pumps, VRF systems or fan coil units. By shifting the outdoor air load over to the DOAS, these systems may be smaller.

The DOAS system is modeled as a conventional HVAC system if that is how it is configured, with inputs for heating and cooling coils as well as fans. The choice of system type will depend upon the type of system being modeled. The DOAS system could be a simple rooftop DX system, or possibly a chilled water air handler with hot water coils fed from a central plant. It is important that the system be specified with 100% outside air, unless a more sophisticated outside air control scheme has been utilized. Optional parameters that could be specified include an exhaust fan and/or a heat recovery component. Heat recovery would require the specification of the heat recovery effectiveness as well as any pumps or fans associated with the heat recovery component. Often DOAS AHUs include precool-reheat loops (wraparound heat pipes or sensible loops) or mixed dual heat recovery systems. If proposed buildings include these systems, software should be chosen that models these systems explicitly. DOAS equipment often delivers warmer air to zones with chilled beams, panels or other local cooling. Where minimum airflows are high, this can lead to significant savings in reheat.

Each HVAC system that receives outside air from the DOAS will be specified as a conventional HVAC system, except that the source of outdoor air will be coupled to the DOAS system associated with this unit. When specifying the ventilation rates for the zones served by the HVAC system, they will be specified as normal. By coupling the HVAC system to the DOAS system, the energy model will utilize that stream of air as the basis of the outdoor air.

If the DOAS only provides outdoor air tempering for other mechanical systems, the baseline building is not modeled with a corresponding DOAS system. However, in the case where the DOAS also provides general space conditioning to a space (such as conditioned air into a hallway, that is then pulled out by other HVAC systems) then that space will be modeled with the HVAC systems defined in Chapter 6.

7.2.4 Displacement ventilation

Displacement Ventilation (DV), a space conditioning technology in use in Europe since the 1970’s, has the ability to reduce energy usage in buildings due to a number of energy saving strategies not found in conventional overhead mixing systems. The fundamental principle involved in a DV system is to supply significantly warmer supply air temperatures during cooling mode, typically 63°F to 68°F. With the use of higher supply air temperatures comes the ability to operate in economizer mode many more hours each year. When producing the higher supply air temperatures, chilled water systems have the ability to operate at much higher chilled water temperatures, thus resulting in a significant increase in the chiller efficiency when producing chilled water. In addition, for systems that will be requiring reheat, additional heating and cooling energy is saved since they will be reheating air that is cooled to only 65°F versus a conventional system that has cooled the air to 55°F.

By not mixing the air in the room, the DV system results in more of a stratification effect. Thus, much of the heat in the space will rise towards the ceiling, where it will be exhausted by the high return air register. A portion of the cooling load in the space, including occupant heat gain, lighting and equipment, never appears as a cooling load.

Some software tools have built-in system types that allow for the direct modeling of DV systems while others will require the user to make approximations of some of the effects associated with DV, in particular, the stratification of room loads. In all cases, the supply air temperature of the system will need to be set to the higher design value of the system, and in most cases the control strategy for the cooling coil will be to reset the leaving temperature based upon the warmest zone requiring cooling.

For modeling the actual zone, the idea is to account for the stratification of air in the zone. One technique is to model the lower 6 feet of the zone as a conventionally conditioned zone and to model the upper portion of the zone as a return air plenum. Loads associated with the wall, roof, lighting and some of the equipment will then be modeled as being part of the return air plenum, rather than part of the space. This has the effect of modeling the stratified, non-mixed air in the zone, placing much of the heat gains into the return air. When the system is operating in economizer mode, these loads will simply be exhausted out of the building, rather than appearing as a cooling load in the space.

Assuming the system is VAV with reheat, each zone will be modeled with a conventional VAV terminal box to account for heating. Note that once modeling has been completed, it is important to verify that the higher supply air temperatures associated with the DV system will in fact meet the loads. Output reports from the software should be checked for unmet load hours. In addition, if working in a humid climate, it is unlikely that the higher temperatures will satisfy the latent loads. One solution is to design the system with a bypass on the cooling coil so that a certain portion of air will be cooled to 55 degrees and dehumidified, with the rest bypassing the coil, resulting in a mixed air temperature of 63°F to 68°F.

Depending upon the strategy used for the coil temperature, the chilled water temperature may also be modeled at a higher temperature. Assuming the bypass strategy is not used, the chilled water temperature should be set based upon the higher design, resulting in additional savings at the chiller.

The baseline building is not modeled with displacement ventilation.

7.2.5 Gas Engine Driven Heat Pumps

These systems typically are conventional DX packaged systems that utilize a natural gas or propane engine in place of an electric motor. During cooling operation, the gas engine will operate the cooling compressor to provide cooling to the DX coil. During heating operation, the same effect will be utilized. In both cases, the manufacturer may include the option for heat recovery from the gas engine for use in building hot water loads, such as domestic hot water or heating coils.

Given the unique nature of these systems, the energy modeling will need to utilize a system selection in the modeling software specific to gas engine driven heat pumps. In addition, user defined operating curves will need to be input to reflect the manufacturer specific operation during heating and cooling modes. Should the system utilize heat recovery, the heat recovery efficiency will need to be determined and assigned to the system. Two possible types of heat recovery include jacket based heat recovery, where heat is extracted from the engine jacket used to cool the engine, and exhaust based heat recovery, where heat is recovered from the engine exhaust. In some cases, heat recovery may come from both sources. The heat recovery energy will then need to be assigned to a hot water or other demand in the building. This might include supplying domestic hot water needs for the occupants or perhaps reheat coils used downstream in the HVAC system.

The baseline building is not modeled with gas engine driven heat pumps.

7.2.6 Ground Source Heat Pumps

Sometimes referred to as geothermal systems, ground source heat pumps (GSHP) couple the condenser water side of the heat pump to a ground source. Possible couplings include vertical wells, horizontal wells or a body of water such as a pond or lake. In closed loop systems, water or an antifreeze solution is circulated through a series of pipes, while in open loop systems, water is pumped through the system and discharged openly.

The temperature of the heat sink available to the GSHP is going to be highly site dependent, and should be based upon the anticipated temperatures that will result after the system has been operational for a reasonable period of time. In some cases, a large lake may have fairly stable temperatures that can be anticipated on a monthly basis based upon historical trends. In other cases, a smaller heat sink such as drilled wells may be subject to localized temperature increases in the areas surrounding the wells, and this will need to be factored in. In addition, sites that have underground aquifers will see different resulting ground temperatures than sites without. As a result, local conditions will need to be factored into the ground temperature assumptions which are key to GSHP modeling.

Modeling of the GSHP systems will begin with the basic zoning of the building. It is common to use fairly small (5 ton and under) systems, so each will typically require a separate zone in the model. In cases where zones have the same GSHP installed and are thermally similar, combining of zones is acceptable. Some large applications of this technology will utilize multiple zone air handlers, in which case conventional zoning procedures will apply. Input descriptions for the GSHP will include heating and cooling capacities, the heating COP and cooling EER, as well as the supply fan and possibly return fan information. On some larger systems, economizers may be included.

The coupling of the GSHP system will occur through the condenser water loop, so the next step is to define this loop. Included in this definition will be information such as the pumping flow rate of the system, type of pumping (variable speed, constant speed), pump motor size as well as whether the GSHP condenser coils include three-way or two-way valves to control flow.

In cold climates, a backup boiler may be included as part of the condenser water system to prevent low water temperatures in the loop. The basic boiler information will need to be specified, as well as a minimum loop temperature which will dictate when the boiler is activated.

The final step is to define the actual ground or pond heat sink. This may include defining a schedule of monthly temperatures to represent a large body of water, although on smaller bodies of water changes in temperature from the GSHP system will need to be accounted for. In the case of a vertical or horizontal well system, information including the type of well, well spacing and well depth will need to be included.

The baseline building will not have a GSHP.

7.2.7 Ice Storage Air Conditioners

Ice Storage Air Conditioner (ISAC) systems contain ice storage tanks distributed throughout the building, with each tank associated with the air-side component of a single HVAC system. In contrast, traditional thermal energy storage systems centralize the storage, which then serves the load of the entire building. The ISAC system will typically rely on cooling fed from the storage tank to an air handler containing either a chilled water or DX coil. The tank will be charged by a condenser during night-time hours, and discharge will occur during the daytime hours. In modeling the ISAC system, the modeler will typically utilize the Split DX system type available in most analysis software. This system type will most closely approximate the performance of the condensing unit that will be used to charge the ice storage tank. In addition, custom cooling curves will need to be input to account for the system performance during the charging mode, since much lower temperatures will need to be produced by the condensing unit.

Operating schedules for the charging and melting model will depend upon the controls configuration of the ISAC system. Some systems are designed and configured to run in a simple charge/melt mode, where the entire daytime load will be handled by the ISAC system, and then the system will be recharged at night. Others are designed to only address peak period loads, and thus will run only during the peak utility period, with the condenser operating in the mornings during the shoulder peak periods. Another variation is an ISAC system that is designed for peak load shaving, with the ice melt supplementing the condenser cooling. These different strategies will require the use of appropriate operating schedules to control the condenser operating strategy as well as the ice tank charge/melt occurrences.

The baseline building does not have ISAC.

7.2.8 Radiant Heating and/or Cooling

Radiant heating systems rely on the delivery of heat via a system located in the floor, or in some cases, ceiling or wall mounted panels. The delivery can be either via a hydronic system coupled to a boiler (or other source of hot water) or using electric radiant panels. In the case of radiant cooling systems, delivery is typically via a hydronic system that is supplied with chilled water from a chiller or other cooling source. One of the most important factors of a radiant cooling system design is the control of the chilled water temperature that is supplied to the system. If the chilled water temperature supplied results in the radiant delivery system surface temperature falling below the dewpoint in the space, condensation will occur on the surface. The result of this would be moisture on the floor or ceiling, depending upon the location of the delivery system. As such, the chilled water supplied to the radiant system will be maintained at a higher temperature than a conventional chilled water system. This higher chilled water temperature will need to be accounted for in the energy modeling as it will impact both the pumping energy use as well as the chiller energy use. "Radiant" heating or cooling systems that utilize concrete slabs may be very slow to react to load changes. Simulation programs should be chosen that account for this or these systems should only be modeled in spaces that will have very slow load changes.

Since these systems rely upon the radiant delivery of heating and cooling, no fans are associated with the radiant component of the system. However, it is common that a fan is associated with the ventilation system. Modeling of the fan associated with the ventilation will depend upon how the ventilation system is configured. One approach is to utilize a Dedicated Outside Air System (DOAS). The modeling procedures for this type of system are described elsewhere in this chapter. Another approach used with radiant systems is to use a displacement ventilation system, in which case modeling of this component will follow procedures dictated elsewhere in this chapter. In some cases, radiant systems utilize natural ventilation as the source of outside air. These procedures are also addressed in this chapter.

The baseline building does not have radiant heating or cooling.

7.2.9 Switchable glazing

Switchable glazing can change the light transmittance, transparency, or shading of windows in response to an environmental signal such as sunlight, temperature or an electrical control. Technologies such as electrochromic and liquid crystal windows change from transparent to darkened by applying an electrical current to the window. Once the change in tint has been initiated, the glazing does not need constant voltage to maintain the tinting, so electrical usage is negligible for energy modeling. In addition, the film can be tuned to block certain wavelengths of light, such as infrared energy.

In modeling switchable glazing that includes an automatic control such as a heat sensor, a control set-point, usually in Btu/h, will be used in the model. The basic window will be modeled with the U-Factor, SHGC and VT (visible transmittance) of the glazing with no tinting applied. The energy model will then include modifiers to each of these values when the control set-point has been reached. Thus, the energy model will reduce the energy gain through the windows in response to solar gains on the particular window.

Another approach is to apply the same modifiers on an hourly basis using a series of schedules. This approach might be used in a circumstance where the glazing is being controlled with a building energy management system and would be applied at a consistent time of day, or seasonally. In this case, the hourly schedule would dictate the multiplier to be applied to the U-Factor, SHGC and/or visible transmittance.

This is but one way to model switchable glazing; other engines such as EnergyPlus have more advanced features and the use of alternative approaches is acceptable.

The baseline building does not have switchable glazing.

7.2.10 UFAD

Underfloor Air Distribution (UFAD) systems provide cooling supply air streams at significantly warmer temperatures than conventional systems, typically 60°F to 68°F. With the use of higher supply air temperatures comes the ability to operate in economizer mode many more hours each year. When producing the higher supply air temperatures, chilled water systems have the ability to operate at much higher chilled water temperatures, thus resulting in a significant increase in the chiller efficiency when producing chilled water. In addition, for systems that will be requiring reheat, additional heating and cooling energy is saved since they will be reheating air that is cooled to only 65°F versus a conventional system that has cooled the air to 55°F.

Since UFAD systems deliver air at lower velocities than conventional system, there is more potential for stratification since room air is mixed less. Thus, a certain portion of the heat in the space will rise towards the ceiling, where it will be exhausted by the return air register. The overall result is that (like with Displacement Ventilation) a portion of the cooling load in the space, including occupant heat gain, lighting and equipment, never appears as a cooling load. Given the fact that at any given point in time, at least some portion of the return air will be exhausted due to outside air requirements, this heat gain will also be exhausted.

Modeling of the UFAD system will follow the same general approach as the Displacement Ventilation systems described earlier. In some instances, fan powered terminal units are used in this application, so a fan powered box may need to be included in the zone inputs.

The baseline building does not have an UFAD system.

7.2.11 Variable Refrigerant Flow

Commonly referred to as VRF systems, Variable Refrigerant Flow systems are produced by a number of manufacturers and consist of both heat pump and heat recovery units. Similar in nature to a Water Source Heat Pump system, the VRF system consists of an outdoor condenser unit tied to a group of indoor heating and cooling units using a piping loop. Unlike a water source heat pump system, however, the VRF system uses a refrigerant loop connection between the indoor and outdoor units. In the case of the heat recovery version of the VRF system, indoor units are able to exchange heating and cooling energy via the refrigerant loop.

Given the nature of partial loading on the outdoor unit from the various indoor units, using a simple full load EER to approximate unit performance will result in a gross underestimation of system performance. Accurate hourly loading of each indoor unit is necessary to derive the maximum accuracy. Each indoor unit must be modeled as a zone or thermostatic control element in the software. In situations where a single zone contains a number of indoor units, it is acceptable to group those units as a single zone, provided each area served by the indoor units is thermally similar. Once the thermal zones have been determined, each indoor unit will be modeled based upon actual heating and cooling capacity and fan characteristics. Some VRF systems include optional components that provide outdoor air heat recovery and/or economizer capability, so these features will need to be specified at the zone level inputs of the software.

Once all the indoor units have been defined, each indoor unit will need to be associated with a loop that connects it to an outdoor unit. As part of the specification of the loop, heat recovery may also be included if the unit has this capability. Each outdoor unit will be specified with inputs for capacity and full load efficiency. In addition, operating curves will be input to adjust the full load efficiency for part load conditions and varying outdoor conditions.

Additionally, some VRF systems include the ability to connect all of the outdoor condensing units to a water or glycol based condenser water loop that includes a cooling tower and possibly a boiler. If this is the case, additional parameters will need to be input to define this water loop including the description of the pumps, cooling tower and boiler. This description will be similar to the parameters that are described for a conventional water source heat pump condenser water loop.

A final variation on the water cooled condensers is the inclusion of a ground coupled system. In this case, the condenser water will be pumped through a series of wells that couple the condenser water to the ground temperature. This portion of the modeling should generally follow the procedures specified in the section on ground source heat pumps elsewhere in this chapter.

The baseline building does not have a VRF system.