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Technical Support Document: Development of the Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities—30% Guide

Eric Bonnema, Ian Doebber,
Shanti Pless, and Paul Torcellini

Technical Report
NREL/TP-550-46314
March 2010

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The authors would like to thank all the members of the Advanced Energy Design Guide (AEDG) project committee (PC) for their valuable input and willingness to share their expertise. Much work went into producing the lighting and daylighting recommendations; many types of heating, ventilation, and air-conditioning (HVAC) systems; and envelope considerations. Without the committee's expertise and differing views and the support of the members' employers, this document would not have been possible.

All the energy modeling analysis was based on two prototype facilities: a community hospital and a surgery center. The authors would like to thank the Community Hospital of Bremen, Indiana, and the architect The Troyer Group of Mishawaka, Indiana, as well as Cogdell Spencer ERDMAN of Middleton, Wisconsin, for providing the facility descriptions and energy use information to develop detailed energy models.

Additional thanks to Adam Hirsch, Feitau Kung, and Chad Lobato (all of NREL) who helped to edit and review the document. Finally, the authors greatly appreciate the assistance of Brent Griffith, Kyle Benne, Dan Macumber, Nicholas Long, and the rest of the NREL EnergyPlus analysis and modeling team. Their simulation development and support allowed us to evaluate the many variations of energy efficiency technologies.

Executive Summary

Background

This Technical Support Document (TSD) describes the process and methodology for the development of the *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities* (SHC-AEDG), which is intended to provide recommendations for achieving 30% whole-building energy savings in small hospitals and healthcare facilities over levels achieved by following the ANSI/ASHRAE/IESNA Standard 90.1-1999, Energy Standard for Buildings Except Low-Rise Residential Buildings. The SHC-AEDG was developed in collaboration with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the American Institute of Architects (AIA), the American Society for Healthcare Engineering (ASHE), the Illuminating Engineering Society of North America (IESNA), the U.S. Green Building Council (USGBC), and DOE.

The 30% energy savings target is the first step toward achieving *net-zero energy small hospitals and healthcare facilities*. Net-zero energy facilities are buildings that draw from outside sources less or equal energy than they generate on site from renewable energy sources during a given year. Previous guides in this series include the *Advanced Energy Design Guide for K-12 Schools*, *Advanced Energy Design Guide for Small Office Buildings*, the *Advanced Energy Design Guide for Small Retail Buildings*, and the *Advanced Energy Design Guide for Small Warehouses and Self-Storage Buildings*. Each provides user-friendly design assistance and recommendations to design, architectural, and engineering firms to achieve energy savings. The SHC-AEDG includes prescriptive recommendations by climate zone for designing the building envelope, fenestration lighting systems (including electrical lights and daylighting), HVAC systems, building automation and controls, outdoor air (OA) treatment, and service water heating (SWH). Additional savings recommendations are also included, but are not necessary for 30% savings. These are provided for exterior lighting; electricity distribution; plug, process, and phantom loads; renewable energy systems; combined heat and power; alternative HVAC systems; and other hot water systems. The SHC-AEDG contains recommendations only and is not a code or standard.

Our objectives in developing the 30% SHC-AEDG included:

- Document the process and schedule we used to develop the Guide.
- Develop baseline and low-energy EnergyPlus small hospital and healthcare facility models.
- Document the EnergyPlus modeling assumptions needed to verify 30% energy savings.
- Present the recommendations for 30% savings over ASHRAE 90.1-1999 for use in the SHC-AEDG.
- Present the recommendations for 30% savings over ASHRAE 90.1-2004.
- Demonstrate that the recommendations result in 30% or greater energy savings by climate zone.

Development Process

The SHC-AEDG was developed by a PC that represents a diverse group of professionals. Guidance and support were provided through collaboration between ASHRAE, AIA, ASHE, IESNA, USGBC, and DOE. PC members came from these partner organizations, the ASHRAE Standing Standards Project Committee 90.1, and the ASHRAE Technical Committee on Healthcare Facilities. A steering committee (SC) made up of representatives of ASHRAE, AIA, IESNA, USGBC, and DOE issued a charge to the PC to develop the Guide. The charge included a timeline for the task, an energy savings goal, an intended target audience, space types to include, and desired design assistance characteristics.

The PC followed SC guidance to develop a one-year plan for completing the document. Key milestones were determined based on a final publication date such that it would be ready for the ASHRAE Winter Meeting in January 2010. The PC used a schedule similar to those developed for the previous guides to plan for two peer review periods that corresponded with a 65% completion draft (technical refinement review) and a 90% completion draft (final review for errors). A focus group reviewed the conceptual 35% draft. Six PC meetings were held at ASHRAE headquarters, at NREL, or at a PC member's office building. Three conference calls with the full PC were also held.

Advanced Energy Design Guide Scope

This Guide applies to healthcare facilities up to 90,000 ft^2 (8,360 m^2), including acute care, outpatient surgical, and small critical access and inpatient community hospitals. These facilities typically include some or all of the following space types: patient rooms, surgery, emergency department, radiology, administration, dining and food preparation, postanesthesia care unit, and recovery, to name a few. The primary focus of this Guide is new construction, but recommendations may be applicable to facilities undergoing total renovation; and in part to many other healthcare renovation, addition, remodeling, and modernization projects (including changes to one or more systems in existing buildings).

The small healthcare facilities included in the Guide are defined as:

- Small acute care hospitals
- Small inpatient community hospitals
- Critical access hospitals with 25 or fewer beds
- Outpatient surgical facilities
- Freestanding birthing centers (similar to outpatient surgical centers)
- Gastrointestinal endoscopy facilities (similar to outpatient surgical centers)
- Renal dialysis centers (similar to medical office buildings)
- Primary care outpatient centers
- Small primary (neighborhood) outpatient facilities
- Freestanding outpatient diagnostic and treatment facilities
- Freestanding urgent care facilities
- Medical office buildings (larger than 20,000 ft^2 [1,860 m^2]).

The Guide does not include all the components listed in Standard 90.1-1999. It focuses only on the primary energy systems within a building, so the underlying energy analysis presumes that all the other components are built according to the criteria in Standards 90.1 and ASHRAE Standard 170.

Certain aspects of energy-efficient design, including steam heat, vehicle and other maintenance areas, and sewage disposal, are excluded. Significant energy efficiency opportunities may be available in these areas; readers are encouraged to take advantage of these opportunities and treat them as "bonuses" beyond the 30% target.

The Guide is also not intended to substitute for rating systems or references that address the full range of sustainable issues in healthcare design, such as acoustics, productivity, indoor air quality, water efficiency, landscaping, and transportation, except as they relate to energy use. Nor is it a design text. The Guide assumes good design skills and expertise in healthcare and hospital design.

Guide Layout and Content

The introduction of the Guide contains information about its goal and scope as well as instructions for its use. The next section provides resources for those who want to understand and adopt an overall, integrated process for designing, constructing, and operating energy-efficient small hospitals and healthcare facilities. The Guide presents an integrated process for achieving energy savings in these facilities and is valuable for designers and builders who want to augment and improve their practices so energy efficiency is deliberately considered at each stage of the development process from project conception through building operation. This section concludes by addressing the details of an integrated design process. It discusses the benefits and features of integrated design, specifics about the process, and step-by-step details about the four phases of the process: predesign, design, construction, and acceptance/occupancy/operation.

The third section contains the climate-specific recommendation tables, a unique set of energy efficiency recommendations for each of the eight DOE climate zones in the United States. Efficiency recommendations are organized by several categories: envelope, electric lighting, daylighting, HVAC, and SWH. The recommendations are simply one path to reach the 30% energy savings target over ANSI/ASHRAE/IESNA Standard 90.1-1999. Other approaches may also save energy, but identifying all possible solutions is not in the scope of this Guide; assurance of the savings from other approaches is left to the user. To achieve 30% energy savings, this Guide assumes compliance with the more stringent of either the applicable edition of Standard 90.1 or the local code requirements in all areas not addressed in the climate-specific recommendation tables. Future editions of energy codes may have more stringent values. In these cases, the more stringent values are recommended.

The fourth section presents seven detailed case studies that illustrate techniques and methods discussed in the Guide. Energy numbers are provided to benchmark these buildings against future buildings. All these case studies use some of the recommendations in the tables, but predate the publication of the Guide and were not developed explicitly using those tables. Readers are encouraged to view more case studies at www.ashrae.org/aedg, and to submit their own. Case studies provide the motivation and the examples for others to follow.

The final section provides guidance about good practices for implementing the recommendations, as well as cautions to avoid known problems in energy-efficient construction. The section is divided into quality assurance and commissioning, envelope, lighting, daylighting, HVAC, SWH, and bonus savings. The bonus savings section includes areas for additional good practice items that, if implemented properly, should achieve savings beyond the 30% level.

The quality assurance and commissioning subsection contains specific details about commissioning and its importance in every step of the design process. The envelope section contains climate zone-specific information about explicit types of walls, roofs, floors, doors, insulation, infiltration, and vertical fenestration. The lighting section details best practices for interior finishes, specific lamp and ballast types, lighting layouts, and control strategies for specific space types. The daylighting section provides tips on general principles, using daylighting analysis tools, daylighting space types and layouts, building shape and orientation with respect to daylighting, window-to-wall ratios, sidelighting, toplighting, skylight construction, shading devices, photosensor specification, and photocell placement.

The HVAC section includes best practices for multiple-zone VAV air-handling systems, water-source (including ground-source) heat pumps, dedicated OA systems, HVAC load calculations, equipment efficiencies, economizers, exhaust air energy recovery, ductwork design, duct insulation, duct sealing, exhaust air systems, system-level control strategies, filters, chilled water systems, heating water systems, and zone-level controls.

The bonus savings section includes good practices for lighting (exterior lighting, lamp types), process loads (medical equipment, high-performance kitchen and laundry equipment), renewable energy (photovoltaic and solar hot water systems, wind turbines), combined heat and power, additional HVAC systems (condenser water heat recovery, ground-source heat pumps, displacement ventilation, demand-controlled ventilation, thermal storage, desiccant-based dehumidification, evaporative condensing), and electrical distribution systems (transformer efficiencies, metering).

Evaluation Approach and Results

The purpose of our building energy simulation analysis is to assess and quantify the energy savings potential of our recommendations. The AEDG contains a set of energy efficiency recommendations for eight climate zones across the country. To provide prescriptive 30% recommendations, a specific quantitative energy savings goal must be measured against Standard 90.1-1999, the “turn of the millennium” standard for each climate zone. The energy savings of the prescriptive recommendations are also determined against ASHRAE 90.1-2004. The Guide contains a set of energy efficiency recommendations for each of the eight climate zones across the United States. The following steps describe how the energy savings potential of the Guide’s recommendations was determined:

1. Develop “typical” small hospital and small healthcare facility prototype

For building characteristics that are not specified by ASHRAE 90.1-1999, ASHRAE 90.1-2004, or ASHRAE 62, but that are needed to develop code-compliant baseline models, the PC chose two recently constructed buildings as references for prototypes: a community hospital and a surgery center. From these two buildings, a prototype small hospital and a prototype small surgery facility were developed (see Table ES-1).

Table ES-1 SHC-AEDG Prototype Characteristics

Building Characteristic	SHC-AEDG Prototype	
Building type	Community hospital	Surgery center
Size	65,000 ft^2	41,000 ft^2
Number of floors	1	3
Number of occupants	675	414
Space types	See Table 4-1	See Table 4-1
Constructions	Steel-frame walls Roof with insulation entirely above deck	Steel-frame walls Roof with insulation entirely above deck
Window area	26% window-to-wall ratio	20% window-to-wall ratio
Occupancy	Fully occupied during the day Partially occupied at night	Fully occupied during the day Vacant at night
Peak plug loads	2.1 W/ft^2	1.8 W/ft^2
Percent conditioned	Fully heated and cooled	Fully heated and cooled
HVAC system types	Baseline: PVAV* with DX** Low-energy: PVAV with DX, air-cooled chiller, and water-cooled chiller	Baseline: PVAV with DX Low-energy: PVAV with DX, air-cooled chiller, and water-cooled chiller

* PVAV = package multizone direct expansion rooftop unit with variable-air volume
** DX = direct expansion

2. Create baseline models from the prototypes that are minimally code compliant for ASHRAE 90.1

The PC documented the baseline small hospital and healthcare facility energy modeling assumptions and methods, including the building form and floor plate, envelope characteristics, building internal loads and operating schedules, ventilation rates and schedules, HVAC equipment efficiency, operation, control and sizing, fan power assumptions, and SWH. The baseline models for the small hospital and healthcare facility were developed by applying the criteria in ASHRAE 90.1, the *2006 AIA Guidelines for Health Care*, and ASHRAE 62 to the prototype characteristics. The criteria in these documents were used as the baselines to calculate energy savings for the SHC-AEDG recommendations. For the baselines needed to verify 30% savings for our DOE analysis, the SHC-AEDG baselines were updated to be minimally code compliant with ASHRAE 90.1-2004.

3. Create the low-energy models based on the recommended energy efficiency technologies

Our final recommendations were determined based on an iterative process using the PC's expertise and results from modeling the recommendations. To quantify the potential energy savings from the final recommended energy efficiency measures (EEMs), we simulated the low-energy building models by implementing the following energy efficiency technologies and documenting the EEMs and EnergyPlus modeling assumptions:

- Enhanced building opaque envelope insulation
- Enhanced window glazing with overhangs
- Reduced lighting power density and occupancy control
- Daylighting in staff areas (exam rooms, nurse stations, offices, corridors) and public spaces (waiting, reception)
- Higher efficiency HVAC equipment
- High-efficiency SWH.

4. *Verify 30% energy savings across HVAC system types over the 15 U.S. climate zones*

Energy savings from our final recommendations are documented, along with the recommendations for 30% savings over ASHRAE 90.1-1999 and ASHRAE 90.1-2004. For each low-energy design, three cooling equipment types were modeled. The low-energy cooling equipment types included a packaged rooftop DX system, a packaged rooftop system with a central air-cooled chiller, and a packaged rooftop system with a central water-cooled chiller. The recommendations in the SHC-AEDG result in more than 30% savings over ASHRAE 90.1-1999 in all climate zones, ranging from 32% to 45% savings depending on the climate zone. This was achieved for each prototype with a range of HVAC system types. Table ES-2 summarizes the percent savings for each prototype model in each climate zone.

Table ES-2 Percent Savings Over ASHRAE 90.1-1999

Climate Zone	Representative City	Community Hospital			Surgery Center		
		Packaged DX	Air-Cooled Chiller	Water-Cooled Chiller	Packaged DX	Air-Cooled Chiller	Water-Cooled Chiller
1A	Miami, Florida	38%	36%	36%	39%	36%	34%
2A	Houston, Texas	40%	39%	38%	39%	38%	36%
2B	Phoenix, Arizona	43%	43%	45%	44%	44%	45%
3A	Memphis, Tennessee	39%	39%	37%	38%	38%	35%
3B	El Paso, Texas	41%	43%	43%	44%	45%	45%
3C	San Francisco, California	44%	45%	43%	45%	45%	42%
4A	Baltimore, Maryland	40%	41%	39%	38%	39%	36%
4B	Albuquerque, New Mexico	42%	44%	44%	44%	45%	45%
4C	Seattle, Washington	41%	41%	40%	42%	42%	40%
5A	Chicago, Illinois	41%	40%	40%	40%	40%	38%
5B	Boise, Idaho	42%	43%	43%	43%	43%	43%
6A	Burlington, Vermont	39%	40%	39%	38%	39%	38%
6B	Helena, Montana	41%	42%	42%	41%	42%	42%
7A	Duluth, Minnesota	39%	39%	39%	37%	37%	36%
8A	Fairbanks, Alaska	33%	33%	33%	33%	33%	32%

For comparison of the low-energy models with ASHRAE 90.1-2004 baseline models, the recommendations are the same as those that are in the SHC-AEDG. However, 30% savings were not achieved for all climate zones over ASHRAE 90.1-2004; energy savings ranged from 26% to 40%, depending on climate zone. The 2004 baseline models are better energy performers than their 1999 counterparts because the 2004 version of the Standard is more stringent than the 1999 version. For example, the allowable lighting power density in ASHRAE 90.1-2004 is lower than that in ASHRAE 90.1-1999, resulting in lower energy use in the baseline models. This ultimately results in lower percent savings when the 2004 baseline models are compared to the low-energy models created using the SHC-AEDG recommendations.

Table ES-3 summarizes the percent savings for each prototype model in each climate zone (the specific model that did not reach 30% savings are indicated in red). The hot-humid climates zones (1A, 2A, 3A) and the extremely cold climates (8A) did not reach 30% savings over ASHRAE 90.1-2004.

Table ES-3 Percent Savings Over ASHRAE 90.1-2004

Climate Zone	Representative City	Community Hospital			Surgery Center		
		Packaged DX	Air-Cooled Chiller	Water-Cooled Chiller	Packaged DX	Air-Cooled Chiller	Water-Cooled Chiller
1A	Miami, Florida	33%	30%	30%	31%	28%	26%
2A	Houston, Texas	35%	34%	33%	32%	31%	29%
2B	Phoenix, Arizona	39%	38%	40%	38%	38%	39%
3A	Memphis, Tennessee	34%	34%	32%	31%	32%	28%
3B	El Paso, Texas	36%	38%	38%	36%	38%	38%
3C	San Francisco, California	40%	40%	38%	39%	39%	36%
4A	Baltimore, Maryland	35%	36%	34%	32%	33%	30%
4B	Albuquerque, New Mexico	37%	39%	39%	37%	39%	38%
4C	Seattle, Washington	36%	37%	35%	36%	36%	34%
5A	Chicago, Illinois	36%	36%	35%	35%	34%	32%
5B	Boise, Idaho	37%	38%	38%	36%	37%	37%
6A	Burlington, Vermont	35%	36%	35%	33%	33%	32%
6B	Helena, Montana	36%	37%	37%	34%	36%	35%
7A	Duluth, Minnesota	34%	35%	34%	31%	31%	31%
8A	Fairbanks, Alaska	29%	30%	29%	27%	28%	27%

The flowchart in Figure ES-1 presents a visual representation of the evaluation approach.

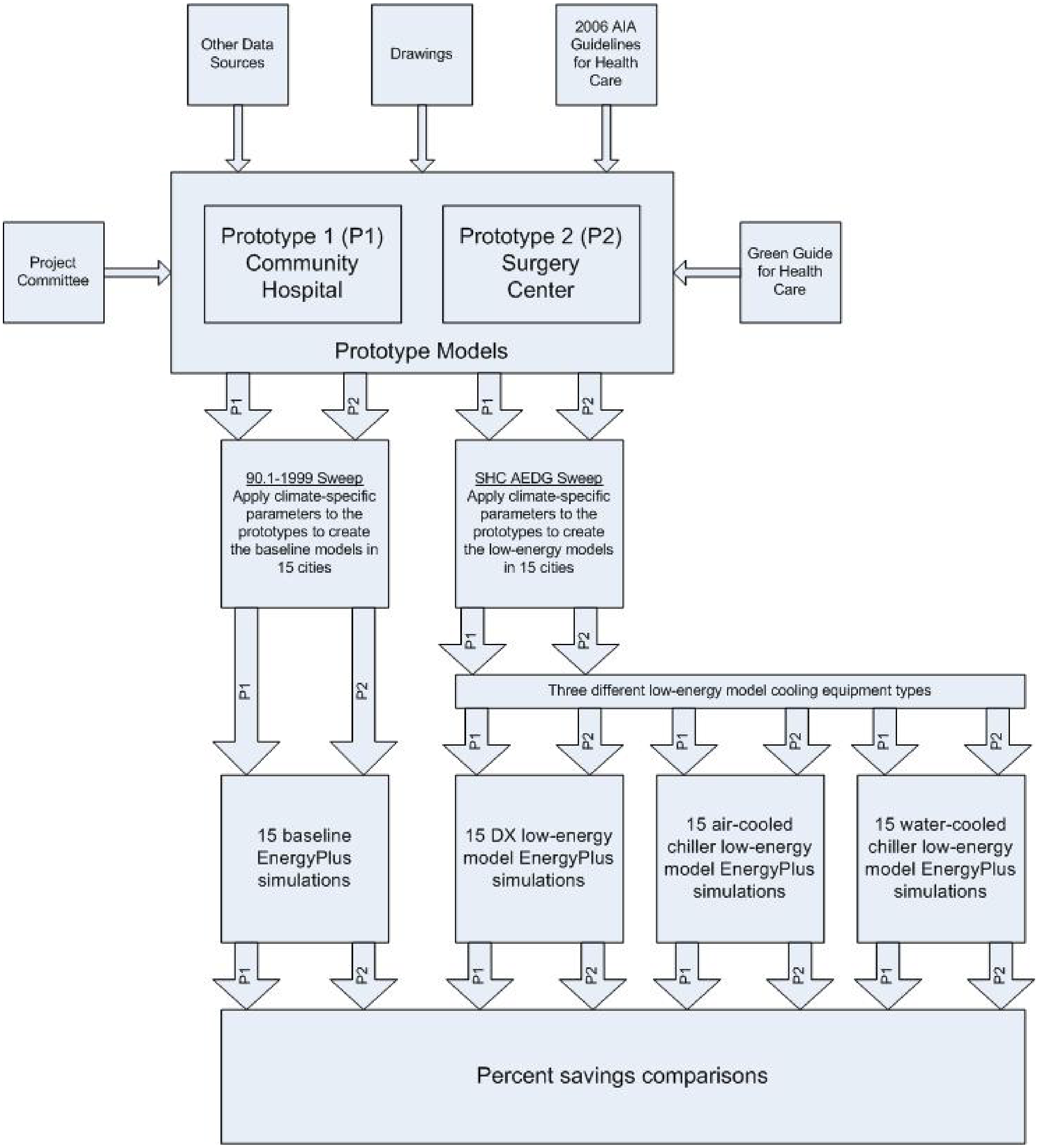

Figure ES-1 Evaluation approach flowchart

Nomenclature

ACH	air changes per hour
AEDG	Advanced Energy Design Guide
AHU	air handling unit
AIA	American Institute of Architects
ARI	Air-Conditioning and Refrigeration Institute
ASHE	American Society for Healthcare Engineering
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CAV	constant air volume
CBECS	Commercial Buildings Energy Consumption Survey
CHWS	chilled water supply
COP	coefficient of performance
CWS	condenser water supply
DOE	U.S. Department of Energy
DX	direct expansion
EA	exhaust air
E_c	combustion efficiency
EEM	energy efficiency measure
EER	energy efficiency ratio
EIR	energy input ratio
E_t	thermal efficiency
EF	energy factor
FSEC	Florida Solar Energy Center
HVAC	heating, ventilation, and air conditioning
HHW	heating hot water
HHWR	heating hot water return
HHWS	heating hot water supply
IESNA	Illuminating Engineering Society of North America
IPLV	integrated part-load value
LEED	Leadership in Environmental and Energy Design
LPD	lighting power density
MLPW	mean lumens per watt
NEMA	National Electrical Manufacturers Association
NREL	National Renewable Energy Laboratory
OA	outdoor air
PC	project committee
PLF	part-load factor
PLR	part-load ratio
PVAV	A package multi-zone DX rooftop with a VAV
RH	relative humidity
SC	steering committee
SHGC	solar heat gain coefficient
SHC-AEDG	Small Hospital and Healthcare Facility Advanced Energy Design Guide
SHR	sensible heat ratio

SRI	Solar Reflective Index
SWH	service water heating
TSD	Technical Support Document
USGBC	U.S. Green Building Council
VAV	variable air volume
VFD	variable frequency drive
w.c.	water column
WWR	window-to-wall ratio

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1. Introduction

The *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities* (SHC-AEDG) (called the Guide or SHC-AEDG in this report) was written to help owners, designers, and builders of small- to medium-size acute care, outpatient, and inpatient buildings achieve site energy savings of at least 30% compared to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999 (ASHRAE 1999), which serves as a baseline. The small healthcare facilities included in the scope of the Guide are smaller than 90,000 ft^2 (8,360 m^2) and are defined as:

- Small acute care hospitals
- Small inpatient community hospitals
- Critical access hospitals with 25 or fewer beds
- Outpatient surgical facilities
- Freestanding birthing centers (similar to outpatient surgical centers)
- Gastrointestinal endoscopy facilities (similar to outpatient surgical centers)
- Renal dialysis centers (similar to medical office buildings)
- Primary care outpatient centers
- Small primary (neighborhood) outpatient facilities
- Freestanding outpatient diagnostic and treatment facilities
- Freestanding urgent care facilities
- Medical office buildings (larger than 20,000 ft^2 [1,860 m^2]).

The Guide includes recommendations for the design of the building envelope; fenestration; lighting systems (including electrical lights and daylighting); heating, ventilation, and air-conditioning (HVAC) systems; building automation and controls; outdoor air (OA) treatment; and service water heating (SWH). Additional savings recommendations are also included, but are not necessary for 30% savings. These are discussed in the bonus savings section and provide recommendations for process, plug, and phantom loads; renewable energy systems; alternative hot water systems; alternative HVAC systems; and electricity distribution. The Guide contains recommendations only and is not a code or standard.

The Guide is intended to show that achieving the 30% target is not only possible, but easily achievable. Case studies show small healthcare facilities around the country that have achieved and surpassed the 30% energy savings target. Best practices and cautions are also provided to demonstrate how to implement the recommendations. The recommendation tables do not include all the components listed in ASHRAE 90.1-1999. Though the Guide focuses only on the primary energy systems in a building, the underlying energy analysis presumes that all the other components are built to the criteria in ASHRAE 90.1 (ASHRAE 2001) and ASHRAE 62.1 (ASHRAE 2004c).

By specifying a target goal and identifying paths for each climate zone to achieve this goal, the Guide provides *a way, but not the only way*, to meet the 30% target and build small healthcare facilities that use substantially less energy than those built to minimum energy code requirements. There may be other means of achieving the target goal, and we hope that the Guide generates ideas for innovation.

The 30% energy savings target is the first step toward achieving *net-zero energy healthcare facilities*. Net-zero energy facilities are buildings that draw from outside energy sources an amount that is less than or equal to the energy that they generate on site from renewable energy sources in a given year. Other guides in this series include the *Advanced Energy Design Guide for Small Office Buildings* (ASHRAE 2004a), the *Advanced Energy Design Guide for Small Retail Buildings* (ASHRAE 2006), the *Advanced Energy Design Guide for K-12 School Buildings* (ASHRAE 2008a), the *Advanced Energy Design Guide for Small Warehouses and Self-Storage Buildings* (2008b), and the *Advanced Energy Design Guide for Highway Lodging*.

The Guide was developed by a project committee (PC) that represents a diverse group of professionals. Guidance and support were provided through a collaboration between the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the American Institute of Architects (AIA), the Illuminating Engineering Society of North America (IESNA), the U.S. Green Building Council (USGBC), and the U.S. Department of Energy (DOE). PC members came from these partner organizations, the ASHRAE Standing Standards Project Committee 90.1, the ASHRAE Technical Committee on Healthcare Buildings (TC 9.6), and the American Society of Healthcare Engineers (ASHE).

1.1 Objectives

Our task in developing the 30% SHC-AEDG was to provide the analysis and modeling support to:

- Verify energy savings. The specific prescriptive recommendations that must, in aggregate, yield 30% savings beyond a benchmark building built to the Standard 90.1-1999 for each climate region. The 30% is measured based on the total energy consumption, not just the regulated loads. It is not an average of the national energy savings. Cities used for testing in the *Advanced Energy Design Guide for Small Office Buildings* were also used for the SHC-AEDG (Jarnagin et al. 2006).
- Develop recommendations that meet a numeric goal value. The energy savings goal is a hard value as opposed to an approximate target. The 30% energy savings value was set to be as consistent as feasible with Leadership in Environmental and Energy Design (LEED) criteria (USGBC, 2006), given that LEED works from a cost basis and this document is based on energy savings. As in past AEDGs, this Guide can be used to obtain LEED Energy and Atmosphere credits.
- Identify methods to achieve the goal. The goal of the Guide is to save energy by identifying packages of design measures and strategies combined with selecting state-of-the-shelf building systems and design concepts (multiple suppliers of a given technology or system) that result in efficient and high-quality spaces.

Separate from the Guide, this Technical Support Document (TSD) was written to document the process used to develop the 30% SHC-AEDG and the analysis and modeling done to support that development. The specific objectives include:

- Document the process and schedule used for developing the Guide.
- Develop prototypical small healthcare facility characteristics.
- Document the EnergyPlus modeling assumptions needed to verify 30% energy savings.
- Develop the baseline and low-energy EnergyPlus small healthcare facility models.

- Present the recommendations for 30% savings over ASHRAE 90.1-1999 for use in the SHC-AEDG.
- Present the recommendations for 30% savings over ASHRAE 90.1-2004.
- Demonstrate that the recommendations result in 30% or greater energy savings by climate zone.

1.2 Literature Review

The first step in developing the 30% SHC-AEDG was to perform a literature review and summary of high-performance small hospital and healthcare facility guidelines. To ensure that the SHC-AEDG did not duplicate previous work in the relatively mature field of high-performance small healthcare facilities, we performed a literature review of the available design guides and rating systems for high-performance small healthcare facilities. Efforts focused on compiling a summary of the available high-performance small healthcare facilities guides available throughout the country. Based on this review, we concluded that the SHC-AEDG is unique. None of the documents reviewed include prescriptive design guidance for targeted levels of energy savings based on climate. The SHC-AEDG should provide a needed resource and complement many available guides and criteria.

In addition to the vast selection of healthcare facility design guides, there are many datasets of physical healthcare facility characteristics and energy performance. The currently available data sources represent existing building stock as well as annual updates for new building construction. We surveyed these datasets to develop "typical" small healthcare facility characteristics and energy performance. Typical healthcare facility characteristics helped to inform our development of realistic prototypical models for the 30% AEDG analysis. Datasets that we evaluated include:

- The Commercial Building Energy Consumption Survey (CBECS) (EIA 2003)
- Additional datasets from the PC, including actual floor plates and space programming requirements for a small community hospital and a surgery center
- The DOE Buildings Database (DOE 2004)
- McGraw Hill Dodge construction data (McGraw Hill 2009)
- The *Green Guide for Health Care* (GGHC 2007)
- The DOE Commercial Buildings Benchmark Project (Torcellini et al. 2008).

1.3 Scope of the SHC-AEDG and Technical Support Document

Each guide in the AEDG series provides recommendations and user-friendly design assistance to designers, developers, and owners of commercial buildings that will encourage steady progress toward net-zero energy buildings. The SHC-AEDG provides prescriptive recommendation packages that can reach the energy savings target for each climate zone and ease the burden of designing and constructing energy-efficient small healthcare facilities.

Certain aspects of energy-efficient design, including steam heat, vehicle and other maintenance areas, and sewage disposal, are excluded. Significant energy efficiency opportunities may be available in these areas; readers are encouraged to take advantage of these opportunities and treat them as "bonuses" beyond the 30% target.

The Guide is also not intended to substitute for rating systems or references that address the full range of sustainable issues in healthcare design, such as acoustics, productivity, indoor air quality, water efficiency, landscaping, and transportation, except as they relate to energy use. Nor is it a design text. The Guide assumes good design skills and expertise in small hospital and healthcare facility design.

The guides in the AEDG series do not provide a detailed documentation for the development of the recommendations or the actual energy savings. This TSD describes the process and methodology for the development of the SHC-AEDG and provides the technical details for determining 30% energy savings, including model inputs and assumptions, the development of the 30% recommendations, and the energy savings.

1.4 Report Organization

This report is presented in four sections: Section 1 introduces the SHC-AEDG and the supporting background information; Section 2 describes the charge given to the PC for developing the Guide and outlines the process and development schedule; Section 3 provides the evaluation approach, including baseline and low-energy modeling methods and assumptions; and Section 4 documents the final recommendations and energy savings.

Additional information on the PC development process is included in Appendix A. Appendix B includes the summary responses to the remarks received on the 65% review draft. Appendix C and Appendix D summarize baseline model inputs. Appendix E summarizes the methodology behind determining the plug loads for small healthcare facilities. Appendix F and Appendix G provide annual energy end use intensities for the primary end uses for the recommendations for 30% savings over ASHRAE 90.1-1999 and for 30% savings over ASHRAE 90.1-2004. Appendix H contains HVAC fan details.

2. Development Process

The Guide was developed by a PC that represents a diverse group of professionals. Guidance and support were provided through collaboration between ASHRAE, AIA, IESNA, USGBC, and DOE. PC members came from these partner organizations, the ASHRAE Standing Standards Project Committee 90.1, the ASHRAE Technical Committee on Healthcare Buildings, and ASHE.

2.1 Charge to the Project Committee

A steering committee (SC) made up of representatives of the partner organizations issued a charge to the PC to develop the Guide. The charge included a timeline for the task, an energy savings goal, an intended target audience, and desired design assistance characteristics. These elements are listed here:

- Develop and document a process to achieve a savings of 30% progress toward a net-zero energy building for small healthcare facilities.
- Produce recommendations in a technically sound SHC-AEDG.
- Publish the Guide within a year.
- Constrain the scope and duration of the analysis effort to maintain the schedule. The PC should rely on current knowledge of energy-efficient building design, supplemented with energy design analysis that can be completed according to the schedule.
- Produce a document that is concise. Use the K-12 AEDG (ASHRAE 2008) to guide size and technical depth; the overall size is expected to be 100 to 200 published pages.

Additional guidance from the SC to the PC was provided in a Scope Document. Elements of the Scope Document are listed here:

- The baseline for energy use evaluation is annual site energy consumption.
- Address in a user friendly way the practical information needs of its intended users who are designers in medium to large firms, design/build contractors, and construction firms.
- The interaction of building components and systems will likely need to be considered rather than having all the savings come from individual parts (savings from integration of systems is encouraged). Accommodate, to the extent practical, some level of design flexibility through use of packages of energy efficiency measures (EEMs) that users may choose from.
- Adopt a prescriptive recommendation approach with packages of measures. This will include envelope, mechanical, lighting, and water heating measures. The document will be formatted for easy use, provide specific procedures, convey best practices, and avoid code language. The apparent complexity of the typical standard/guideline layout and format should be avoided to ease usability by the target audience.
- In addition to prescriptive EEMs, the Guide should contain "how to" guidance that will help the designer construct an energy-efficient small healthcare facility. In recognition of the constrained design fees available, the document should be presented in a very user-friendly manner to reduce design time. By focusing on user-friendly layouts and presentation as well as prescriptive design recommendations, the Guide should ease the

burden for the designers and give small healthcare facility decision makers an overview of specific, easy-to-follow recommendations.

- The prescriptive recommendations presented should be sufficient to allow innovative firms to extend the design information that might be evaluated on performance-based criteria. That is, some additional allowance or flexibility should be provided for those accustomed to performance-based documents.
- Several case studies should be included to illustrate the energy efficiency components identified. These case studies can focus on the geographic regions (as in the K-12 AEDG) or to illustrate particular items or techniques recommended.

2.2 Inclusion of Economics and Cost

The guidance provided in the SHC-AEDG should help designers design energy-efficient small healthcare facilities. The goal of 30% energy savings is to be considered its primary focus; i.e., the focus is on high-performance buildings and the energy savings related thereto, not on installations that have a payback less than some given number of years. Cost and payback are factors, but they are secondary to achieving buildings that use 30% less energy.

Therefore, energy use is to be considered the independent variable that is specified, and cost effectiveness (as measured by, for example, simple payback period) is the dependent (or resulting) variable. Although some of the products or recommendations may be considered premium, products of similar performance must be available from multiple manufacturers.

2.3 Approval Authority

The final approval for the Guide is the responsibility of the SC. SC members represent various interested parties and are responsible for reflecting the opinions of the group represented. This includes consulting with the groups, getting buy-in from them during the entire process, and providing the peer review. Efforts should be made to agree on the content, as was done, for example, for the *ASHRAE Handbook: Fundamentals* (ASHRAE 2009b); however, the Guide is not a consensus document.

2.4 Project Committee Organization and Membership

The Guide was developed by a PC administered under ASHRAE's Special Project procedures. The SHC-AEDG PC was designated as ASHRAE Special Project 127 (SP-127), and included membership from each partner organization. Table 2-1 lists the PC members and their PC function.

The SC selected PC members with energy efficiency experience in small healthcare facilities. Each representative organization was given the chance to provide peer review input on the review drafts. In effect, these representatives were intended to be the interfaces to their respective organizations to ensure a large body of input into the development of the document.

Table 2-1 SHC-AEDG Project Committee Member Chart

Member	PC Function
Shanti Pless	Chairman
Merle McBride	Vice-Chairman
Don Colliver	SC Liaison
Walt Vernon	USGBC Representative
John Gill	IESNA Representative
Tom Myers	IESNA Representative
Bernard Cole	AIA Representative
Jeff Boldt	ASHRAE Representative
John Murphy	ASHRAE HVAC Representative
Dennis Wessel	ASHRAE Technical Committee on Healthcare Buildings Representative
Michael Meteyer	Member at Large
Bruce Hunn	ASHRAE Staff Liaison
Lilas Pratt	ASHRAE Staff Liaison
Ian Doebber	Model Support (nonvoting consultant)
Eric Bonnema	Model Support(nonvoting consultant)

2.5 Development Schedule and Process

Following the guidance from the SC, the SP-127 committee developed a one-year plan for completing the document. Key milestones were determined based on a final publication date in December 2009 (ready for the ASHRAE Winter Meeting in January 2010). The PC determined the time needed for the publication process and then determined the dates of review periods for the various completion stages for the draft document. The PC used a schedule similar to those developed for the previous guides to plan for two peer review periods that corresponded with a 65% completion draft (technical refinement review) and a 90% completion draft (final review for errors). A focus group reviewed the conceptual draft. Six PC meetings were held at ASHRAE Headquarters, at NREL, or at the office of a PC member. Three conference calls were also held. The schedule shown Table 2-2 outlines key dates in the development of the SHC-AEDG.

Table 2-2 SHC-AEDG PC Development Schedule

Date	Event	Description
September 4–5, 2008	Kick-off/PC meeting #1	Kick-off introduction meeting, first PC meeting
October 15, 2008	Conference call #1	Conference call to discuss concept draft
October 29–30, 2008	PC meeting #2	Discuss baseline modeling assumptions
December 10–11, 2008	PC meeting #3	Discuss progress of 65% draft
January 5, 2009	65% draft complete	65% draft complete
January 5–16, 2009	65% draft review	65% draft review
February 11–12, 2009	PC meeting #4	Review simulation results, address 65% review remarks
March 3, 2009	Conference Call #2	Review modeling results
April 27–28, 2009	PC meeting #5	Further develop 90% draft, finalize responses for 65% review remarks
May 11, 2009	90% draft complete	90% draft complete
May 11–29, 2009	90% draft review	90% draft review
June 4–5, 2009	PC meeting #6	Address 90% review remarks, finalize draft for 100%
July 8, 2009	Conference call #3	Finalize modeling results
August 21, 2009	SC approval	Steering committee approval
August 14, 2009	Final 100% document to publications	Final 100% document to publications
October 22, 2009	Document to printers	Document to printers
November 10, 2009	Printed document complete	Printed document complete

The development of the prototype, baseline, and low-energy models was an iterative process, with discussion of the model inputs and the current model results at every meeting and conference call. Results from the modeling, combined with input from the PC, led to the development of the final recommendations. The following steps show the modeling process used, from the initial prototype development to the final recommendations:

- Determine prototype models inputs from the PC, ASHRAE 90.1-1999 (ASHRAE 1999), ASHRAE 62 (ASHRAE 2001), and AIA 2006.
- Present preliminary baseline results for the prototype surgery center.
- Develop a consensus from the PC on the prototype model inputs.
- Develop initial recommendations and the corresponding low-energy models, including daylighting types, HVAC systems, and envelope recommendations.
- Present the low-energy modeling results and identify recommendations that do not result in 30% energy savings.
- Fine tune the recommendations to achieve at least 30% whole-building energy savings in all climate zones for the various HVAC options and building types.
- Determine final recommendations for the SHC-AEDG that achieve 30% savings.

The following sections of this TSD present the prototype development results from Step 3, the baseline model results from Step 4, and the final recommendations and energy savings results as determined in Step 8.

Because the document was developed under the ASHRAE special project procedures, and not the standards development procedures, the peer reviews were not considered true “public” reviews. However, review copies were made available to all partner organizations, and to the various bodies within ASHRAE represented by the PC membership. Interested members may download review copies from the ASHRAE Web site (www.ashrae.org). The responses to the remarks and suggestions received from the 65% review draft are summarized in Appendix B.

Further information about each meeting and conference call are included in the meeting agendas and conference call agendas (see Appendix A). These agendas were updated after each meeting or call to reflect the discussions and length of time spent on each item. After each conference call and meeting, the meeting notes, agenda, action items, future schedules, and other related documents were compiled into a meeting report. These were very useful for reference and organizational purposes during the development of the Guide.

2.6 Focus Group

To evaluate the concept of the SHC-AEDG, ASHRAE convened a focus group (see Table 2-3) of small healthcare facility administrators, designers, and energy management staff to review the conceptual draft. The focus group was brought to ASHRAE headquarters to discuss the concept of the SHC-AEDG.

Table 2-3 SHC-AEDG Focus Group Participants

Member	Organization
Michael Harris	Burrell Group
Tim Dudte	Health Facilities Group
Ted Blosser	Midwest Engineering Inc.
Jeff Blackwood	Healthsouth
Wayne Carr	Surgical Care Affiliates
David Lennon	Nash Lipsey Burch, LLC

Before the meeting, the participants reviewed the concept draft, the scoping document, and examples of the recommendation tables and case studies from the previous guides. The questions asked of the focus group to stimulate discussion and solicit feedback are shown in Appendix A.4. The highlights of the focus group feedback are shown below.

- Consider first cost compared to life cycle cost (need to make the business case)
- Provide a more detailed list of facility types the Guide does and does not cover
- Address different audiences: profit versus nonprofit, ownership model variation
- Refine message to healthcare providers (hospital board members, doctors, chief financial officers)
    - Must reach doctors
    - Want to appeal to the health ethic (improvement in care, specifically “patient days”)
- Keep it simple: Simple, passive systems should be first focus, rather than mechanical or control systems that require additional maintenance
- Reduce design time to evaluate the options—the Guide’s prescriptive nature would help with that
- Provide some guidance on the life cycle analysis
- Commissioning is very important, at least at startup
- Mixed reaction to daylighting
- Would like to have these recommendations be required by code or have incentives built into the funding and reimbursement systems for hospitals
- Would like to have case studies in their geographical areas

- Technology case studies are a great idea
    - Need to show what is doable in their area
    - Need to show energy numbers, metrics, and use
    - Want to see the economics (even percentages or orders of magnitude)
    - Architects felt case studies would be helpful in selling the idea of energy efficiency.

In developing the SHC-AEDG, the PC attempted to include the results from the focus group by:

- Including time for discussion by the decision makers such as hospital board members and doctors
- Focusing on simpler systems
- Emphasizing operations and maintenance
- Addressing plug loads
- Addressing specialty spaces
- Providing a wider range of daylighting and HVAC recommendations
- Providing case studies with at least two years of measured energy performance as well as examples of cost-effective implementation of the Guide's recommendations.

3. Evaluation Approach

This chapter describes the analysis methods used to support development of the SHC-AEDG. It presents how 30% energy savings were quantified, how prototype models were developed, and how the prototype models were converted into baseline and low-energy models.

3.1 Determining 30% Savings

The purpose of the building energy simulation analysis is to assess and quantify the energy savings potential of the Guide's final recommendations. The AEDGs contain a set of energy efficiency recommendations for eight U.S. climate zones. To provide prescriptive 30% recommendations, a specific quantitative energy savings goal must be measured against a specific version of Standard 90.1. For the SHC-AEDG, this is 90.1-1999, the "turn of the millennium" standard (ASHRAE 1999). The energy savings of the prescriptive recommendations were also examined relative to ASHRAE 90.1-2004 (ASHRAE 2004).

The following steps were used to determine 30% savings:

- Develop "typical" small healthcare facility prototype characteristics.
- Create baseline models from the prototypes that are minimally code compliant for ASHRAE 90.1-1999 and ASHRAE 90.1-2004.
- Create the low-energy models based on the recommended energy-efficient technologies in the Guide.
- Verify 30% energy savings for the various HVAC system types across the 15 U.S. climate zones and subzones.

These steps are presented in a linear fashion but include some iteration. For example, certain baseline model inputs were determined by features included in the low-energy models, such as glass and skylight areas.

The flowchart in Figure 3-1 presents a visual representation of the evaluation approach.

3.1.1 Site Energy Use

The 30% energy savings goal of the AEDG series is based on site energy savings between a minimally code-compliant small healthcare facility and a low-energy small healthcare facility that uses the recommendations in the Guide. Other metrics, such as energy cost savings, source energy savings, or carbon savings, could be used as alternative reference values for energy savings comparisons and accountability (Torcellini et al. 2006). Each metric has advantages and disadvantages from an implementation and calculation perspective, and each can favor different technologies and fuel types. The SHC-AEDG uses site energy savings, as directed by the SC, for the sake of consistency with the previous AEDGs.

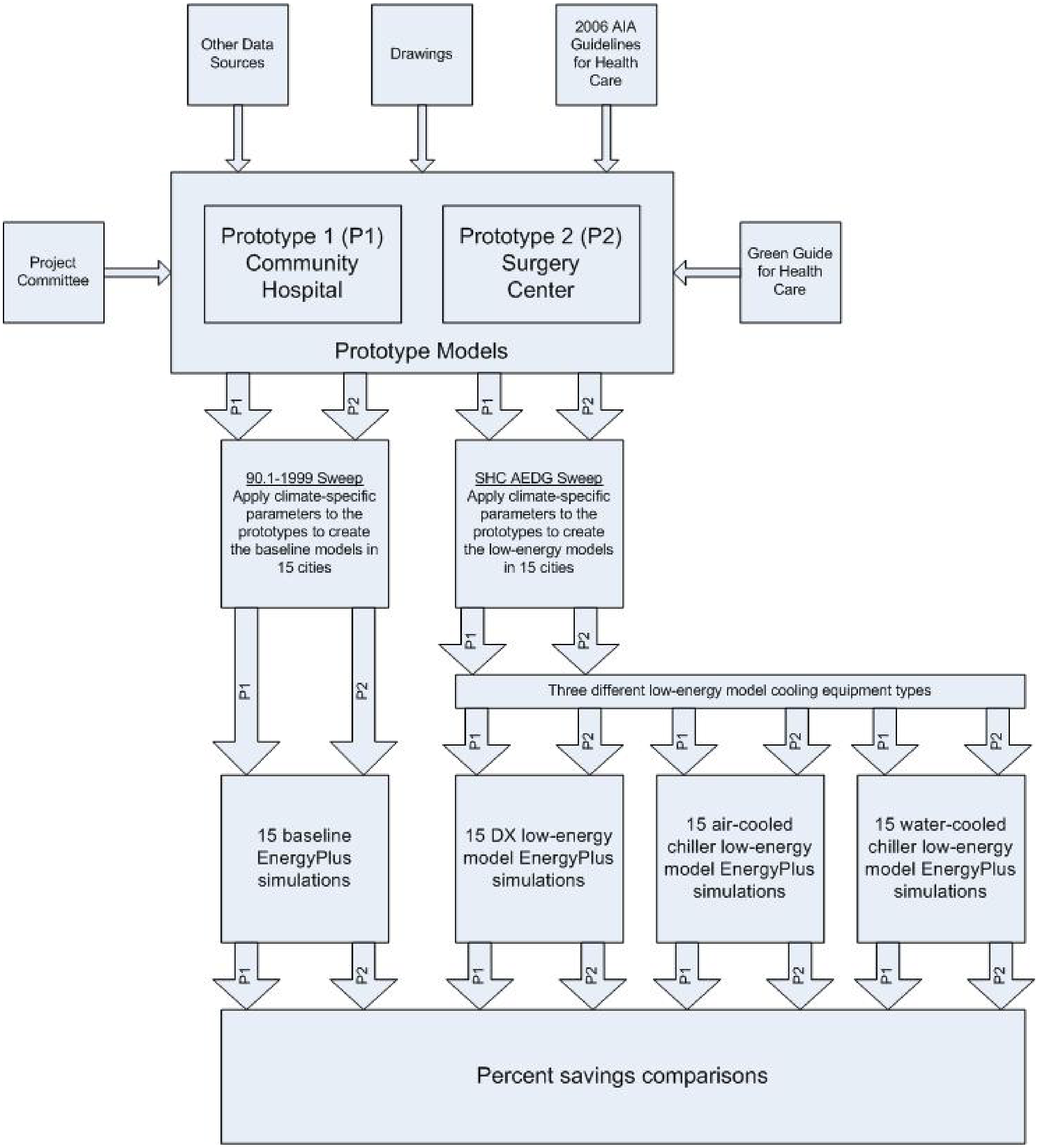

Figure 3-1 Evaluation approach flowchart

3.1.2 Whole-Building Energy Savings

Historically, energy savings have been expressed in two ways: energy savings of regulated loads and energy savings of the whole building. The regulated loads energy savings indicate the savings when the unregulated loads are not included in the total loads. These typically include plug and some process loads. The whole-building energy savings indicate the savings when all the loads (regulated and unregulated) are included in the energy savings calculations. In general, for the same level of percent savings, whole-building savings are more challenging than regulated loads savings. In LEED 2.1 (USGBC 2006), plug loads are included in the required energy simulation (to capture proper heat loads), but not in the denominator of the energy savings calculation. In the case of Appendix G in ASHRAE 90.1-2004 (ASHRAE 2004b) and in LEED 2.2 (USGBC 2006), plug loads are included in the denominator, i.e., the whole-building method, which includes the unregulated loads for calculating energy savings. The SHC-AEDG uses the whole-building method for determining 30% energy savings. (See Appendix E for more information about determining the plug loads for small healthcare facilities.)

3.1.3 ASHRAE Baseline

The SHC-AEDG was written to help owners and designers of small hospitals and healthcare facilities achieve energy savings of at least 30% compared to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999 (ASHRAE 1999), which serves as a baseline. The baseline level energy use was set for buildings built at the turn of the millennium, which are assumed to be based on Standard 90.1-1999. The selection of this standard for the baseline was also based on the fact that it was the most recent standard for which DOE had issued a formal determination of energy savings at the time the first AEDG was prepared.

The use of ASHRAE 90.1-1999 as a baseline for determining 30% energy savings for the SHC-AEDG is also consistent with other AEDGs (Jarnagin et al. 2006; Liu et al. 2006). There has been considerable discussion between the SC and the SHC-AEDG PC about having the energy savings based on a percentage below a specific version of 90.1 (1999, 2001, 2004, 2007, etc.). The SC realized that a moving baseline would result if designers were always attempting to use the most current version of the standard. This would cause considerable confusion in the marketplace because recommendations would always be changing based on which version of 90.1 was being used. Two very similar buildings could have different recommendations, solely because different baselines were being used. Therefore, the SC decided to look at the other end of the scale and describe the energy savings as the progress toward a net-zero energy building. The top end of the scale, or 0% progress, would be set as the energy used by a structure built to the energy standards at the turn of the millennium (90.1-1999). The bottom end of the scale, or 100%, is the net-zero energy building.

For our analysis, the recommendations needed to achieve 30% savings over ASHRAE 90.1-2004 have been determined as well. Recommendation tables and energy savings are provided for 30% savings over 90.1-1999 and 90.1-2004.

3.1.4 Modeling Methods

3.1.4.1 EnergyPlus

EnergyPlus Version 3.1 (DOE 2009) was used to complete the energy simulations. It was selected because it is the contemporary DOE tool that accounts for the complicated interactions between climate, internal gains, building form and fabric, HVAC systems, and renewable energy systems. The simulations are run with EnergyPlus Version 3.1 compiled to run on a 64-bit Linux cluster supercomputer at NREL. EnergyPlus is a heavily tested program with formal BESTEST validation efforts repeated for every release (Judkoff and Neymark 1995). All simulations were completed with the NREL analysis platform (called Opt-E-Plus) that manages inputs and outputs of the EnergyPlus simulations. Its core functionality is the user's ability to pass high-level parameters of the building (building area, internal gains per zone, HVAC system configuration, etc.) to generate a fully parameterized input file for EnergyPlus. Such files are generated rapidly and can be easily changed to incorporate changes during the evolution of the model. The high-level parameter file is a structured text file written in Extensible Markup. Modifying the high-level parameters is preferred over modifying the EnergyPlus input file because it greatly simplifies the modeling input development process. Modifying EnergyPlus input files can be time intensive when the high-level parameters have a one-to-many relationship with the input objects in the low-level input file.

3.1.4.2 Simulation Details

3.1.4.2.1 Advanced Energy Design Guide Simulations

The AEDG simulations are used to evaluate the Guide recommendations. There are one baseline and three low-energy (three HVAC system types) models for each prototype (surgery center and community hospital) for a total of eight separate seed (starting point) energy models. The Opt-E-Plus software then takes these eight seed models and "sweeps" them across the 15 cities representing all the climate zones in the United States. The Opt-E-Plus "sweep" takes the seed energy model files and creates 15 separate energy models while applying climate zone specific details such as weather data, utility rates, economizer use, and building envelope specifications from ASHRAE 90.1 (for the baseline model) or the AEDG (for the low-energy models). This results in 120 energy models for the AEDG simulations.

3.1.4.2.2 Bundled Energy Efficiency Measure Analysis

NREL researchers performed the bundled EEM analysis to better understand how each EEM from the AEDG affected energy performance. In the AEDG simulations, all AEDG EEMs are applied in a single operation; in the bundled EEM analysis, the AEDG EEMs are applied incrementally (and aggregately) to investigate how individual measures affect energy performance. (See Section 8.4 for more details about the bundled EEM analysis.) This analysis used the same "sweep" in Opt-E-Plus to apply climate zone-specific information, but it was performed for six steps in which individual AEDG EEMs were applied to the model. This analysis was performed for the surgery center and community hospital in the 15 cities representing all the U.S. climate zones, resulting in 180 energy models for the bundled EEM analysis.

3.1.4.2.3 Managing Simulations

Between the two separate analyses performed for the AEDG, 300 energy models required processing through the EnergyPlus engine. The 150 surgery center models averaged approximately 3 hours per simulation for a total of 450 simulation hours. The 150 community hospital models averaged about 5 hours per simulations for a total of 750 simulations hours. The prototypes together resulted in approximately 1200 simulation hours, equivalent to 50 days.

The development of the AEDG recommendations was an iterative process, and often modeling results were used to gauge the performance of a specific recommendation. To process all the simulations in a reasonable time, a Linux supercomputer (distributed computing) was used. Opt-E-Plus has a built-in run manager that was used create simulation queues and to submit simulations for processing to the supercomputer. For these simulations, 18, 8-core processors (for a total of 144) were dedicated to this project. Using the supercomputer allowed the simulations to be completed in about 12 hours. The increase was attributed to the overhead computing power needed to manage the simulations. The Linux supercomputer was essential to completing the AEDG in the required timeframe.

3.1.4.3 Climate Zones

The AEDGs contain a unique set of energy efficiency recommendations for a range of climate zones. The six AEDGs developed to date have standardized climate zones that the International Energy Conservation Code and ASHRAE have adopted for residential and commercial applications. The common set includes eight zones covering the entire United States (see Figure 3-2). Climate zones are categorized by heating degree days and cooling degree days, and range from the very hot zone 1 to the very cold zone 8. Some climate zones are divided into subzones based on humidity levels. Humid subzones are "A" zones, dry subzones are "B" zones, and marine subzones are "C" zones. These climate zones may be mapped to other climate locations for international use (ASHRAE 2004b).

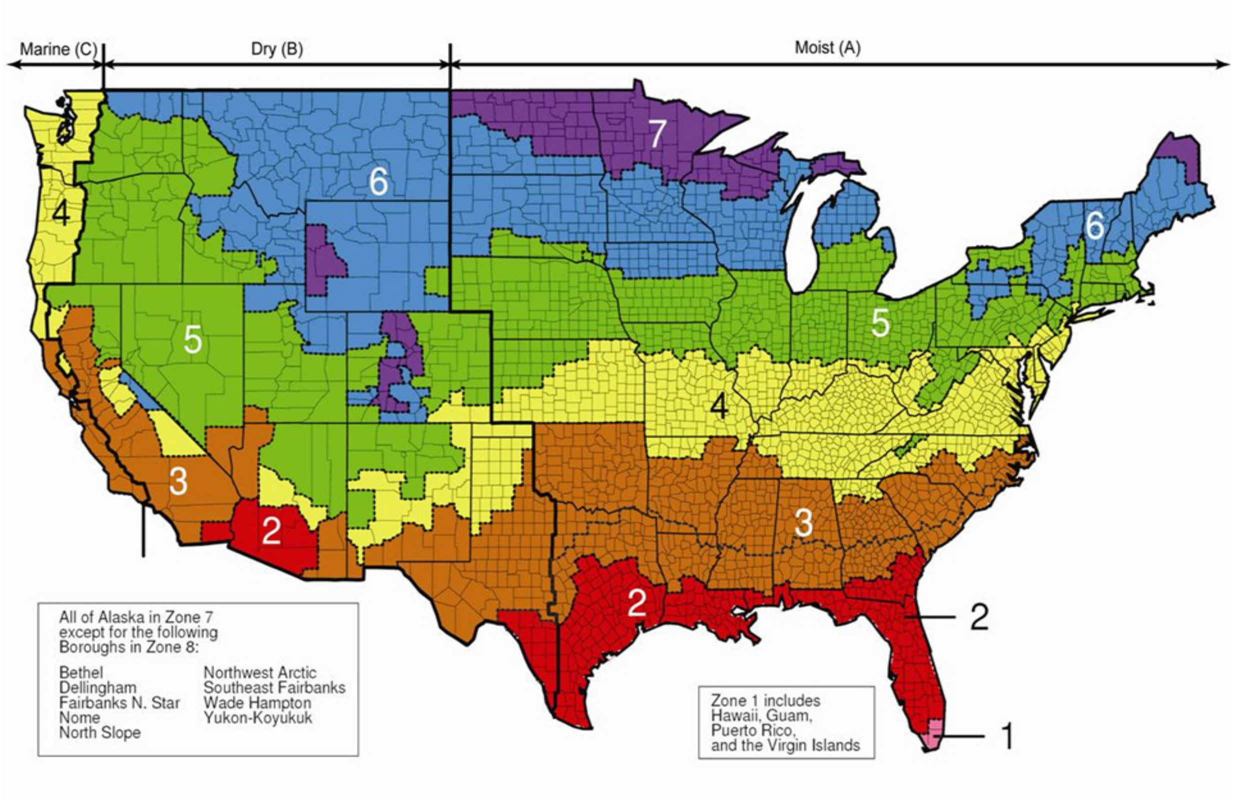

Figure 3-2 DOE climate zones and representative cities
(Credit: American Society of Heating, Refrigerating and Air-Conditioning Engineers)

When the climate zones were being developed, 15 specific climate locations (cities) were selected as being most representative of each (see Figure 3-2 and the following list). To determine energy savings, weather files for each zone were used to simulate the baseline and low-energy models.

- Zone 1: Miami, Florida (hot, humid)
- Zone 2A: Houston, Texas (hot, humid)
- Zone 2B: Phoenix, Arizona (hot, dry)
- Zone 3A: Memphis, Tennessee (hot, humid)
- Zone 3B: El Paso, Texas (hot, dry)
- Zone 3C: San Francisco, California (marine)
- Zone 4A: Baltimore, Maryland (mild, humid)
- Zone 4B: Albuquerque, New Mexico (mild, dry)
- Zone 4C: Seattle, Washington (marine)
- Zone 5A: Chicago, Illinois (cold, humid)
- Zone 5B: Boise, Idaho (cold, dry)
- Zone 6A: Burlington, Vermont (cold, humid)
- Zone 6B: Helena, Montana (cold, dry)
- Zone 7: Duluth, Minnesota (very cold)
- Zone 8: Fairbanks, Alaska (extremely cold).

4. Prototype Model Development Assumptions

Similar to other principal commercial building types, there are not many datasets of small healthcare facility characteristics and performance data, so the PC provided complete drawings for two small healthcare buildings—a small community hospital and a surgery center. These drawings were used to develop the prototype model geometry, space layouts, space types, and sizes. The space types that are in the prototype models are shown in Table 4-1.

Table 4-1 SHC-AEDG Prototype Designs Space Types

Space Types	Community Hospital	Surgery Center
Emergency room	X	
Postanesthesia care unit/recovery	X	X
Exam/treatment	X	X
Nurse station	X	X
Pharmacy	X	X
Patient room	X	
Operating room	X	X
Nursery	X	
Staff work/supply	X	X
Physical therapy	X	X
Radiology/imaging	X	X
Laundry		
Office/administration	X	X
Conference	X	X
Lobby	X	X
Lounge/waiting	X	X
Dining	X	
Food preparation	X	
Corridors/stairs	X	X
Storage	X	X

4.1 Prototype Model Summary

This section summarizes how the data for the surgery center and the community hospital were used to formulate the prototype models for the SHC-AEDG. For facility characteristics that are not specified by ASHRAE 90.1-1999, ASHRAE 90.1-2004, ASHRAE 62.1-2004, or AIA (2006), but that are necessary to develop code compliant baseline and low-energy models, we tried to document "typical" small healthcare facility practices, characteristics, and features to formulate the prototype SHC-AEDG models.

The first characteristic to establish was the facility type. Based on input from the PC, we determined that there was enough physical and operational variation over community hospitals and surgery centers to develop different prototypes for each. The actual SHC-AEDG model sizes, along with additional inputs and SHC-AEDG characteristics, are shown in Table 4-2.

Table 4-2 SHC-AEDG Prototype Characteristics

	Building Characteristic	Community Hospital Prototype	Surgery Center Prototype
Form and Fabric	**Size**	65,000-ft^2 community hospital	41,000-ft^2 surgery center
	Number of floors	1	3
	Number of occupants	675	414
	Space types	See Table 4-1	See Table 4-1
	Constructions	Steel-frame walls, insulation entirely above deck roof	Steel-frame walls, insulation entirely above deck roof
	Window area	26%	20%
Operations	**Occupancy**	Fully occupied during the day, partially occupied at night	Fully occupied during the day, vacant at night
	Peak plug loads	2.1 W/ft^2	1.8 W/ft^2
	Percent conditioned	Fully heated and cooled	Fully heated and cooled
HVAC	**System types**	Baseline: PVAV* with DX** cooling Low energy: PVAV with DX cooling, air-cooled chiller, and water-cooled chiller	Baseline: PVAV with DX cooling Low energy: PVAV with DX cooling, air-cooled chiller, and water-cooled chiller

* PVAV = package multizone DX rooftop unit with variable air volume
** DX = direct expansion

4.2 Prototype Space Type Sizes and Layout

The drawings for a community hospital and surgery center were used to develop the prototype floor plans and space layouts. In general, the community hospital is divided into quadrants as follows:

- Quadrant 1 contains critical care spaces such as operating rooms and radiology imaging centers.
- Quadrant 2 contains office spaces and examination rooms.
- Quadrant 3 contains patient rooms and nurse staff areas.
- Quadrant 4 contains mechanical rooms and storage spaces.

The first floor of the surgery center contains the critical care areas such as operating and recovery rooms; the second and third floors contain examination rooms, office spaces, and physical therapy areas. Total space sizes of the prototype models are shown in Table 4-3. The floor plans for the community hospital and surgery center prototypes are shown in Figure 4-1 through Figure 4-7.

Table 4-3 Total Space Sizes Included in the AEDG Prototype

Space Type	Community Hospital		Surgery Center	
	Total Size (ft^2)	% of Total	Total Size (ft^2)	% of Total
Anesthesia	72	0.1%	108	0.3%
Clean	1,354	2.1%	291	0.7%
Conference	1,137	1.8%	336	0.8%
Corridor	9,838	15.3%	8,475	20.7%
Dining	736	1.1%	420	1.0%
Examination room	3,669	5.7%	4,213	10.3%
Food preparation center	1,480	2.3%	0	0.0%
Laboratory	1,344	2.1%	0	0.0%
Lounge	1,494	2.3%	1,979	4.8%
Nurse station	2,422	3.8%	773	1.9%
Nursery	165	0.3%	0	0.0%
Office	11,799	18.3%	7,685	18.8%
Operating room	2,520	3.9%	1,416	3.5%
Patient corridor	2,752	4.3%	0	0.0%
Patient room	6,012	9.3%	527	1.3%
Physical therapy	1,584	2.5%	1,892	4.6%
Procedure room	656	1.0%	285	0.7%
Radiology	1,018	1.6%	1,508	3.7%
Reception area	2,380	3.7%	2,115	5.2%
Recovery room	1,440	2.2%	948	2.3%
Soiled	1,052	1.6%	362	0.9%
Storage	3,153	4.9%	6,284	15.3%
Toilet room	3,133	4.9%	790	1.9%
Trauma room	280	0.4%	0	0.0%
Triage	180	0.3%	0	0.0%
Utility	2,656	4.1%	539	1.3%

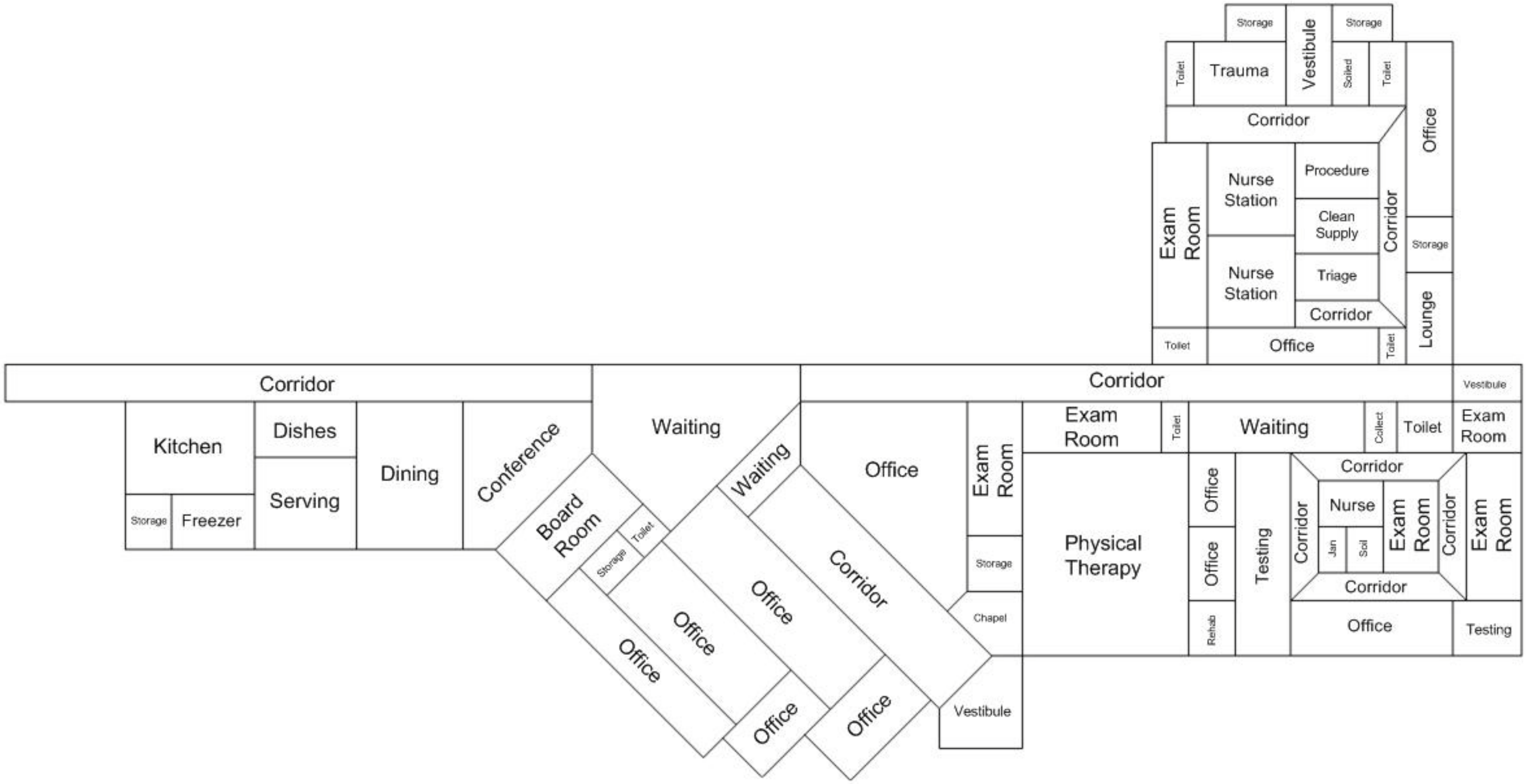

Figure 4-1 Community hospital prototype quadrant 1 layout

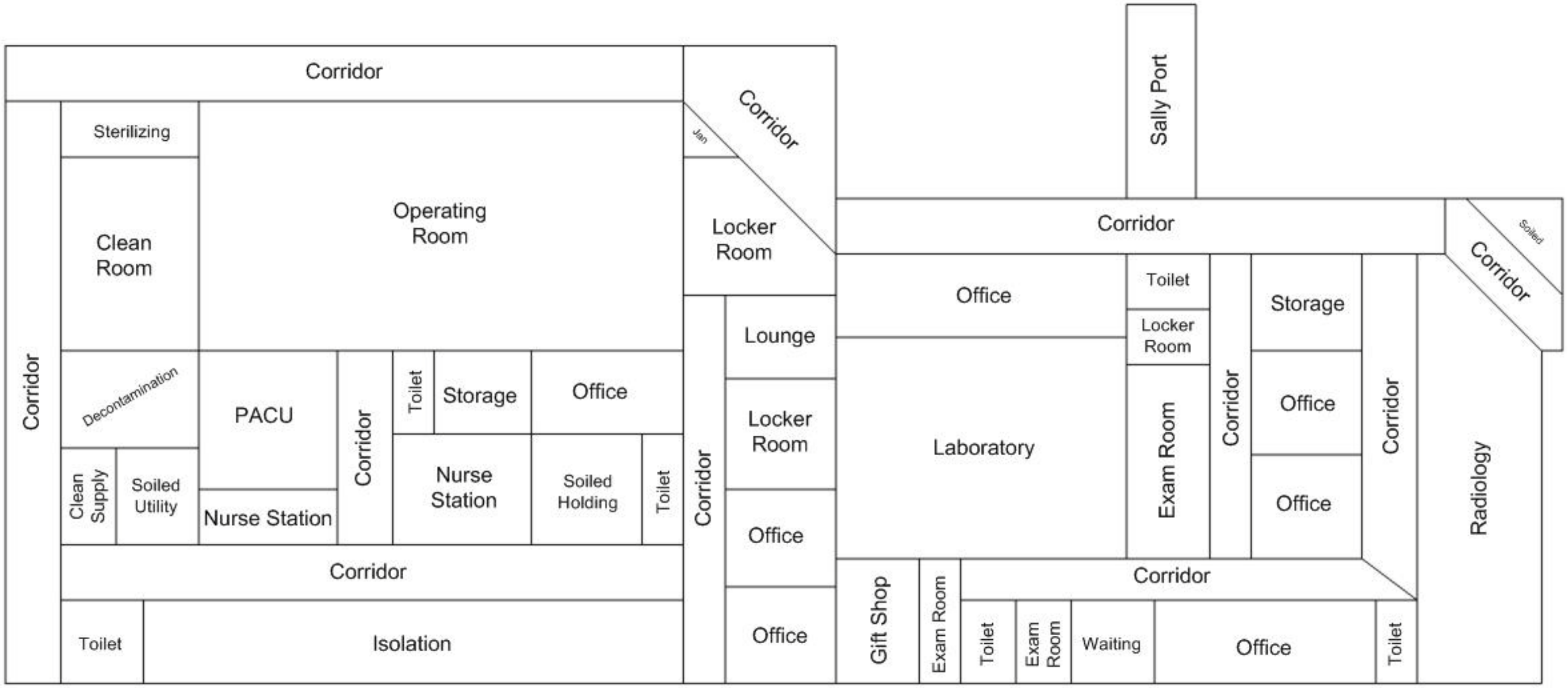

Figure 4-2 **Community hospital prototype quadrant 2 layout**

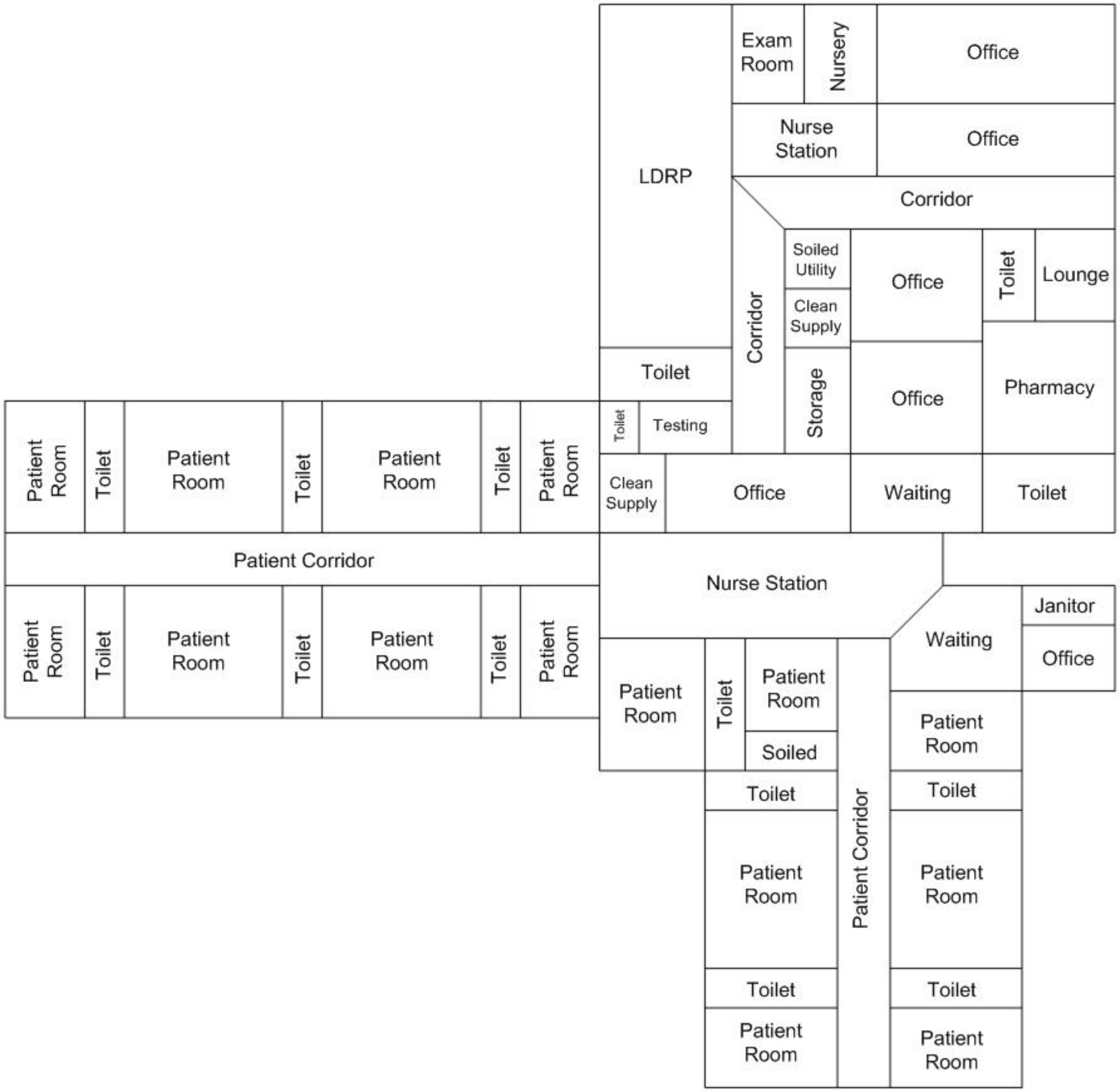

Figure 4-3 Community hospital prototype quadrant 3 layout

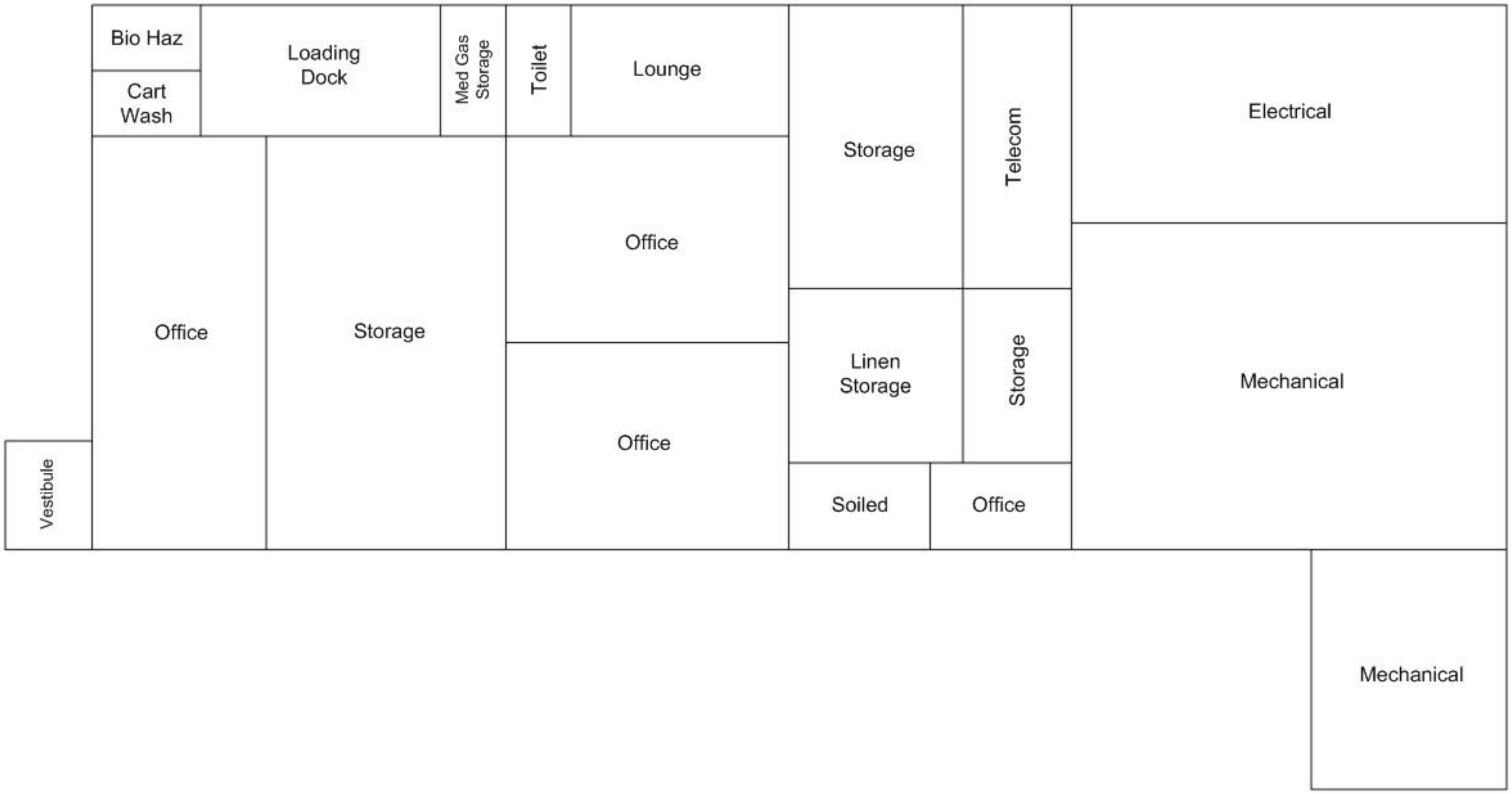

Figure 4-4 Community hospital prototype quadrant 4 layout

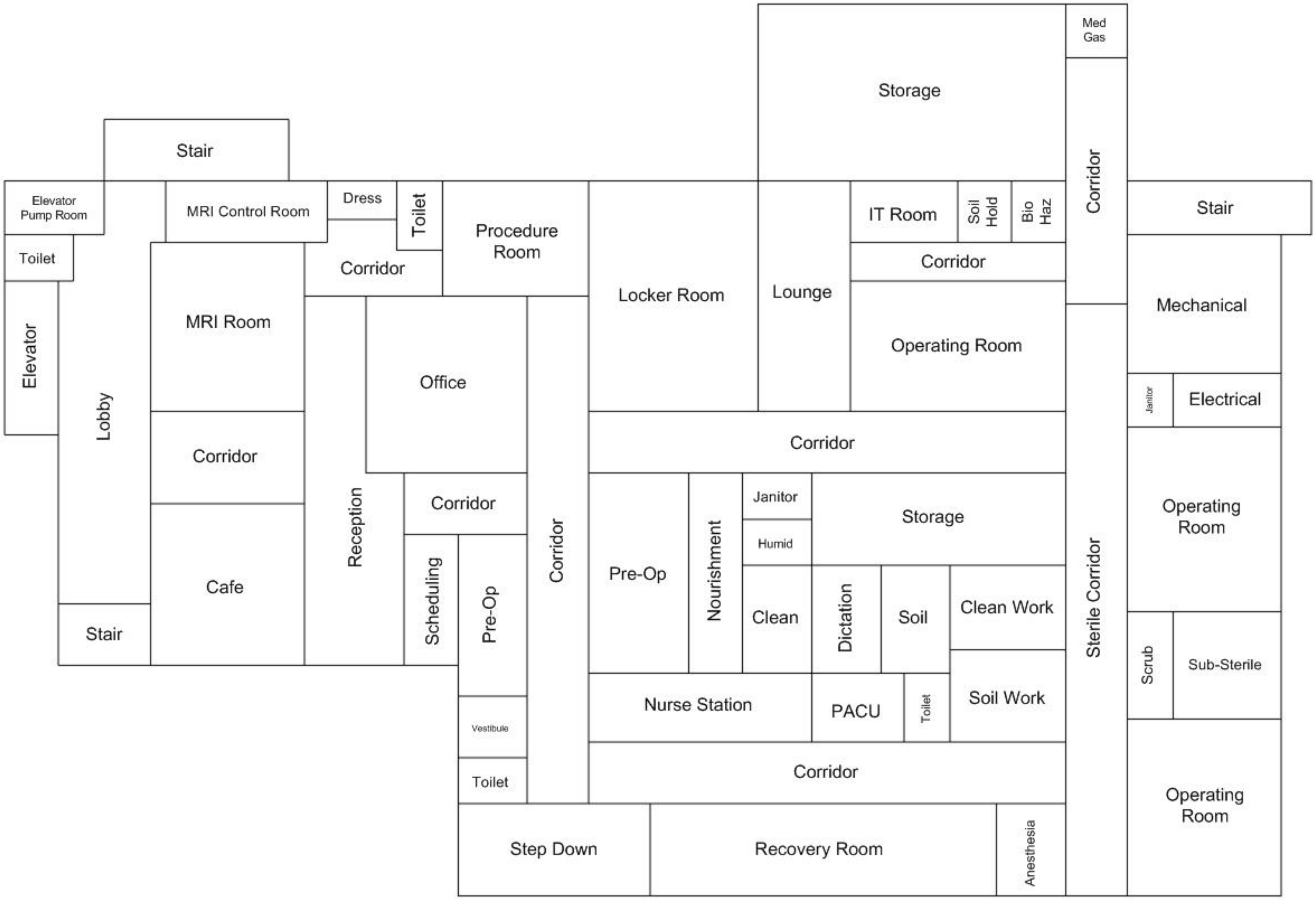

Figure 4-5 Surgery center prototype floor 1 layout

Figure 4-6 Surgery center prototype floor 2 layout

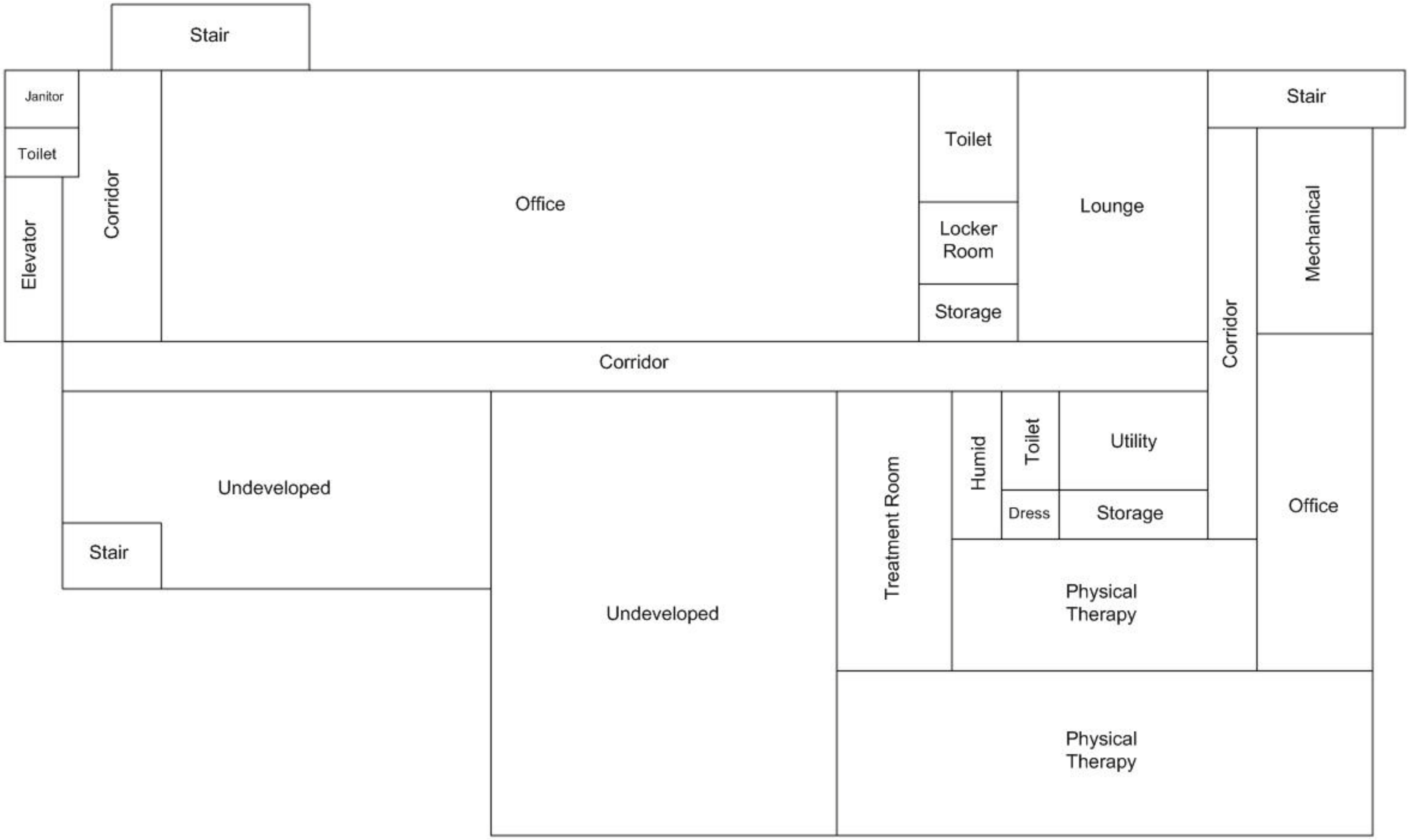

Figure 4-7 Surgery center prototype floor 3 layout

5. Model Details

This section contains a topic-by-topic description of the EnergyPlus model inputs for the baseline and low-energy building models. These inputs include the building form and floor plate; envelope characteristics; building internal loads and operating schedules; ventilation rates and schedules; HVAC equipment efficiency, operation, control, and sizing; fan power assumptions; and SWH.

5.1 Model Development and Assumptions

5.1.1 Baseline Model

The criteria in ASHRAE 90.1-1999 and ASHRAE 62-2004 were used for the baselines to calculate 30% savings for the SHC-AEDG recommendations. For the baselines needed to verify 30% savings for our DOE analysis, the SHC-AEDG baselines were updated to be minimally code compliant with ASHRAE 90.1-2004. The ASHRAE 90.1-1999 community hospital baseline inputs are summarized in a table in Appendix C and the surgery center ASHRAE 90.1-1999 baseline input tables are summarized in Appendix D.

5.1.2 Low-Energy Model

The final recommendations were determined based on an iterative process using the PC's expertise and results from modeling the recommendations. To quantify the potential energy savings from the final recommended EEMs in the Guide, the energy efficiency technologies listed below were implemented to simulate the low-energy building models. This section contains a topic-by-topic description of the low-energy building models and how the recommended EEMs were implemented into the low-energy modeling. The EEMs included in the 30% saving calculation are:

- Enhanced building opaque envelope insulation
- High-performance window glazing with overhangs
- Reduced lighting power density (LPD) and occupancy controls
- Daylighting in common areas (corridor, reception, dining) and permanently occupied staff areas (offices, nurse stations, exam rooms)
- Lower pressure ductwork design and higher efficiency fans
- Higher efficiency HVAC equipment
- High-efficiency SWH.

Plug load reductions are not credited to the calculated 30% energy savings, as these energy efficiency opportunities are not part of the prescriptive recommendations. They do, however, form a prominent part of the additional savings section.

5.1.3 Developing the Low-Energy Recommendations

The PC used the following guiding principles to develop the final recommendation for the SHC-AEDG:

- Provide recommendations that represent responsible small healthcare design practices. If a recommendation generally represents good design practice, it is recommended for all climate zones, even if the resulting savings exceed 30%.

- Use off-the-shelf technologies that are available from multiple sources. The PC did not recommend technologies or techniques that are one of a kind or available from a single manufacturer.
- Provide recommendations that are at least as stringent as those in the forthcoming ASHRAE 90.1-2010. We did not want our recommendations to be less stringent than the most recent version of ASHRAE 90.1.
- Use the recommendations from the previous K-12 schools AEDG as a starting point for fine tuning the SHC-AEDG recommendations. Develop recommendations to address the focus group's concerns about usability, operations and maintenance, simplicity, and flexibility.
- Verify 30% energy savings for the recommendations that represent the most typical small healthcare facility components, or for the components that are the least likely to result in 30% savings.

5.2 Form and Floor Plate

5.2.1 Baseline Model

The prototype characteristics as documented in the previous section, combined with modeling assumptions, were used to generate the baseline models form and floor plate. The PC scrutinized the following form and floor plate modeling assumptions (see Table 5-1) to verify they were typical characteristics for small hospitals and healthcare facilities. The fenestration was equally applied over all exterior walls. No overhangs were included in the baseline model and no plenums were modeled.

Table 5-1 Selected Baseline Modeling Assumptions

Model Parameters	Value	
	Community Hospital	Surgery Center
Ceiling height	9 ft	10 ft
Fraction of fenestration to gross wall area	26%	20%
Glazing sill height	4 ft	4 ft

Renderings of the community hospital and surgery center baseline models are shown in Figure 5-1 and Figure 5-2, respectively. Each shows an isometric view from the southwest.

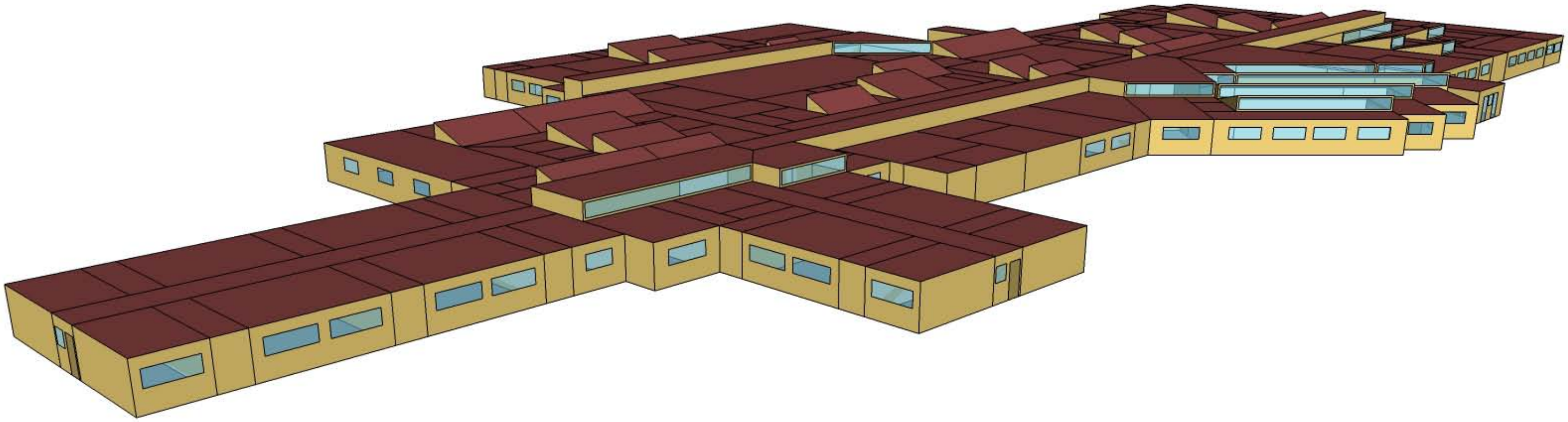

Figure 5-1 Community hospital baseline model rendering: View from southwest
Credit: Eric Bonnema/NREL

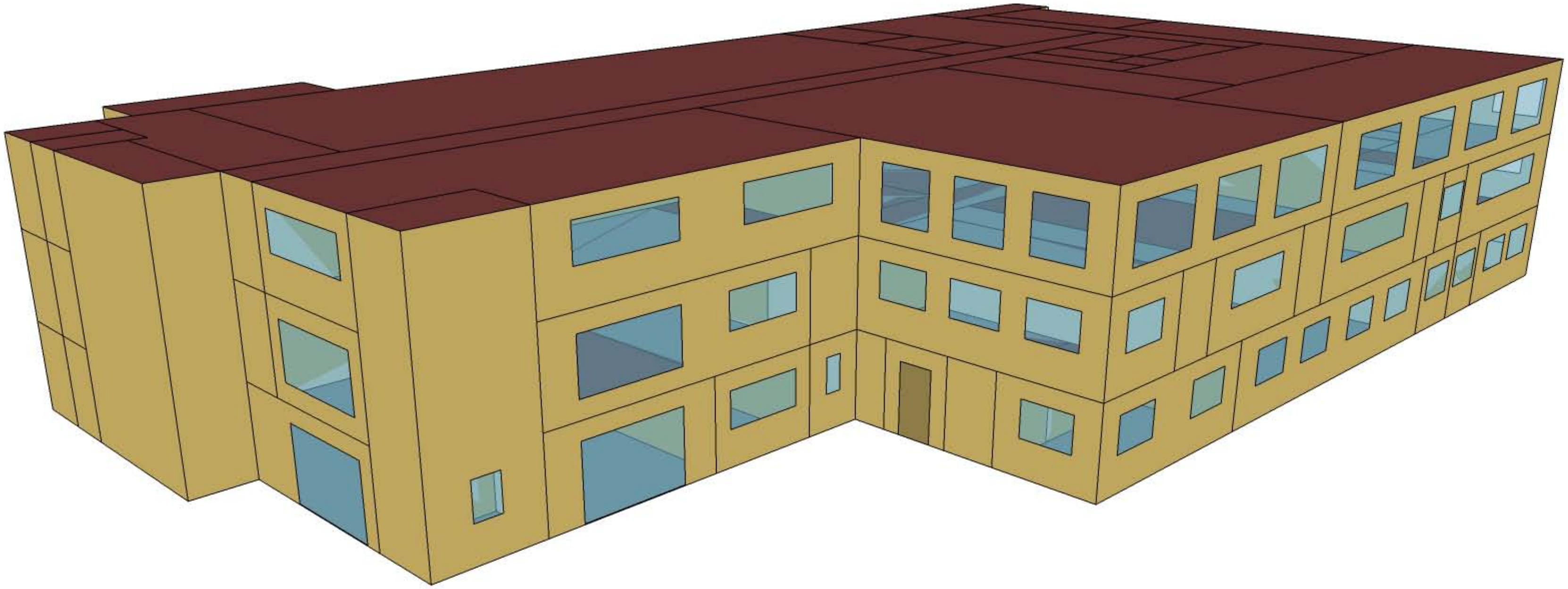

Figure 5-2 Surgery center baseline model rendering: View from southwest
Credit: Eric Bonnema/NREL

5.2.2 Low-Energy Model

The low-energy building models had conditioned floor area and exterior dimensions and orientations that were identical to those of the baseline buildings, except for the following components:

5.2.2.1 Overhangs

The Guide recommends overhangs with a projection factor of 0.5 on south-facing windows and clerestories in all climate zones. Therefore, low-energy models included fixed shading by assuming that the overhang starts just above the window and extends out from the façade half the window height to provide the projection factor of 0.5.

5.2.2.2 Skylights and Clerestories

The Guide recommends a 3% roof area maximum skylight distribution. Skylights were applied only in the surgery center prototype, as this part of the building is composed almost entirely of medical office building spaces. Skylights were not applied to the community hospital prototype. The PC felt skylights were not applicable to this type of building because of the potential direct solar beam radiation. Instead, clerestories were modeled in both the baseline and low-energy models to provide daylighting to certain spaces. These clerestories are visible in Figure 5-1 for the baseline model and Figure 5-3 for the low-energy model. The only difference between the clerestories in the baseline and low-energy models is that the low-energy models have overhangs (0.5 projection factor). The general approach to adding clerestory glass to the community hospital was to focus on adding north-facing clerestories to permanently occupied staff spaces (exam rooms, nurse stations, corridors, offices) and public spaces (waiting rooms, reception areas). South-facing clerestories were added when north-facing was not possible. The clerestory glazing is 3 ft (0.9 m) tall. Adding these clerestories results in approximately 22,550 ft^2 (2,095 m^2) of building area with clerestories, representing 35% of the total building area. Renderings of the community hospital and surgery center low-energy models (with overhangs in both and skylights in the surgery center) are shown in Figure 5-3 and Figure 5-4, respectively. Each shows an isometric view from the southwest.

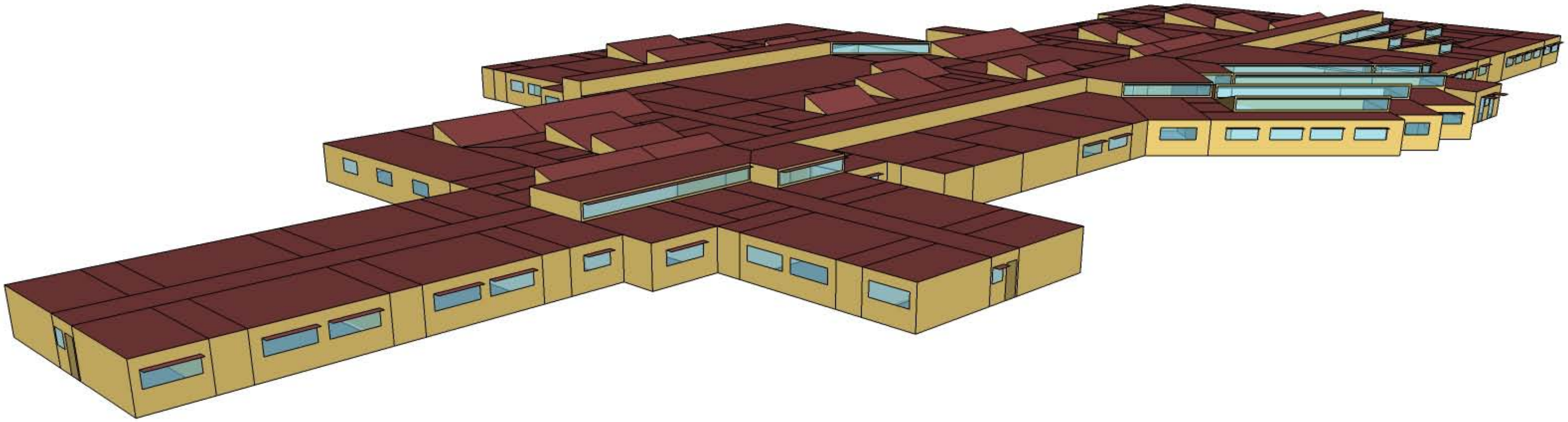

Figure 5-3 Community hospital low-energy model rendering: View from southwest
Credit: Eric Bonnema/NREL

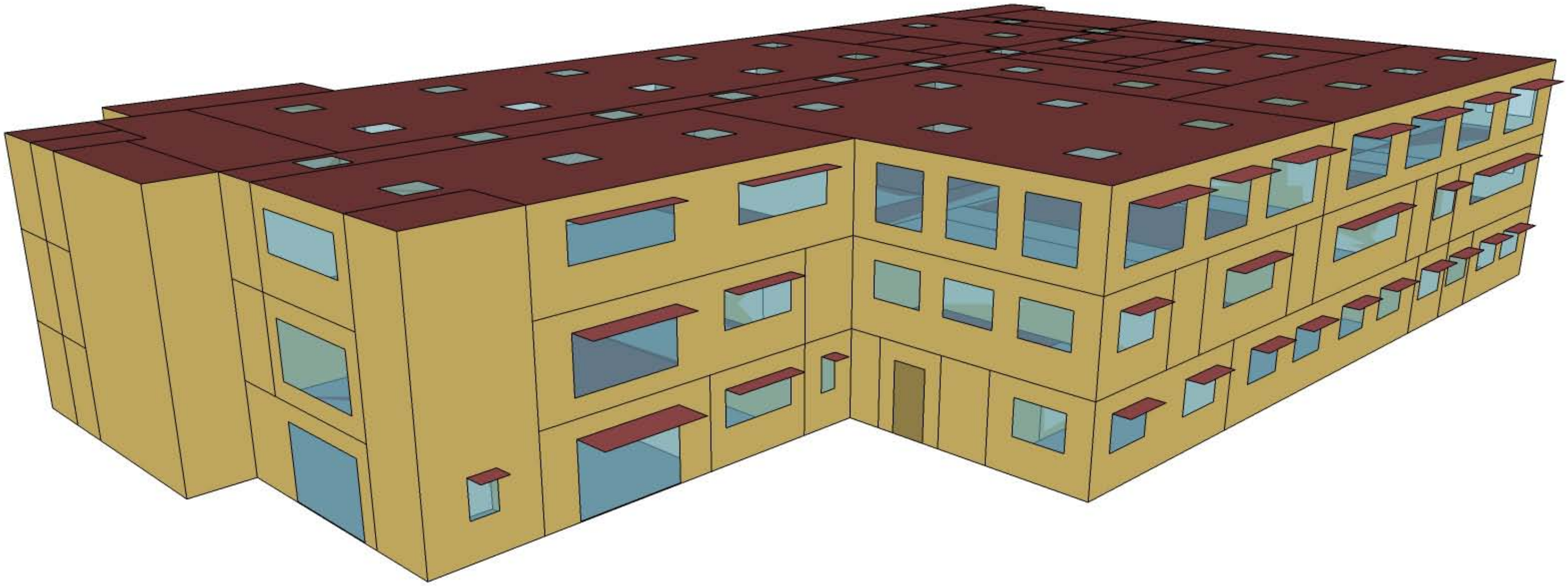

Figure 5-4 Surgery center low-energy model rendering: View from southwest
Credit: Eric Bonnema/NREL

5.3 Envelope

5.3.1 Baseline Model

The PC assumed, based on the experience of those in the small hospital and healthcare facilities construction industry, that these facilities are typically constructed with steel-framed exterior walls, built-up roofs, and slab-on-grade floors. These constructions represent common practices. There is some regional variation, but the PC felt that steel-framed walls and built-up roofs were the most common techniques.

The baseline small healthcare facility envelope characteristics were developed to meet the prescriptive design option requirements in accordance with ASHRAE 90.1-1999 Section 5.3. For the ASHRAE 90.1-2004 baselines, the prescriptive building envelope option in Section 5.5 was used. Layer-by-layer descriptions of the constructions of exterior surfaces were used to model the building thermal envelope in EnergyPlus.

5.3.2 Low-Energy Model

The low-energy building models had building envelope characteristics that were identical to those of the baseline buildings, except the exterior walls and roofs.

5.3.3 Exterior Walls and Roofs

5.3.3.1 Baseline Model

The baseline building exterior walls are modeled with steel-framed wall constructions. The layers consist of exterior sheathing, batt insulation between steel studs, and interior gypsum board. The U-factors of the insulation varied based on the applicable standard and were adjusted to account for the standard film coefficients. R-values for most of the layers were derived from Appendix A of ASHRAE 90.1-1999. Insulation R-values for continuous insulations were selected to meet the insulation minimum R-values required in Appendix B of ASHRAE 90.1-1999, as defined by climate range. The baseline exterior wall U-factors are in Appendix C and Appendix D of this report. Similar wall insulation values were modeled in the ASHRAE 90.1-2004 baselines, as the steel-framed wall requirements did not change appreciably from ASHRAE 90.1-1999 to ASHRAE 90.1-2004. The steel-framed wall layer details are as follows:

- Exterior air film (calculated by EnergyPlus)
- Nominally R-2 exterior sheathing
- Batt wall insulation (R-value varies by climate)
- 0.5-in. thick gypsum board
- Interior air film (calculated by EnergyPlus).

To calculate the thermal performance of the interior air films, the “detailed” algorithm in EnergyPlus for surface heat transfer film coefficients was used, and to calculate the thermal performance of the exterior air films, the “DOE-2” algorithm in EnergyPlus for surface heat transfer film coefficients was used. These are based on linearized radiation coefficients that are separate from the convection coefficients, as determined by surface roughness, wind speed, and terrain. However, standardized combined film coefficients are used to target assembly U-factors.

Built-up, rigid insulation above a structural metal deck roof was used in the baseline models. The layers consisted of the roof membrane, roof insulations, and metal decking. The U-factors varied based on the applicable standard and were adjusted to account for the standard film coefficients. Added insulation is continuous and uninterrupted by framing. Roof insulation R-values were also set to match the minimum roof insulation requirements in Appendix B of ASHRAE 90.1-1999, by climate. The baseline roof U-factors are in Appendix C and Appendix D. Similar roof insulation values were modeled in the ASHRAE 90.1-2004 baselines, as the insulation above deck roof requirements did not change significantly from ASHRAE 90.1-1999 to ASHRAE 90.1-2004.

Standard 90.1-1999 does not specify absorptance or other surface assumptions. The roof exterior finish was assumed to be a single-ply roof membrane with gray ethylene propylene diene terpolymer membrane in the baseline models. Therefore, a solar reflectance of 0.3, a thermal absorption of 0.9, and a visible absorption of 0.7 were assumed.

5.3.3.2 Low-Energy Model

The recommendations in the SHC-AEDG are all at least as stringent as the most recent version of ASHRAE 90.1 (ASHRAE 90.1-2010). (See Table 8-1 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 1–4 and Table 8-2 for the low-energy exterior wall and roof thermal characteristics.)

The SHC-AEDG recommends the use of high albedo roofs with a Solar Reflective Index (SRI) of 0.78 in climate zones 1 through 3. To model the high albedo roofs, we assumed the outer layer of the roof has a thermal absorption of 0.9, a solar reflectivity of 0.7, and a visible absorption of 0.3.

5.3.4 Slab-on-Grade Floors

5.3.4.1 Baseline Model

The baseline buildings were modeled with slab-on-grade floors. The layers consist of carpet pad over 8 in. (0.2 m) of heavyweight concrete. A separate program called slab.exe, which determines the temperature of the ground under the slab based on the area of the slab, the location of the building, and the type of insulation under or around the slab, was used to model the ground coupling (DOE, 2009). For the baseline models, slab.exe was used to run a simple building in each location with the slab insulation requirements in ASHRAE 90.1-1999. Slab.exe reports the perimeter ground monthly temperatures, the core ground monthly temperatures, and average monthly temperatures. For this analysis, the average monthly temperatures were used as the input for the ground temperatures under the floor slab in the EnergyPlus input files.

5.3.4.2 Low-Energy Model

The low-energy building slab-on-grade floors are the same as those in the baseline model, which is consistent with the Guide's recommendation to comply with Standard 90.1.

5.3.5 Fenestration

5.3.5.1 Baseline Model

Fenestration systems in the baseline buildings were modeled at 26% fenestration to gross wall area for the community hospital and 20% fenestration to gross wall area for the surgery center. The fenestration on the community hospital includes the clerestory daylighting glass. Windows frames were not explicitly modeled to reduce complexity in the EnergyPlus models and make the simulations run faster. The window performance is modeled as representing the entire glazed area. U-factor and solar heat gain coefficient (SHGC) values were treated as representing the whole window assembly. Window U-factor and SHGC were set to match the fenestration performance criteria outlined in Appendix B of ASHRAE 90.1-1999, by climate zone. If the SHGC had no recommended value in ASHRAE 90.1 (1999 or 2004), it was set to the previous table's value. Similar window U-factors and SHGCs were modeled in the ASHRAE 90.1-2004 baselines, as the window requirements did not change significantly from ASHRAE 90.1-1999 to ASHRAE 90.1-2004.

Window fenestration U-factors and SHGC values are listed in Appendix C and Appendix D. These are the targets used in an iterative process to refine the material properties in the layer-by-layer descriptions to just match the assembly performance level. The multipliers from the visible light transmittance tables in ASHRAE 90.1-2004, Appendix C, Table C3.5 (ASHRAE 2004b) were used to calculate baseline visible light transmittance values for the windows.

The SHC-AEDG recommends daylighting in the public spaces (corridors, reception, waiting areas), exam rooms, and permanently occupied staff areas (nurse stations, offices, dining areas). The surgery center daylighting option includes skylights with an area of 5% of the floor area. The community hospital daylighting option includes clerestories. The baseline models also include the clerestories, but without daylighting controls, as recommended in Appendix G of ASHRAE 90.1-2004. Skylight and clerestory U-factor and SHGCs are set to match the fenestration performance criteria outlined in Appendix B of ASHRAE 90.1-1999, by climate zone.

5.3.5.2 Low-Energy Model

The vertical fenestration and skylight U-factors were modeled to meet the minimum requirements for each climate. (See Table 8-1 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 1–4 and Table 8-2 for the low-energy fenestration thermal characteristics.) Horizontal overhangs with no offset and a projection factor of 0.5 were added to the south-facing windows (including clerestories) in the low-energy models.

5.4 Infiltration

5.4.1 Baseline Model

Building air infiltration is addressed indirectly in the 90.1 Standard through the requirements in building envelope sealing, fenestration, and door air leakage. ASHRAE 90.1 does not specify the air infiltration rate. For this analysis (based on input from the PC), the infiltration rate was assumed to be a constant 0.2 cfm/ft^2 (1.0 (L/s)/m^2) of exterior wall area. For equipment sizing simulations in EnergyPlus, the infiltration rate was assumed to be 0.4 cfm/ft^2 (2.0 (L/s)/m^2) of exterior wall area, applied only to perimeter zones.

5.4.2 Low-Energy Model

The infiltration in the low-energy model is the same as in the baseline model.

5.5 Air Flow Rates

5.5.1 Baseline Model

Ventilation air requirements for specific spaces are addressed directly in AIA 2006. This was the primary reference used to determine ventilation air flow rates for specific zone types. If a specific zone type was not present in the AIA Guidelines, ASHRAE 62.1-2004 was used to determine the per-floor area and per-occupant ventilation air flow rates.

Exhaust air requirements for specific spaces are addressed directly in the AIA 2006. Not all spaces have exhaust requirements.

Total air requirements for specific spaces are addressed directly in AIA 2006. Not all spaces have exhaust requirements.

Table 5-2 shows the ventilation, exhaust, and total air flow rates used in the energy model.

Table 5-2 Ventilation and Exhaust Inputs

Space Type	AIA Guidelines Ventilation Air (ACH*)	62.1-2004 Ventilation (cfm/occupant)	62.1-2004 Ventilation (cfm/ft^2)	AIA Guidelines Exhaust (ACH)	AIA Guidelines Total Air (ACH)
Anesthesia	–	–	0.12	8	8
Clean	–	–	0.12	–	4
Conference	–	5	0.06	–	–
Corridor	–	–	0.06	–	–
Dining	–	7.5	0.18	–	–
Examination room	–	–	0.12	–	6
Food preparation center	–	–	0.12	625 CFM	10
Laboratory	–	–	0.12	–	6
Lounge	–	–	0.12	–	–
Nurse station	–	–	0.12	–	–
Nursery	2	–	–	–	6
Office	–	5	0.06	–	–
Operating room	3	–	–	–	20
Patient corridor	–	–	0.06	–	2
Patient room	2	–	–	–	6
Physical therapy	–	–	0.12	–	6
Procedure room	3	–	–	–	15
Radiology	–	–	0.12	12	–
Reception area	–	5	0.06	–	–
Recovery room	2	–	–	–	6
Soiled	–	–	0.12	10	10
Storage	–	–	0.12	–	–
Toilet room	–	–	0.12	10	10
Trauma room	3	–	–	–	15
Triage	2	–	–	12	12
Utility	–	–	0.12	–	–

* Air changes per hour

** This value was changed from the 15 ACH that is listed in the AIA guidelines based on recommendations from the PC.

5.5.2 Low-Energy Model

The ventilation, exhaust, and total air flow rates in the low-energy model are the same as in the baseline model.

5.6 Internal Loads

5.6.1 Baseline Model

Internal loads include heat generated from occupants, lights, and appliances (plug loads such as computers, printers, and medical equipment and gas loads such as cooking equipment and medical sterilization equipment). For the occupancy loads, the load intensity refers to the maximum occupancy at the peak time of a typical day. Lighting, plug, and gas loads are represented by peak power density in watts per square foot. The assumed equipment load intensities are based on GGHC 2007. The equipment loads include all loads not associated with HVAC, SWH, and lighting. In addition to all loads that are plugged in, equipment loads include items such as elevators, distribution transformer losses, cooking appliances, and walk-in refrigerators.

The occupancy loads are based on the default occupant density from ASHRAE 62.1-2004 (ASHRAE 2004c). The baseline interior LPD for each specific area is derived by using the space-by-space method described in Standard 90.1-1999. The baseline ASHRAE 90.1-1999 and ASHRAE 90.1-2004 LPDs, peak plug loads, and peak occupancy by space type are shown in Table 5-3. Table 5-4 shows area weighted averages of the ASHRAE 90.1-1999 and ASHRAE 90.1-2004 LPDs, peak plug loads, and peak occupancy. Plug load, occupancy, and lighting schedules are documented in Section 5.7. The location of each space type can be found in Figure 4-1 through Figure 4-7.

Table 5-3 Internal Loads by Space Type

Space Type	ASHRAE 90.1-1999 LPD (W/ft^2)	ASHRAE 90.1-2004 LPD (W/ft^2)	Peak Plug Load (W/ft^2)	Peak Process Gas Load (W/ft^2)	Maximum Occupants ($\#/1000\ ft^2$)
Anesthesia	2.9	0.9	2.0	–	–
Clean	1.5	1.1	2.0	–	20
Conference	1.5	1.3	1.0	–	50
Corridor	1.6	1.0	0.4	–	–
Dining	1.4	0.9	1.0	–	100
Examination room	1.6	1.5	1.1	–	20
Food preparation center	2.2	1.2	4.0	5	15
Laboratory	1.8	1.4	3.0	–	25
Lounge	1.4	0.8	3.0	–	15
Nurse station	1.8	1.0	2.0	–	20
Nursery	1.0	0.6	1.0	–	20
Office	1.5	1.1	1.1	–	5
Operating room	7.6	2.2	4.0	7	20
Patient corridor	1.6	1.0	0.4	–	–
Patient room	1.2	0.7	2.0	–	10
Physical therapy	1.9	0.9	1.5	–	20
Procedure room	2.8	2.7	3.0	–	20
Radiology	0.4	0.4	10.0	–	20
Reception area	1.8	1.3	1.1	–	30
Recovery room	2.6	0.8	3.0	–	20
Soiled	1.5	1.1	2.0	–	20
Storage	2.9	0.9	0.1	–	–
Toilet room	1.0	0.9	0.4	–	–
Trauma room	1.6	1.5	2.0	–	20
Triage	2.8	2.7	2.0	–	20
Utility	1.3	1.5	5.0	–	–

Table 5-4 Area-Weighted Average Internal Loads by Prototype

Prototype	ASHRAE 90.1-1999 LPD (W/ft^2)	ASHRAE 90.1-2004 LPD (W/ft^2)	Peak Plug Load (W/ft^2)	Number of Occupants ($\#/1000\ ft^2$)
Community hospital	1.9	1.1	2.1	10.5
Surgery center	1.8	1.1	1.8	10.1

5.6.2 Low-Energy Model

The internal loads for the low-energy model are the same as for the baseline building, except for the LPD and lighting controls.

5.6.2.1 Lighting Power Density

The SHC-AEDG provides recommendations for LPD by space type and an average LPD for the entire building. The baseline and SHC-AEDG LPD recommendations are shown in Table 5-5 for ASHRAE 90.1-1999 and in Table 5-7 for ASHRAE 90.1-2004. Whole-building values for ASHRAE 90.1-1999 are in Table 5-6 and whole building values for ASHRAE 90.1-2004 are in Table 5-8.

Table 5-5 Space-by-Space AEDG LPD Versus ASHRAE 90.1-1999

Space Type	ASHRAE 90.1-1999 LPD (W/ft^2)	SHC-AEDG LPD (W/ft^2)	ASHRAE 90.1-1999 Percent Reduction
Anesthesia	2.9	0.8	72%
Clean	1.5	0.9	40%
Conference	1.5	1.2	20%
Corridor	1.6	0.7	56%
Dining	1.4	0.9	36%
Examination room	1.6	1.2	25%
Food preparation center	2.2	1.2	45%
Laboratory	1.8	0.9	50%
Lounge	1.4	0.8	43%
Nurse station	1.8	1.0	44%
Nursery	1.0	0.6	40%
Office	1.5	0.9	40%
Operating room	7.6	2.0	74%
Patient corridor	1.6	0.7	56%
Patient room	1.2	0.7	42%
Physical therapy	1.9	0.9	53%
Procedure room	2.8	2.0	29%
Radiology	0.4	0.8	–
Reception area	1.8	0.9	50%
Recovery room	2.6	0.8	69%
Soiled	1.5	0.9	40%
Storage	2.9	0.8	72%
Toilet room	1.0	0.9	10%
Trauma room	1.6	1.2	25%
Triage	2.8	2.0	29%
Utility	1.3	0.9	31%

Table 5-6 Whole-Building AEDG LPD Versus ASHRAE 90.1-1999

Space Type	ASHRAE 90.1-1999 LPD (W/ft^2)	SHC-AEDG LPD (W/ft^2)	ASHRAE 90.1-1999 Percent Reduction
Community hospital	1.85	0.92	50%
Surgery center	1.87	0.88	54%

Table 5-7 Space-by-Space AEDG LPD Versus ASHRAE 90.1-2004

Space Type	ASHRAE 90.1-2004 LPD (W/ft^2)	SHC-AEDG LPD (W/ft^2)	ASHRAE 90.1-2004 Percent Reduction
Anesthesia	0.9	0.8	11%
Clean	1.1	0.9	18%
Conference	1.3	1.2	8%
Corridor	1.0	0.7	30%
Dining	0.9	0.9	0%
Examination room	1.5	1.2	20%
Food preparation center	1.2	1.2	0%
Laboratory	1.4	0.9	36%
Lounge	0.8	0.8	0%
Nurse station	1.0	1.0	0%
Nursery	0.6	0.6	0%
Office	1.1	0.9	18%
Operating room	2.2	2.0	9%
Patient corridor	1.0	0.7	30%
Patient room	0.7	0.7	0%
Physical therapy	0.9	0.9	0%
Procedure room	2.7	2.0	26%
Radiology	0.4	0.8	-
Reception area	1.3	0.9	31%
Recovery room	0.8	0.8	0%
Soiled	1.1	0.9	18%
Storage	0.9	0.8	11%
Toilet room	0.9	0.9	0%
Trauma room	1.5	1.2	20%
Triage	2.7	2.0	26%
Utility	1.5	0.9	40%

Table 5-8 Whole-Building AEDG LPD Versus ASHRAE 90.1-2004

Space Type	ASHRAE 90.1-2004 LPD (W/ft^2)	SHC-AEDG LPD (W/ft^2)	ASHRAE 90.1-2004 Percent Reduction
Community hospital	1.11	0.92	17%
Surgery center	1.06	0.88	17%

5.6.2.2 Lighting Controls

The SHC-AEDG recommends daylighting controls in common areas (corridors, reception areas, dining areas) and permanently occupied staff spaces (nurse stations, offices, exam rooms). Continuous dimming daylighting controls that turn off when daylighting can meet the entire lighting load were modeled. Each daylight zone was modeled with one daylighting reference point controlling all lights in the zone. The daylighting control was not placed directly under a skylight or too near a window. The lights were controlled based on a daylighting set point of 40 fc (400 lux). In the top floor of the surgery center with skylights, the daylighting control point was placed between the skylights to represent the lowest lighting level in the zone.

For the low-energy models, manual-on, auto-off occupancy sensors for certain zones are recommended. These include clean rooms, conference rooms, exam rooms, offices, soiled rooms, storage areas, restrooms, and utility (mechanical/electrical) rooms. Occupancy sensors were modeled by an additional 10% LPD reduction in the applicable zones. The baseline and SHC-AEDG LPD recommendations with a 10% reduction for occupancy sensors are shown in Table 5-9 for ASHRAE 90.1-1999 and Table 5-11 for ASHRAE 90.1-2004. Whole-building values for ASHRAE 90.1-1999 are in Table 5-10 whole-building values for ASHRAE 90.1-2004 are in Table 5-12.

Table 5-9 Space-by-Space AEDG LPD With Occupancy Sensors Versus ASHRAE 90.1-1999

Space Type	ASHRAE 90.1-1999 LPD (W/ft^2)	SHC-AEDG LPD With Occupancy Sensors (W/ft^2)	ASHRAE 90.1-1999 Percent Reduction
Anesthesia	2.9	0.8	72%
Clean	1.5	0.8	46%
Conference	1.5	1.1	28%
Corridor	1.6	0.7	56%
Dining	1.4	0.9	36%
Examination room	1.6	1.1	33%
Food preparation center	2.2	1.2	45%
Laboratory	1.8	0.9	50%
Lounge	1.4	0.8	43%
Nurse station	1.8	1.0	44%
Nursery	1.0	0.6	40%
Office	1.5	0.8	46%
Operating room	7.6	2.0	74%
Patient corridor	1.6	0.7	56%
Patient room	1.2	0.7	42%
Physical therapy	1.9	0.9	53%
Procedure room	2.8	2.0	29%
Radiology	0.4	0.8	–
Reception area	1.8	0.9	50%
Recovery room	2.6	0.8	69%
Soiled	1.5	0.8	46%
Storage	2.9	0.7	75%
Toilet room	1.0	0.8	19%
Trauma room	1.6	1.2	25%
Triage	2.8	2.0	29%
Utility	1.3	0.8	38%

Table 5-10 Whole-Building AEDG LPD With Occupancy Sensors Versus ASHRAE 90.1-1999

Space Type	ASHRAE 90.1-1999 LPD (W/ft^2)	SHC-AEDG LPD With Occupancy Sensors (W/ft^2)	ASHRAE 90.1-1999 Percent Reduction
Community hospital	1.85	0.88	52%
Surgery center	1.87	0.83	56%

Table 5-11 Space-by-Space AEDG LPD With Occupancy Sensors Versus ASHRAE 90.1-2004

Space Type	ASHRAE 90.1-2004 LPD (W/ft^2)	SHC-AEDG LPD With Occupancy Sensors (W/ft^2)	ASHRAE 90.1-2004 Percent Reduction
Anesthesia	0.9	0.8	11%
Clean	1.1	0.8	26%
Conference	1.3	1.1	17%
Corridor	1.0	0.7	30%
Dining	0.9	0.9	0%
Examination room	1.5	1.1	28%
Food preparation center	1.2	1.2	0%
Laboratory	1.4	0.9	36%
Lounge	0.8	0.8	0%
Nurse station	1.0	1.0	0%
Nursery	0.6	0.6	0%
Office	1.1	0.8	26%
Operating room	2.2	2.0	9%
Patient corridor	1.0	0.7	30%
Patient room	0.7	0.7	0%
Physical therapy	0.9	0.9	0%
Procedure room	2.7	2.0	26%
Radiology	0.4	0.8	–
Reception area	1.3	0.9	31%
Recovery room	0.8	0.8	0%
Soiled	1.1	0.8	26%
Storage	0.9	0.7	20%
Toilet room	0.9	0.8	10%
Trauma room	1.5	1.2	20%
Triage	2.7	2.0	26%
Utility	1.5	0.8	46%

Table 5-12 Whole-Building AEDG LPD With Occupancy Sensors Versus ASHRAE 90.1-2004

Space Type	ASHRAE 90.1-2004 LPD (W/ft^2)	SHC-AEDG LPD With Occupancy Sensors (W/ft^2)	ASHRAE 90.1-2004 Percent Reduction
Community hospital	1.11	0.88	21%
Surgery center	1.06	0.83	22%

5.7 Schedules

5.7.1 Baseline Model

The schedules were developed by modifying the standard healthcare building schedule sets available in ASHRAE 90.1-1989 (ASHRAE, 1989) based on input from each PC member. Schedules are presented as fractions of peak, unless otherwise noted. Administrative and critical schedules were created. The administrative schedules apply to quadrants 1 and 4 of the community hospital and to the entire surgery center. These spaces have schedules that are more typical of office buildings, with a near-vacant state at nights. The administrative schedules also have different schedules for weekdays, Saturdays, and all other days (Sundays and holidays), whereas the critical schedules are the same every day. The critical schedules applied to quadrants 2 and 3 of the community hospital, where there is 24-hour access. Each respective administrative and critical schedule follows the same time patterns; nighttime reduction is greater in the administrative schedules. Table 5-13 shows the administrative and critical lighting schedules; Figure 5-5 represents the same data graphically.

Table 5-13 Building Lighting Schedule

Hour	Critical All Days	Administrative Weekday	Administrative Saturday	Administrative All Other Days
1	0.5	0.1	0.1	0.05
2	0.5	0.1	0.1	0.05
3	0.5	0.1	0.1	0.05
4	0.5	0.3	0.1	0.05
5	0.7	0.3	0.1	0.05
6	0.7	0.6	0.1	0.05
7	0.9	0.9	0.1	0.05
8	0.9	0.9	0.3	0.05
9	0.9	0.9	0.3	0.1
10	0.9	0.9	0.4	0.1
11	0.9	0.9	0.4	0.1
12	0.9	0.9	0.4	0.1
13	0.9	0.9	0.4	0.1
14	0.9	0.9	0.4	0.1
15	0.9	0.9	0.4	0.1
16	0.9	0.9	0.3	0.1
17	0.9	0.9	0.3	0.1
18	0.9	0.9	0.3	0.05
19	0.7	0.6	0.3	0.05
20	0.7	0.6	0.3	0.05
21	0.7	0.3	0.1	0.05
22	0.7	0.3	0.1	0.05
23	0.5	0.1	0.1	0.05
24	0.5	0.1	0.1	0.05

Each zone in the baseline models used the same thermostat set point schedules (see Table 5-14 and Table 5-15, except for the operating rooms, which used the thermostat set point schedule in Table 5-16. The HVAC systems are controlled with dual thermostatic control based on dry bulb temperature in the zones. Zone thermostat set points are generally 70ºF (21ºC) for heating and 72ºF (22ºC) for cooling. Thermostat setup to 77ºF (25ºC) and setback to 65ºF (18ºC) were included in the models. A visual representation of the thermostat set point schedules can be seen in Figure 5-6 and Figure 5-7.

According to AIA 2006, the relative humidity (RH) of the critical spaces needs to be maintained between 30% and 60%. Dedicated steam humidifiers are included in air handlers serving critical zones and have a humidistat set point of 40% as good design practice. Dehumidification is addressed indirectly by controlling air handler deck temperature. Set points for the supply air temperature in the baseline and low-energy models are 52ºF (11ºC) for air handlers serving critical zones and 55ºF (13ºC) for air handlers serving administrative zones.

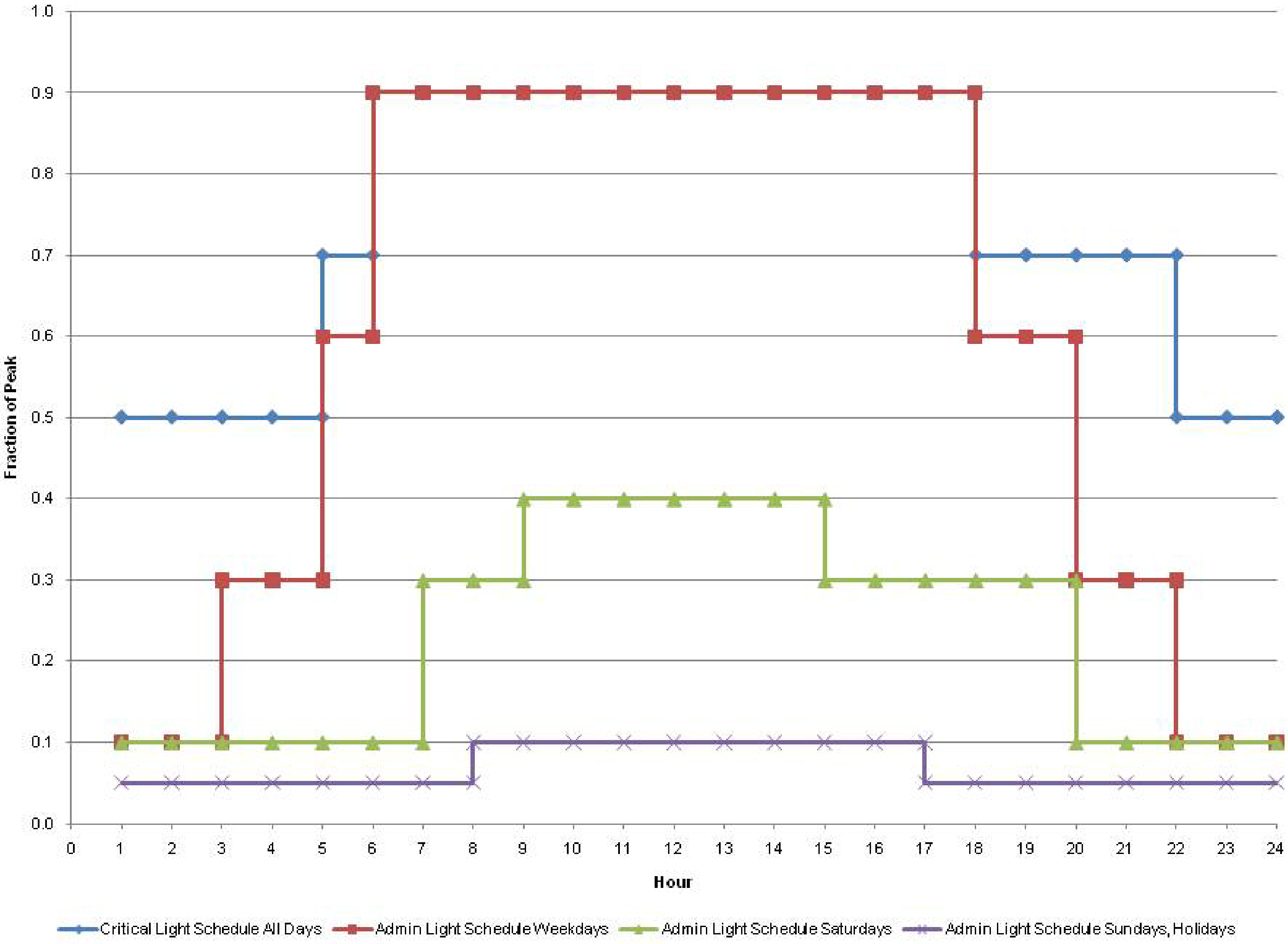

Figure 5-5 Building lighting schedule

Table 5-14 Building Heating Set Point Schedules

Hour	Critical All Days (ºF)	Administrative Weekday (ºF)	Administrative Saturday (ºF)	Administrative All Other Days (ºF)
1	70	65	65	65
2	70	65	65	65
3	70	65	65	65
4	70	65	65	65
5	70	65	65	65
6	70	70	65	65
7	70	70	65	65
8	70	70	70	65
9	70	70	70	65
10	70	70	70	65
11	70	70	70	65
12	70	70	70	65
13	70	70	70	65
14	70	70	70	65
15	70	70	70	65
16	70	70	65	65
17	70	70	65	65
18	70	70	65	65
19	70	65	65	65
20	70	65	65	65
21	70	65	65	65
22	70	65	65	65
23	70	65	65	65
24	70	65	65	65

Table 5-15 Building Cooling Set Point Schedules

Hour	Critical All Days (ºF)	Administrative Weekday (ºF)	Administrative Saturday (ºF)	Administrative All Other Days (ºF)
1	72	77	77	77
2	72	77	77	77
3	72	77	77	77
4	72	77	77	77
5	72	77	77	77
6	72	72	77	77
7	72	72	77	77
8	72	72	72	77
9	72	72	72	77
10	72	72	72	77
11	72	72	72	77
12	72	72	72	77
13	72	72	72	77
14	72	72	72	77
15	72	72	72	77
16	72	72	77	77
17	72	72	77	77
18	72	72	77	77
19	72	77	77	77
20	72	77	77	77
21	72	77	77	77
22	72	77	77	77
23	72	77	77	77
24	72	77	77	77

Table 5-16 Operating Room Heating and Cooling Set Point Schedules

Hour	Heating (ºF)	Cooling (ºF)
1	65	72
2	65	72
3	65	72
4	65	72
5	65	72
6	65	72
7	65	65
8	65	65
9	65	65
10	65	65
11	65	65
12	65	65
13	65	65
14	65	65
15	65	65
16	65	65
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18	65	72
19	65	72
20	65	72
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22	65	72
23	65	72
24	65	72

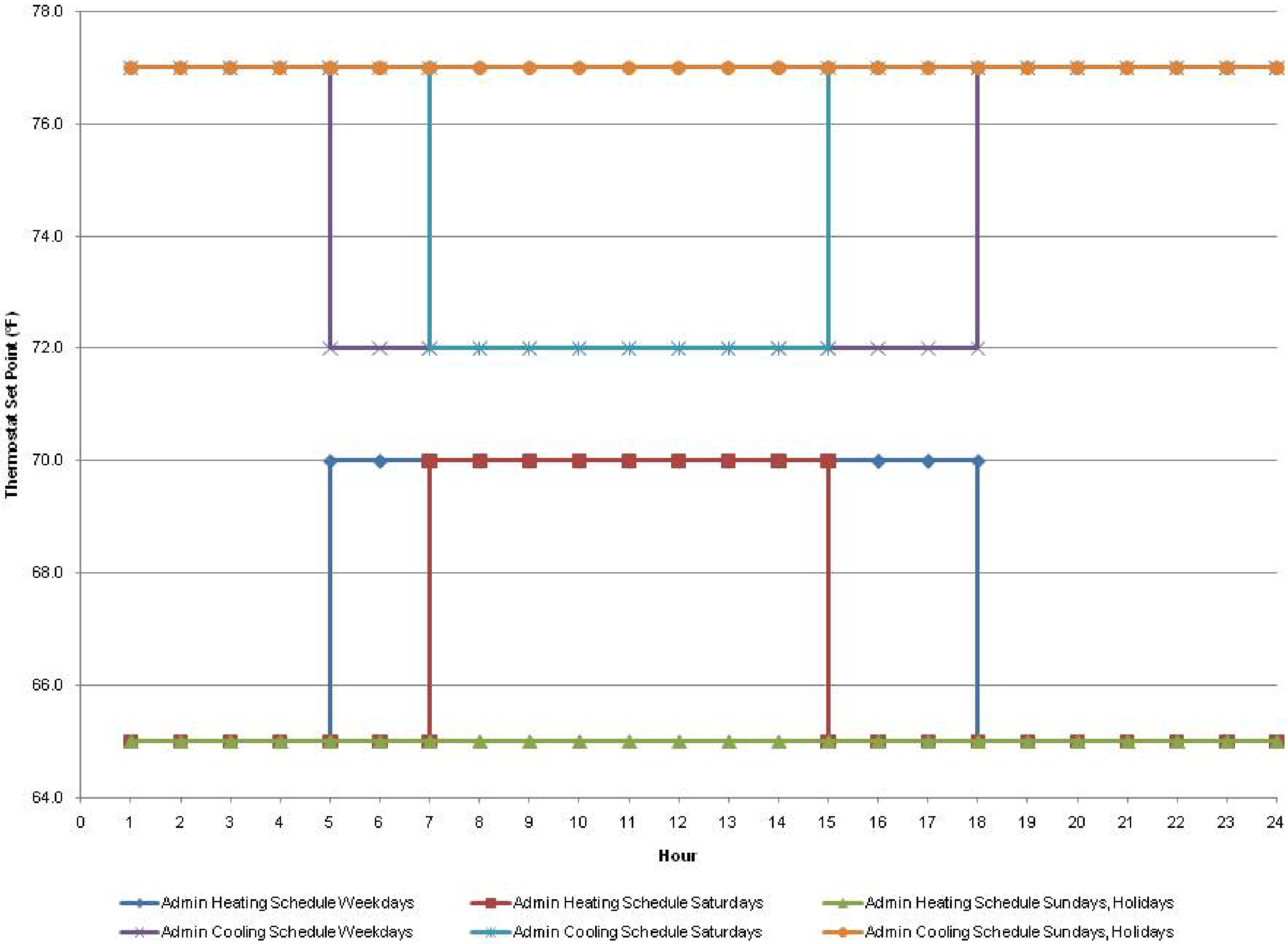


Figure 5-6 **Administrative space set point schedule**

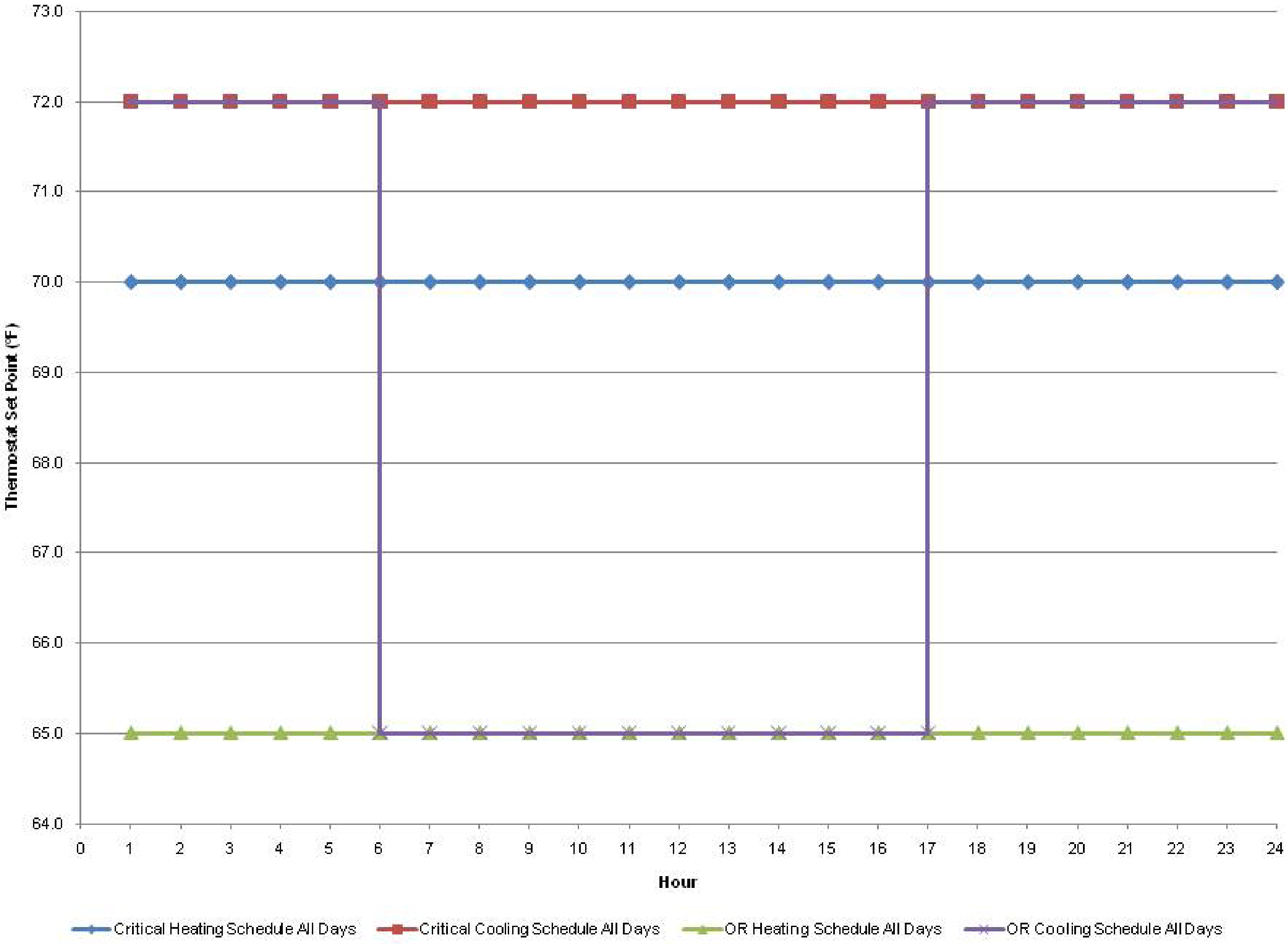


Figure 5-7 Critical space and operating room set point schedule

Each zone in the baseline models used the same equipment schedules (see Table 5-17 and Figure 5-8).

Table 5-17 Building Equipment Schedule

Hour	Critical All Days	Administrative Weekday	Administrative Saturday	Administrative All Other Days
1	0.5	0.3	0.3	0.3
2	0.5	0.3	0.3	0.3
3	0.5	0.3	0.3	0.3
4	0.5	0.3	0.3	0.3
5	0.8	0.5	0.3	0.3
6	0.8	0.5	0.3	0.3
7	1.0	1.0	0.3	0.3
8	1.0	1.0	0.5	0.3
9	1.0	1.0	0.5	0.5
10	1.0	1.0	0.8	0.5
11	1.0	1.0	0.8	0.5
12	1.0	1.0	0.8	0.5
13	1.0	1.0	0.8	0.5
14	1.0	1.0	0.8	0.5
15	1.0	1.0	0.8	0.5
16	1.0	1.0	0.5	0.5
17	1.0	1.0	0.5	0.5
18	1.0	1.0	0.5	0.3
19	0.8	0.5	0.5	0.3
20	0.8	0.5	0.5	0.3
21	0.5	0.3	0.3	0.3
22	0.5	0.3	0.3	0.3
23	0.5	0.3	0.3	0.3
24	0.5	0.3	0.3	0.3

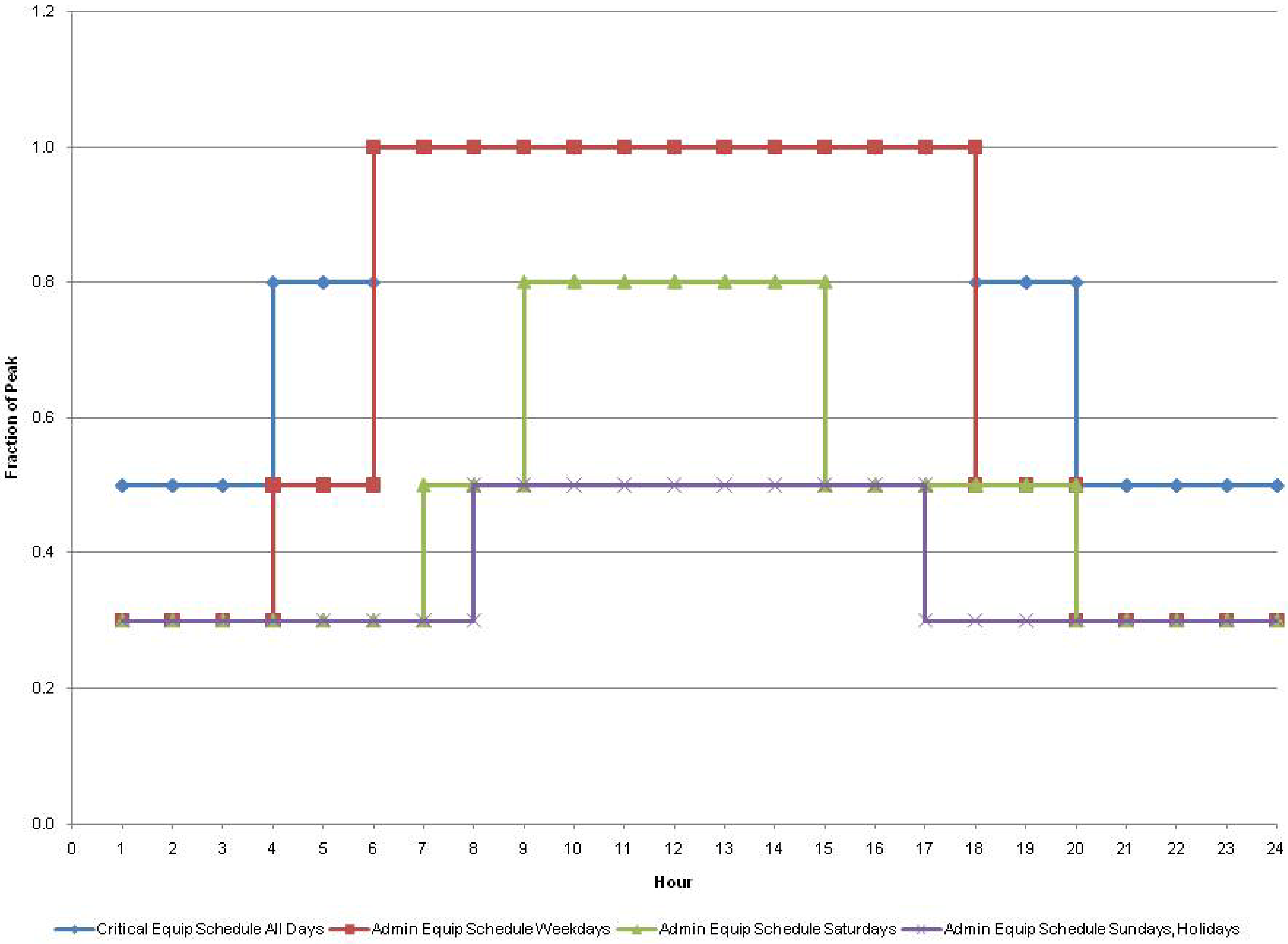


Figure 5-8 Building equipment schedule

Each zone in the baseline models used the same occupancy schedules (see Table 5-18 and Figure 5-9).

Table 5-18 Building Occupancy Schedule

Hour	Critical All Days	Administrative Weekday	Administrative Saturday	Administrative All Other Days
1	0.4	0.05	0.05	0.0
2	0.4	0.05	0.05	0.0
3	0.4	0.05	0.05	0.0
4	0.4	0.05	0.05	0.0
5	0.65	0.2	0.05	0.0
6	0.65	0.2	0.05	0.0
7	0.9	0.5	0.05	0.0
8	0.9	0.9	0.2	0.0
9	0.9	0.9	0.2	0.05
10	0.9	0.9	0.3	0.05
11	0.9	0.9	0.3	0.05
12	0.9	0.9	0.3	0.05
13	0.9	0.9	0.3	0.05
14	0.9	0.9	0.3	0.05
15	0.9	0.9	0.3	0.05
16	0.9	0.9	0.2	0.05
17	0.9	0.9	0.2	0.05
18	0.9	0.9	0.2	0.0
19	0.65	0.5	0.2	0.0
20	0.65	0.5	0.2	0.0
21	0.65	0.2	0.05	0.0
22	0.65	0.2	0.05	0.0
23	0.4	0.05	0.05	0.0
24	0.4	0.05	0.05	0.0

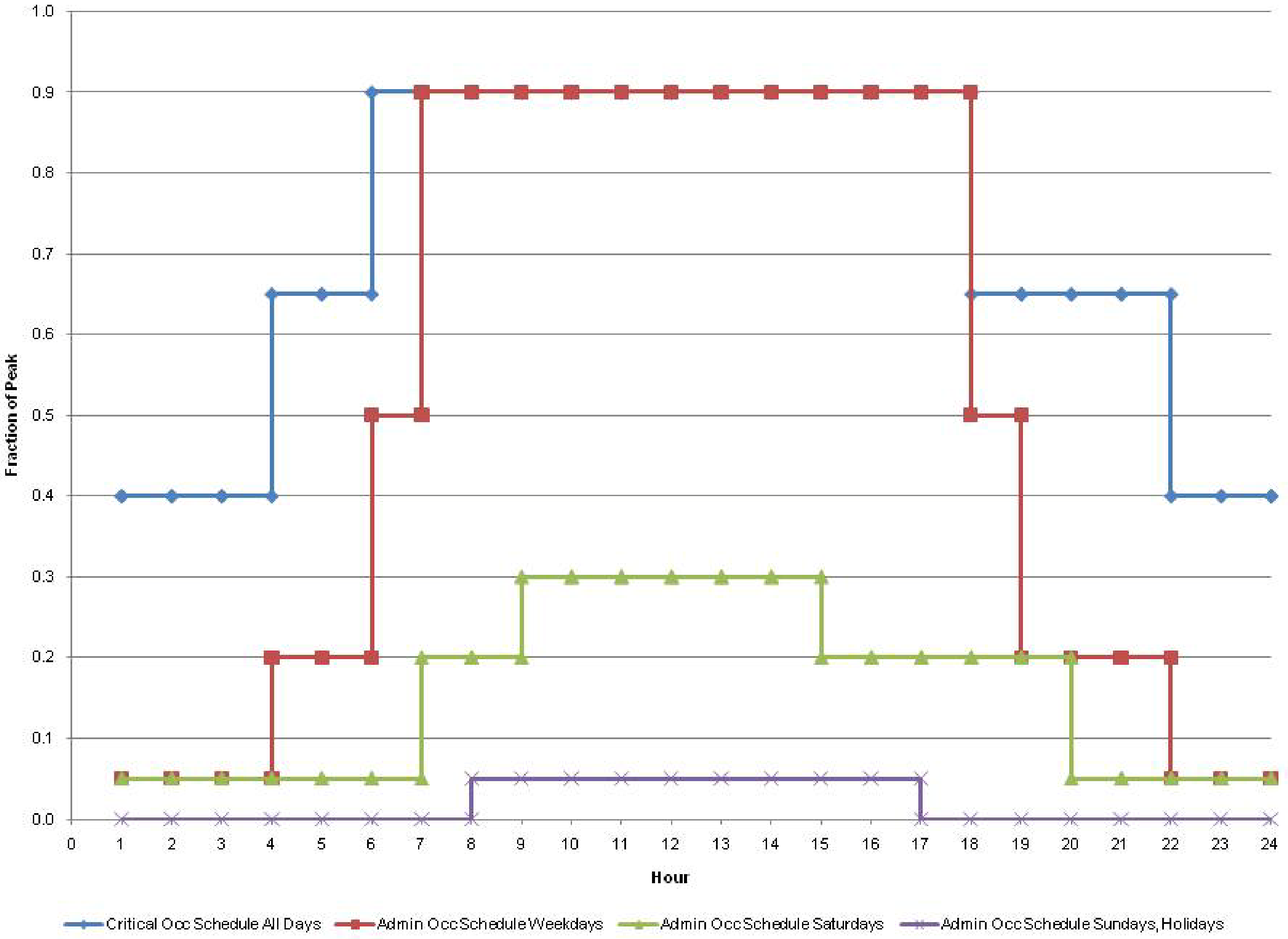


Figure 5-9 Building occupancy schedule

The building SWH schedules are shown in Table 5-19 and Figure 5-10.

Table 5-19 Building SWH Schedule

Hour	Weekday	Saturday	All Other Days
1	0.01	0.01	0.01
2	0.01	0.01	0.01
3	0.01	0.01	0.01
4	0.01	0.01	0.01
5	0.01	0.01	0.01
6	0.01	0.01	0.01
7	0.01	0.01	0.01
8	0.17	0.01	0.01
9	0.58	0.20	0.01
10	0.66	0.28	0.01
11	0.78	0.30	0.01
12	0.82	0.30	0.01
13	0.71	0.24	0.01
14	0.82	0.24	0.01
15	0.78	0.23	0.01
16	0.74	0.23	0.01
17	0.63	0.23	0.01
18	0.41	0.10	0.01
19	0.18	0.01	0.01
20	0.18	0.01	0.01
21	0.18	0.01	0.01
22	0.10	0.01	0.01
23	0.01	0.01	0.01
24	0.01	0.01	0.01

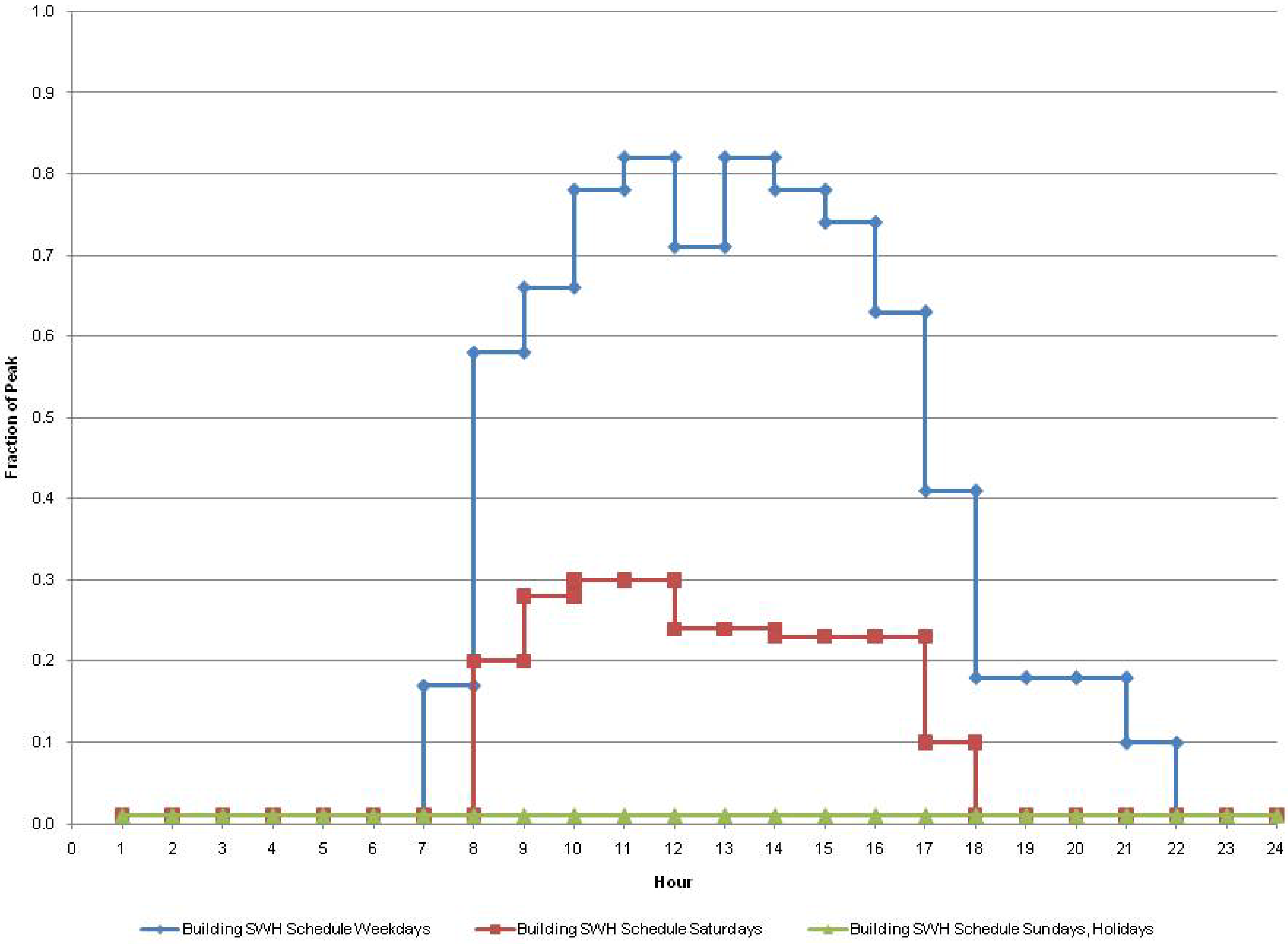


Figure 5-10 Building SWH schedule

The infiltration schedules and HVAC operational schedules are shown in Table 5-20. The OA and fan schedules are the same as the HVAC operational schedules. There are two HVAC operation schedules: one for 24-hour critical access areas and another for administrative areas. During off hours, the HVAC system is shut off and cycles on only when the setback thermostat control calls for heating or cooling to maintain the setback temperature. During unoccupied hours, the OA is turned off with motorized dampers. Therefore, no OA is available when the system night cycles.

Table 5-20 Infiltration and HVAC Operation Schedules

Hour	Infiltration	Critical HVAC Operation	Administrative HVAC Operation
1	1.0	1.0	0.0
2	1.0	1.0	0.0
3	1.0	1.0	0.0
4	1.0	1.0	0.0
5	1.0	1.0	0.0
6	1.0	1.0	0.0
7	1.0	1.0	1.0
8	1.0	1.0	1.0
9	1.0	1.0	1.0
10	1.0	1.0	1.0
11	1.0	1.0	1.0
12	1.0	1.0	1.0
13	1.0	1.0	1.0
14	1.0	1.0	1.0
15	1.0	1.0	1.0
16	1.0	1.0	1.0
17	1.0	1.0	1.0
18	1.0	1.0	1.0
19	1.0	1.0	0.0
20	1.0	1.0	0.0
21	1.0	1.0	0.0
22	1.0	1.0	0.0
23	1.0	1.0	0.0
24	1.0	1.0	0.0

5.7.2 Low-Energy Model

The schedules used in the low-energy models were the same as the baseline schedules, except when schedules were added to model a specific recommendation. One recommendation in the AEDG is to schedule the terminal box minimum flow fraction to be 1 during occupied hours (to mimic a constant volume box and meet AIA guidelines) and to reduce the minimum flow fraction during unoccupied hours of critical spaces to save HVAC energy. These are not critical spaces with 24-hour requirements (patient rooms, for example); rather, they are critical spaces that have predictable occupied and unoccupied times (such as operating rooms). Two terminal box schedules were used: one for humid climate zones and one for the other climate zones. The minimum flow fraction for the humid climates is larger than that of the other climates to better dehumidify the spaces during unoccupied hours. Climate zones 1A, 1B, 2A, 3A, and 4A use the schedule with larger minimum flow fraction values during unoccupied hours.

Table 5-21 Building Terminal Box Minimum Flow Fraction Schedule

Hour	Humid Locations	All Other Locations
1	0.5	0.3
2	0.5	0.3
3	0.5	0.3
4	0.5	0.3
5	0.5	0.3
6	0.5	0.3
7	1.0	1.0
8	1.0	1.0
9	1.0	1.0
10	1.0	1.0
11	1.0	1.0
12	1.0	1.0
13	1.0	1.0
14	1.0	1.0
15	1.0	1.0
16	1.0	1.0
17	1.0	1.0
18	1.0	1.0
19	0.5	0.3
20	0.5	0.3
21	0.5	0.3
22	0.5	0.3
23	0.5	0.3
24	0.5	0.3

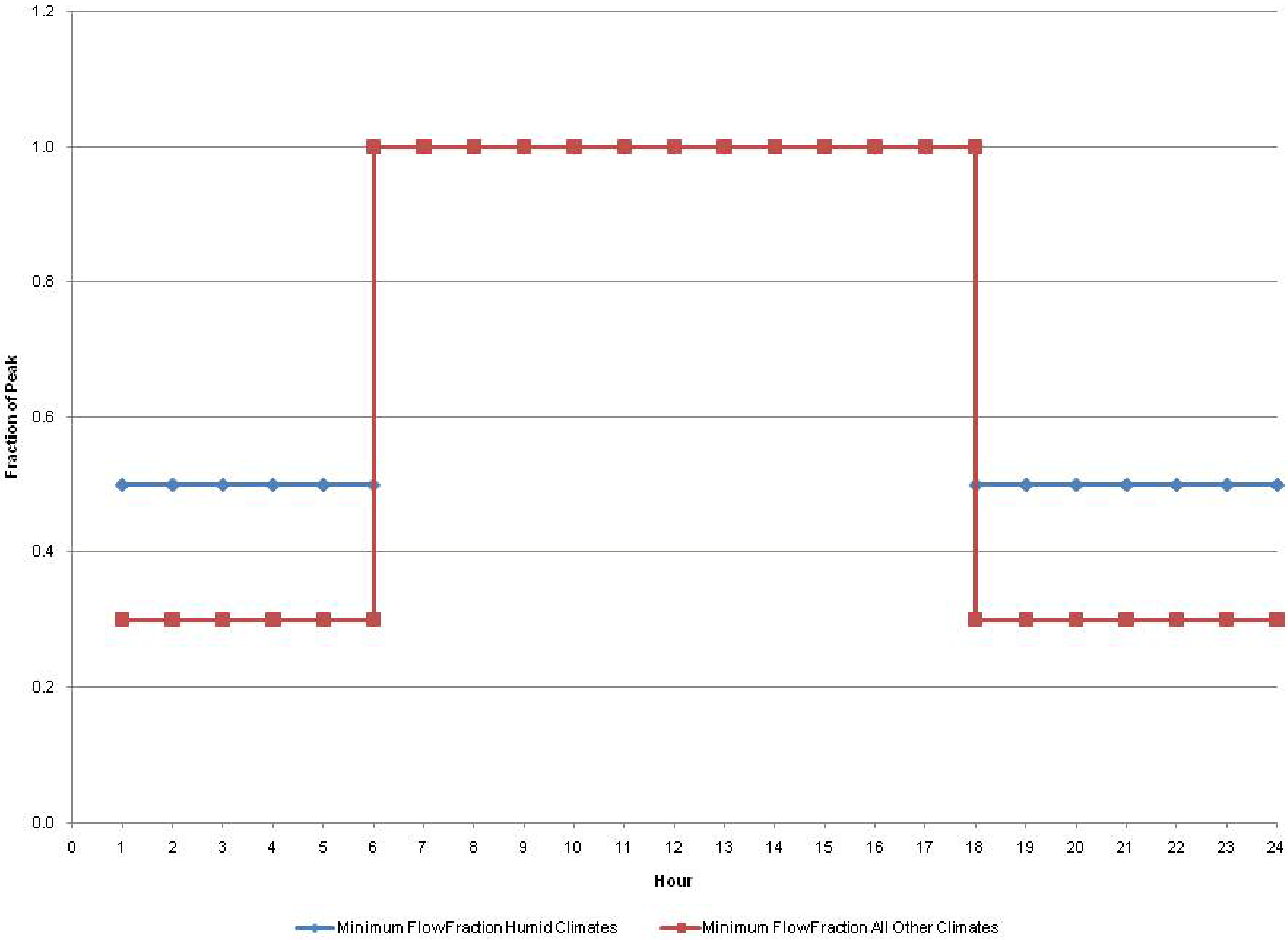


Figure 5-11 Building terminal box minimum flow fraction schedule

5.8 Service Water Heating

5.8.1 Baseline Model

The PC defined the baseline SWH system for the small hospitals and healthcare facilities as a gas-fired storage water heater that meets the minimum requirement for medium-sized water heaters under Standard 90.1-1999. Gas water heaters were chosen for the baseline to be consistent with the use of gas for heating in the baseline prototype buildings. The thermal efficiency (E_t) of the baseline water heaters is 80% for both ASHRAE 90.1-1999 and ASHRAE 90.1-2004.

The hot water consumption rates were determined as documented in the DOE Benchmark Hospital, one of the buildings in the DOE benchmark buildings set (Torcellini et al. 2008). The hot water was assumed to be used at 104ºF (40ºC). The set point of the water heater was 140ºF (60ºC). For reporting purposes in Section 7, the gas use for SWH is stated as "Water Systems."

5.8.2 Low-Energy Model

The SHC-AEDG provides recommendations for gas-fired storage and electric instantaneous and storage service water heaters. The recommendations were based on the K-12 AEDG SWH recommendations. For our analysis to verify 30% savings, the low-energy models included 90% efficient gas storage service water heaters.

5.9 Air Handler Assignment

Air handlers were assigned in the energy model according to the as-built drawings of the prototypes provided by the PC. The air handler assignment was consistent for the baseline and low-energy models.

The two total air handlers in the surgery center are assigned by floor. A constant air volume (CAV) air handler serves the first floor, where the critical healthcare functions are conducted. A variable air volume (VAV) system serves the second and third floors, where less critical healthcare functions are conducted.

Air handlers in the community hospital (single story) were assigned according to building quadrant. Figure 5-12 shows each of the four quadrants in a different color. The red areas are administrative spaces and are served by a VAV air handler. The yellow areas are mechanical/electrical rooms and storage spaces and are served by a VAV air handler. The blue areas contain patient rooms and are served by a CAV air handler without a night air flow setback (see Section 5.7.2). The green areas are critical healthcare spaces and are served by a CAV air handler with a night air flow setback.

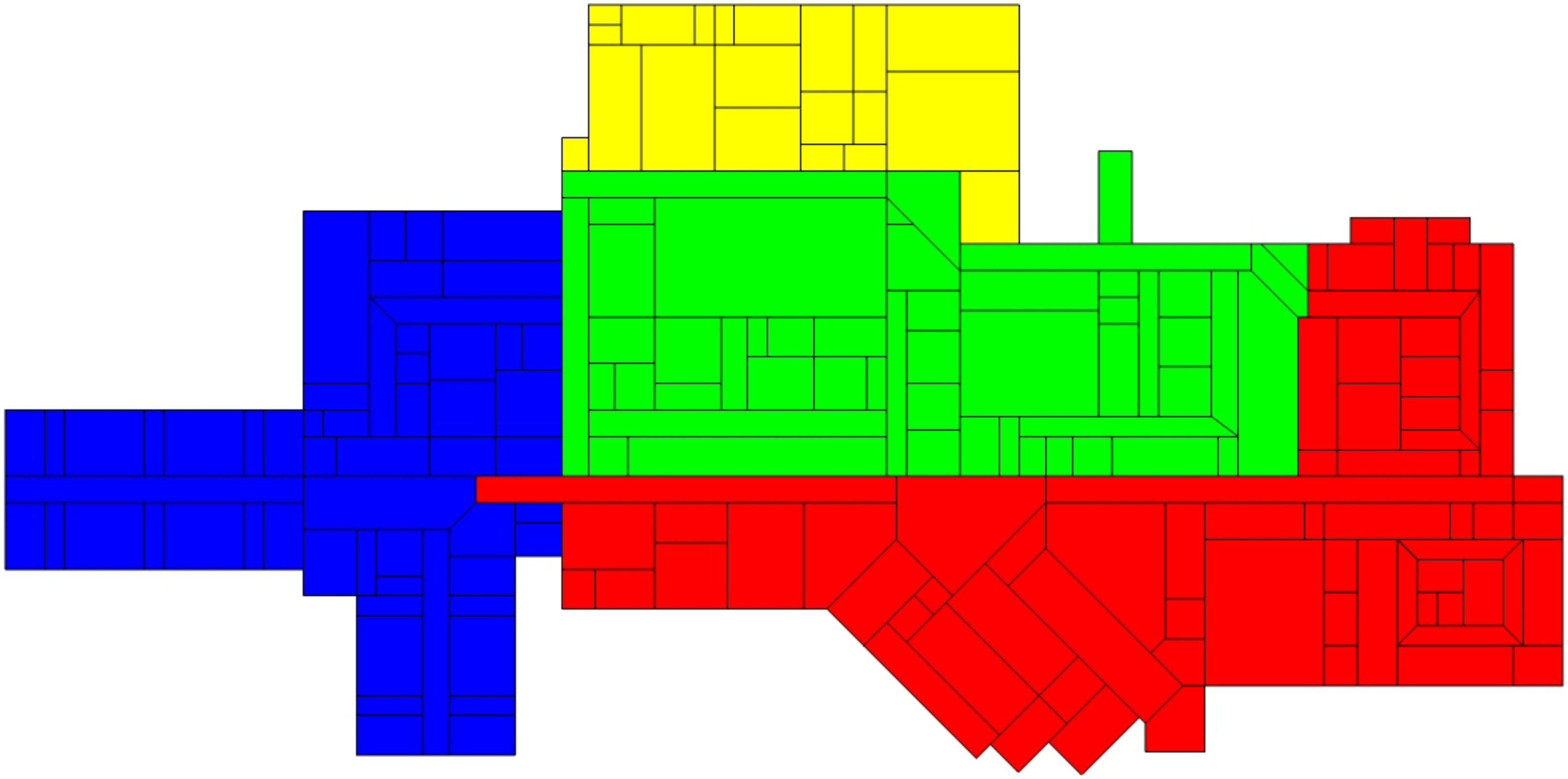


Figure 5-12 **Community hospital air handling unit (AHU) map**
Credit: Eric Bonnema/NREL

6. HVAC Systems and Components

Before reviewing the modeling procedure of the HVAC systems and components, Sections 6.1 and 6.2 focus on the importance of sizing equipment to improve the accuracy of simulations and how the proper sizing routine can be used to streamline whole-building modeling during the design process. Section 6.1 defines sizing programs versus whole-building simulation programs and why merging their strengths is integral to improving the design process. Section 6.2 reviews in depth the comprehensive sizing strategy applied to EnergyPlus to ensure the proper sizing of the terminal units serving each zone and the air handling unit (AHU) serving them. The sizing of the airside system is the initial—and thus the most crucial—step in sizing an entire HVAC system. Section 6.2 shows that when a whole-building simulation program such as EnergyPlus is used correctly, it can be used to size the HVAC system and to conduct annual simulations.

These sections review the modeling inputs for the HVAC systems and components, which include:

- Section 6.3: Fans
- Section 6.4: Pumps
- Section 6.5: Economizers
- Section 6.6: Packaged Direct Expansion Systems
- Section 6.7: Air-Cooled Chiller Systems
- Section 6.8: Water-Cooled Chiller Systems
- Section 6.9: Cooling Tower Systems
- Section 6.10: Boilers
- Section 6.11: Service Water Heaters
- Section 6.11: Humidifiers.

6.1 Sizing Programs Versus Whole-Building Simulation Programs

The HVAC design industry currently distrusts whole-building simulation programs to size HVAC systems. For this document, these programs will be referenced as *whole-building simulation programs.* This distrust stems from two main issues:

- Whole-building simulation programs focus primarily on annual simulation and only secondarily on system sizing.
- Whole-building simulation programs do not clearly output the equipment size or provide established engineering checks such as cfm/ton, which designers refer to when evaluating the legitimacy of the equipment size.

Instead, design engineers use programs that are almost exclusively developed by HVAC manufacturers to size HVAC equipment. For this document, these programs will be referenced as *sizing programs*. HVAC engineers trust sizing program due to the following two main issues:

- Sizing programs are dedicated to sizing equipment, and only secondarily to annual simulation.

- Sizing programs tend to be conservative and typically oversize equipment. This gives the designer confidence that the installed equipment will be able to meet peak heating or cooling loads.

However, oversizing can provide a false sense of security. For example, oversizing direct expansion (DX) rooftop equipment prevents the system from meeting dehumidification load under design and part-load conditions.

On the other hand, the HVAC design community typically does not consider sizing programs to be reliable for annual simulation. A great deal of this uncertainty stems from the lack of detailed outputs that prevent the user from verifying that the simulation program is functioning properly. From an annual simulation perspective, sizing programs typically behave as "black boxes," and the user has limited exposure to the program's internal calculations.

Some whole-building simulation programs, used correctly, are as accurate as sizing programs. Fortunately, EnergyPlus implements robust sizing routines that will size HVAC systems to the same level of confidence and conservatism (if deemed by the engineer) as industry-accepted sizing programs. Also, ensuring the proper sizing in EnergyPlus is integral to modeling accuracy and to integrating whole-building simulation into the standard design process.

From a modeling perspective, the accuracy of the whole-building simulation is contingent on correctly sizing and simulating the operating conditions of HVAC equipment. The energy performance of such equipment is extremely sensitive to part-load performance. Primary equipment—chillers and boilers in particular—experience a wide range of energy performance, depending on their part-load operation (see Sections 6.7, 6.8, and 6.10). All too often, capturing the part-load performance of primary equipment is emphasized and the validity of the equipment size is rarely checked. An accurate model is realized only when both tasks are completed.

From a design perspective, whole-building simulation will become streamlined in a standard design process only if design engineers can use it to confidently size their HVAC equipment and run annual simulations. Ideally, whole-building simulation and sizing programs can be merged into a single program. The whole-building simulation will save time and better reflect the actual performance of the system, because the installed equipment sizes will be used in the model. All too often, the equipment sizes calculated from the sizing program are not reconciled with the sizing calculated by the whole-building simulation program. Consequently, the whole-building simulations are based on equipment sizes that differ substantially from the installed ones. Streamlining the process of sizing and annual simulation into a single program would alleviate this problem.

6.2 Airside System Type and Sizing

The following sections step through the process of calculating the total and ventilation air flow rates to maintain comfort and meet the requirements established by AIA 2006 and ASHRAE 62.1-2004 (ASHRAE 2004c). The procedure begins with sizing the terminal units and then sizing the AHU based on the units it serves.

6.2.1 Constant Air Volume, Variable Air Volume, and Exhaust Air Systems

The community hospital and surgery center models consisted of three types of air systems:

- The CAV system maintains a constant air flow rate. The CAV system served air loops dominated by critical space types that required stringent air-change and pressurization requirements, according to AIA 2006. Each zone has its own CAV terminal box that modulates a damper based on static pressure fluctuations to ensure a constant flow rate is delivered to the zone. Even noncritical spaces served by the CAV system were supplied a constant air flow. This design strategy represents HVAC best practices to ensure that the positive or negative pressurization requirements of certain critical spaces are not compromised. More specifically, VAV terminal units on the same air loop may cause rapid static pressure fluctuations such that the CAV dampers would be unable to maintain the constant air flow rate necessary to meet the pressurization requirements.

- The VAV system modulates the air flow rate between a peak design and a minimum flow rate. The air flow rate varies by modulating the fan speed using a variable frequency drive (VFD) attached to the electric motor. In the case of healthcare facilities, the VAV system serves air loops with predominantly noncritical spaces (no stringent air change or pressurization requirements, based on AIA 2006). VAV systems often serve air loops that contain critical spaces, as long they are far fewer than the number of noncritical spaces. The critical spaces are still served by CAV terminal boxes and those typically allowed to be on a VAV air system do not have pressurization requirements.

  Each zone was served by a VAV terminal box that modulates its damper position, based on the zone thermostat to vary flow between a maximum and a minimum flow rate. Although the damper position can also be controlled by the space RH or carbon dioxide concentration, this additionally sophisticated control is not typically implemented because of the RH/carbon dioxide sensor reliability issues and the correct implementation of the control based on three inputs instead of one. The main supply fan modulates its speed to maintain a constant static pressure at a sensor as far downstream from the AHU as possible. The minimum flow rate is typically 30% of the maximum to maintain sufficient flow across the fan motor to prevent overheating.

- The exhaust air (EA) system included dedicated exhaust fans serving a critical zone required by AIA 2006 to exhaust all the supply air to the outdoors. To prevent cross-contamination, each critical zone requiring exhaust had its own dedicated exhaust fan and ductwork.

6.2.2 Terminal Box Sizing

The HVAC sizing methodology begins with calculating the terminal unit size, which is based solely on its air flow rate. For the CAV terminal unit, this rate remains constant. For the VAV terminal unit, this is the maximum rate. The VAV terminal unit can modulate the air flow rate down to a specified minimum air flow rate based on temperature control, reviewed in detail in 6.2.1. Equation 6-1 summarizes the sizing algorithm.

$$TerminalUnitSize = max(\dot{V}_{SENSIBLE\_COOLING}, \dot{V}_{SENSIBLE\_HEATING}, \dot{V}_{TOTAL}, \dot{V}_{EXHAUST}, \dot{V}_{OA}) \qquad 6\text{-}1$$

Where:

The variable $\dot{V}_{SENSIBLE\_COOLING}$ represents the total air flow rate at the design cooling supply air condition necessary to offset the design cooling load. The calculation focuses on the sensible heat gain of the space; hence the subscript sensible. (See Section 6.2.2.2 for more detail behind the calculation procedure.)

The variable $\dot{V}_{SENSIBLE\_HEATING}$ represents the total air flow rate at the design heating supply air condition necessary to offset the design heating load. The calculation focuses on the sensible heat loss of the space, hence the subscript sensible. See Section 6.2.2.3 for more detail behind the calculation procedure.

The variable $\dot{V}_{TOTAL}$ represents the total air flow rate mandated by Table 2.1-2 of AIA 2006.

The variable $\dot{V}_{EXHAUST}$ represents the total air flow rate that needs to be supplied onto the space to offset the dedicated EA flow rate mandated by Table 2.1-2 of AIA 2006.

The variable $\dot{V}_{OA}$ represents the total air flow rate necessary to satisfy the ventilation requirements of the zone(s) being served. The variable $\dot{V}_{OA}$ is NOT the ventilation flow rate but rather the total air flow rate necessary to ensure that the necessary ventilation air flow rate is provided. This is addressed by accounting for the design OA fraction of the AHU serving that space. The ventilation requirements are based on Table 2.1-2 of AIA 2006 or the ventilation rate procedure specified in ASHRAE 62.1-2004. The $\dot{V}_{OA}$ calculation procedure is different for CAV versus VAV systems. See Section 6.2.2.4 for more detail.

The total air flow and EA flow calculations are straightforward, simply converting the air change requirement in Table 2.1-2 of AIA 2006 into a flow rate. The other calculations are more involved. Therefore, Sections 6.2.2.1 and 6.2.2.4 include more detail behind the calculation procedure for the variables sensible cooling/heating, and OA flow rates, respectively. Section 6.2.2.5 steps through the calculation of all the air flow rates for a north-facing patient room in Chicago to ultimately determine the CAV terminal unit size.

6.2.2.1 Calculating Sensible Air Flow Rates

Sensible air flow rates are calculated based on a guarantee that a comfortable space, dry bulb temperature dead band is maintained during peak load conditions. The calculation procedure is the same for both flow rate requirements. The two main parameters needed are the space peak cooling or heating load and the dry bulb temperature difference between the set point and the supply air condition.

The rest of the section specifies the set points and supply air conditions used in sizing the terminal boxes for the AEDG modeling process and the reasoning behind these design values.

6.2.2.2 Calculating Sensible Cooling Air Flow Rates

The cooling supply air condition is dictated by dehumidification needs. The supply air needs to have a low moisture content to ensure the space never exceeds a design peak RH. Although ASHRAE 62.1-2004 specifies the peak RH to be 65%, the PC specified that 60% should be used based on design best practices. The design community has established approximately 52° to 55°F (11° to 13°C) dry bulb supply off the cooling coil as a rule of thumb, because its associated moisture content (approximately 50 gr/lb [7.2 g/kg]) is low enough to offset the latent gains from occupants, process loads, and infiltration of moist air.

The PC specified different supply air conditions for CAV than for VAV systems as an established best practice (see Table 6-1). The CAV supply dry bulb temperature and humidity ratio are lower as added safety factors to guarantee that these spaces, which fall under the critical care category, will be sufficiently cooled and dehumidified. Figure 6-1 plots the cooling set point and cooling design supply conditions on the psychrometric chart.

Table 6-1 Cooling Set Point and Cooling Supply Air Conditions

	Dry Bulb Temperature*	Humidity Ratio
Cooling set point	72°F	71 g/lb
CAV cooling supply	52°F	49 g/lb
VAV cooling supply	55°F	55 g/lb

* Includes the sensible heat gain across the fan.

6.2.2.3 Calculating Sensible Heating Air Flow Rates

Unlike the cooling supply air condition, the heating supply air condition does not need to take into account the latent needs of the space. The humidifier, if one is needed, will ensure the supply air has adequate moisture to maintain a minimum design RH. (See Section 6.12 for more detail about the AHU humidifier.) Instead, the heating supply air condition is based on the performance limitation of the reheat coil to ensure the ventilation air supplied to the space reaches the breathing zone. Reheat performance and ventilation effectiveness are based on the design heating supply dry bulb temperature.

Whether in heating, cooling, or economizing mode, the supply air leaving the AHU is maintained at a constant 52°F (11°C) dry bulb temperature for a CAV and 55°F (13°C) dry bulb temperature for a VAV system. It depends on the reheat coil, whether electric resistance or heating hot water (HHW), to heat the air to the design heating supply dry bulb temperature. The higher that temperature, the greater the heating rate the reheat coil needs to provide. For an electric resistance reheat coil, this may mean an unrealistically large power draw. For an HHW reheat coil, this may mean higher hot water supply and return temperatures, which degrade boiler performance, increase HHW pump power, and may require two row coils that add an unnecessary pressure drop to the supply fan.

Hot design heating supply temperatures will compromise the ability of the supply ventilation air to reach the breathing zone. Because of buoyancy, the hotter the incoming air relative to the space temperature, the greater percentage of the supply air remains at the ceiling, where it short circuits via the return grill without entering the breathing zone. ASHRAE 62.1-2004 quantifies this behavior by assigning a ventilation effectiveness for a given supply and return grill configuration (ceiling supply and return) and temperature difference between the supply air and the space set point. Based on Table 6-2 in ASHRAE 62.1-2004, the "ceiling supply of warm air 15°F (8°C) or more above the space temperature and ceiling return" has a ventilation effectiveness of 0.8 (ASHRAE 2004c). As a result, this Standard stipulates ventilation flow rate based on the per-occupant and per-area requirements would need to be increased by 20% to account for a ventilation effectiveness of 0.8. To achieve a ventilation effectiveness of unity under ASHRAE 62.1-2004, the design heating supply air temperature should be lower than 85°F (29°C) with a 70°F (21°C) heating set point.

However, healthcare design practitioners do not typically increase ventilation levels to account for ventilation effectiveness based on design heating supply temperatures of 85°F (29°C) or higher. Healthcare spaces are internal load driven and mitigate infiltration through pressurization, so terminal units need heating for short durations only. Furthermore, during these brief heating episodes, the supply temperature will rarely be above 85°F (29°C). The PC therefore recommended the design heat supply temperature be set to 95°F (35°C) as established best practice. Table 6-2 shows the heating set point and design supply air conditions. Figure 6-1 plots the heating set point and heating design supply conditions on the psychrometric chart.

Table 6-2 Heating Set Point and Heating Supply Air Conditions

	Dry Bulb Temperature*
Heating set point	70°F
CAV–VAV heating supply	95°F

* Includes sensible heat gain across the fan.

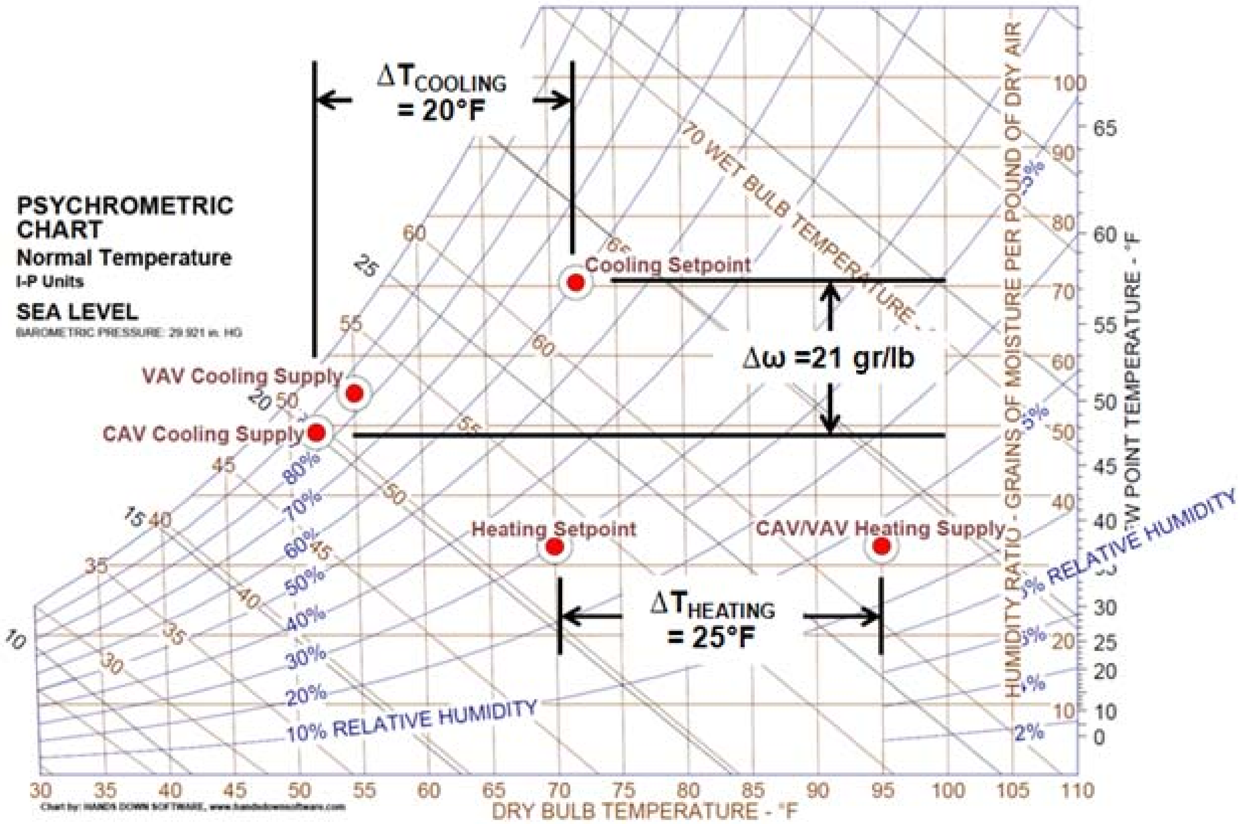


Figure 6-1 Psychrometric chart showing space set points and supply air conditions

6.2.2.4 Calculating Outdoor Air Flow Rate

The calculation of the OA flow rate guarantees that the space served by the terminal unit is provided the required ventilation flow rate, based on Table 2.1-2 of AIA 2006 or the ventilation rate procedure of ASHRAE 62.1-2004. The OA flow rate is not the ventilation flow rate but the total air flow rate of the terminal unit. The following sections discuss the difference in the calculation procedure between CAV and VAV systems.

6.2.2.4.1 Constant Air Volume System

The calculation of the OA flow rate for a CAV system is straightforward because the OA fraction remains constant. The AHU OA fraction is specified by the mechanical engineer and typically ranges from 0.25 to 0.35. The CAV AHUs on the surgery center and community hospital models used a constant 0.33 OA ratio, which is based on the patient room OA ratio of 2 air changes of ventilation for every 6 air changes of total air flow (from Table 2.1-2 of AIA 2006). Therefore, the ventilation air flow requirements are simply divided by the OA ratio, 0.33 in the AEDG models case, to determine the total air flow necessary to ensure proper ventilation.

6.2.2.4.2 Variable Air Volume System

The calculation of the OA flow rate for a VAV system is more complicated, because neither the OA fraction nor the air flow rates through the VAV terminal units remain constant. First, the OA requirements for each space must be calculated based on Table 2.1-2 of AIA 2006 or the ventilation rate procedure of ASHRAE 62.1-2004. The ASHRAE 62.1-2004 ventilation rate procedure for multizone systems outlines in detail how to compile these individual space ventilation flow rate requirements into the OA flow rates required of the AHU. (Refer to the ASHRAE 62.1-2004 ventilation rate procedure and ASHRAE 62.1-2004 users' manual for explicit step-by-step instructions and examples for properly calculating the system's OA fraction and VAV terminal box minimum flow fraction.) Based on the experience of the PC, VAV systems typically have a 0.25 OA fraction.

6.2.2.5 Example Patient Room Constant Air Volume Terminal Unit Calculation

The following illustrates the sizing of a terminal unit serving a north-facing patient room in Chicago. Table 6-3 provides a high-level overview of the information necessary for calculating the air flow rates for the patient room.

Table 6-3 Patient Room Geometry, Envelope Characteristics, and Internal Loads

Category	Value
Floor area	225 ft^2
Floor-to-ceiling height	10 ft
Room volume	2,250 ft^3
Glazing geometry	4 ft × 5 ft punched window
Opaque wall	R-value = 15 h·ft^2·°F/Btu
Glazing properties	SHGC = 0.25/U-factor = 0.5 Btu/h·ft^2·°F
Occupant density	7 occupants /1000 ft^2
Lighting power density	1.2 W/ft^2
Process power density	2.0 W/ft^2
Design infiltration rate	0.2 cfm/ft^2-external wall

Before diving into the calculations, the type of terminal unit (CAV or VAV) serving the patient room must be determined. According to Table 2.1.1 of AIA 2006, the patient room must have 6 air changes per hour (ACH) total flow rate and 2 ACH ventilation flow rate. These required total and ventilation constant air flow rates mean that a CAV terminal unit will serve the patient room. The next step is to determine whether the CAV terminal unit is served by a CAV or VAV AHU. Patient rooms are typically grouped into patient wings along with other spaces served by CAV terminal units, so the patient room in this example will be served by a CAV AHU. Section 6.2.1 explains in more detail the methodology behind specifying a CAV or VAV system.

6.2.2.5.1 Total Air Flow Rate

Based on Table 2.1.1 of AIA 2006, the patient room must have 6 ACH total flow rate, which equates to 225 cfm (106 L/s).

6.2.2.5.2 Exhaust Air Flow Rate

Based on Table 2.1.1 of AIA 2006, the patient room has no exhaust requirements.

6.2.2.5.3 Sensible Cooling Air Flow Rate

The calculation procedure first requires the space peak cooling load. Table 6-4 summarizes the patient room peak cooling load breakdown. The cooling set point and cooling supply air dry bulb temperatures are based on Table 6-1. Equation 6-2 shows the calculation procedure to determine the sensible cooling air flow rate.

Table 6-4 Patient Room Envelope and Internal Heat Gains

Category	Cooling Load
Wall conduction	164 Btu/h
Window conduction	190 Btu/h
Window solar	315 Btu/h
Infiltration sensible	615 Btu/h
Occupant	400 Btu/h
Lighting	922 Btu/h
Process	1,536 Btu/h
Total heat gain	4,142 Btu/h

$$Total\ Heat\ Gain = 1.08\ \frac{Btu}{h - cfm - °F} \cdot \dot{V}_{SENSIBLE_{COOLING}} \cdot \left(T_{COOLING_{SETPOINT}} - T_{COOLING_{SUPPLY}}\right) \quad 6\text{-}2$$

$$4{,}142\ Btu/h = 1.08\ \frac{Btu}{h - cfm - °F} \cdot \dot{V}_{SENSIBLE\_COOLING} \cdot (72° - 52°F) \quad 6\text{-}3$$

$$\dot{V}_{SENSIBLE\_COOLING} = 192\ cfm \quad 6\text{-}4$$

6.2.2.5.4 Sensible Heating Air Flow Rate

The calculation of the space peak heating load is summarized in Table 6-5. The heating set point and heating supply air dry bulb temperatures are based on Table 6-2. Equation 6-5 shows the calculation procedure to determine the sensible heating air flow rate.

Table 6-5 Patient Room Envelope and Internal Heat Losses

Category	Heating Load
Wall conduction	–692 Btu/h
Window conduction	–760 Btu/h
Window solar	–
Infiltration sensible	–2,462 Btu/h
Occupant	400 Btu/h
Lighting	–
Process	–
Total heat gain	–3,514 Btu/h

$$Total\ Heat\ Gain = 1.08\ \frac{Btu}{h - cfm - °F} \cdot \dot{V}_{SENSIBLE\_HEATING} \cdot \left(T_{HEATING\_SETPOINT} - T_{HEATING\_SUPPLY}\right) \quad 6\text{-}5$$

$$-3{,}514\ Btu/h = 1.08\ \frac{Btu}{h - cfm - °F} \cdot \dot{V}_{SENSIBLE\_HEATING} \cdot (95° - 70°F) \quad 6\text{-}6$$

$$\dot{V}_{SENSIBLE\_HEATING} = 130\ cfm \quad 6\text{-}7$$

6.2.2.5.5 Outdoor Air Flow Rate

Based on Table 2.1.1 of AIA 2006, the patient room must have 2 ACH ventilation flow rate. This equates to 74 cfm (35 L/s). An OA fraction of 0.33 is specified by the mechanical engineer.

$$\dot{V}_{OA} = \frac{74\ cfm}{0.33\ OA\ fraction} = 225\ cfm \qquad 6\text{-}8$$

6.2.2.5.6 Terminal Unit Size

Table 6-6 compiles the air flow requirements based on the different sizing criteria. As shown, the total air flow and OA flow criteria are the largest; thus, the CAV terminal unit serving the patient room is sized to 225 cfm (106 L/s).

Table 6-6 CAV Terminal Unit Size for Example Patient Room

Requirement	Air Flow Rate	Description
$\dot{V}_{SENSIBLE\_COOLING}$	192 cfm	Meeting peak cooling load
$\dot{V}_{SENSIBLE\_HEATING}$	130 cfm	Meeting peak heating load
$\dot{V}_{TOTAL}$	225 cfm	6 ACH total flow per AIA 2006, Table 2.1-2
$\dot{V}_{EXHAUST}$	–	No requirement per AIA 2006, Table 2.1-2
$\dot{V}_{OA}$	225 cfm	2 ACH ventilation flow per AIA 2006, Table 2.1-2 and 0.33 OA fraction

6.2.3 Air Handing Unit Sizing

The AHU size is defined by its peak flow rate and is a summation of the terminal unit air flows it serves. There are two methods to sum the air flows: coincident and noncoincident. The coincident method sizes the AHU air flow rate based on the sum of the coincident zone air flows. Noncoincident sizes the AHU air flow rate based on the sum of the noncoincident zone air flows. The CAV systems used noncoincident sizing; the VAV systems used coincident sizing.

6.3 Fans

EnergyPlus requires three inputs to define the performance characteristics of a fan:

- Total static pressure drop across the fan at the design flow rate
- Fan, motor, and belt drive combined efficiency at the static pressure and flow rate
- Fan power part-load factor (PLF) curve that defines the power draw of a variable-speed fan as it ramps down from its full load condition.

6.3.1 Static Pressure Drop

The total static pressure drop across the fan is the summation of the internal and external pressure drops. The internal pressure drop is the pressure force the fan needs to exert to overcome the friction imposed on the air flow by the AHU's internal components, such as the heating and cooling coils and filters. Table 6-7 provides the PC-recommended breakdown of the component pressure drops. The critical CAV system experiences an additional 1.5 in. w.c. (375 Pa) because a MERV 14 or greater filter is required, per AIA 2006. The PC recommended that the low-energy model experience lower internal pressure drops by increasing the heating and cooling coils' cross-sectional area to reduce face velocity and therefore pressure drop.

Table 6-8 reviews the internal pressure drop associated with the return fan. The noncritical VAV system low-energy cooling coil pressure drop was supposed to decrease to 0.75 in. w.c. (187 Pa) like the critical CAV system low-energy cooling coil.

Table 6-7 Baseline and Low-Energy Supply Fan Internal Static Pressure Drop Breakdown

Device	Critical CAV System		Noncritical VAV System	
	Baseline	Low-Energy	Baseline	Low-Energy
Heating coil	0.5 in. w.c.	0.25 in. w.c.	0.5 in. w.c.	0.25 in. w.c.
Cooling coil	1.0 in. w.c.	0.75 in. w.c.	1.0 in. w.c.	1.0 in. w.c.
25% filter	0.5 in. w.c.	0.5 in. w.c.	0.5 in. w.c.	0.5 in. w.c.
95% filter	1.5 in. w.c.	1.5 in. w.c.	–	–
Total	3.5 in. w.c.	3.0 in. w.c.	2.0 in. w.c.	1.75 in. w.c.

* Average of clean and dirty filters.

Table 6-8 Baseline and Low-Energy Return Fan Internal Static Pressure Drop Breakdown

Device	Critical CAV System		Noncritical VAV System	
	Baseline	Low-Energy	Baseline	Low-Energy
Motorized damper	0.25 in. w.c.	0.25 in. w.c.	0.25 in. w.c.	0.25 in. w.c.
Total	0.25 in. w.c.	0.25 in. w.c.	0.25 in. w.c.	0.25 in. w.c.

The external pressure drop is the pressure force the fan needs to exert to overcome the friction imposed by components, namely ductwork, external to the AHU. Table 6-9 shows the external pressure drop breakdown recommended by the PC. Guidance for reducing this drop is provided in the SHC-AEDG. The low-energy model experiences 0.5 in. w.c. (125 Pa) less pressure drop through a better engineered outlet transition with turning vanes and larger ductwork.

Table 6-9 Baseline and Low-Energy Supply Fan External Static Pressure Drop Breakdown

Device	Critical CAV System and Noncritical VAV System	
	Baseline	Low-Energy
Inlet transition	0.1 in. w.c.	0.1 in. w.c.
Outlet transition	0.4 in. w.c.	0.2 in. w.c.
Duct mains	1.0 in. w.c.	0.8 in. w.c.
Duct branches	0.5 in. w.c.	0.4 in. w.c.
Terminal box	0.5 in. w.c.	0.5 in. w.c.
Total	2.5 in. w.c.	2.0 in. w.c.

* Includes sound attenuation and electric or hot water coil.

Table 6-10 Baseline and Low-Energy Return Fan External Static Pressure Drop Breakdown

Device	Critical CAV System		Noncritical VAV System	
	Baseline	Low-Energy	Baseline	Low-Energy
Plenum/duct mains	1.5 in. w.c.	1.5 in. w.c.	1.5 in. w.c.	1.5 in. w.c.
Total	1.5 in. w.c.	1.5 in. w.c.	1.5 in. w.c.	1.5 in. w.c.

Table 6-11 and Table 6-12 show the combined internal and external pressure drops for the supply and return fans, respectively. The low-energy model realizes a 1.0 in. w.c. (250 Pa) reduction for the CAV System and 0.75 in. w.c. reduction for the VAV system. As previously stated, the VAV system low-energy cooling coil pressure drop was supposed to decrease to 0.75 in. w.c. (187 Pa) such that the low-energy model realized a 1.0 in. w.c. (250 Pa) total static pressure drop reduction.

Table 6-11 Baseline and Low-Energy Supply Fan Total Static Pressure Drop Breakdown

Device	Critical CAV System		Noncritical VAV System	
	Baseline	Low-Energy	Baseline	Low-Energy
Internal pressure drop	3.5 in. w.c.	3.0 in. w.c.	2.0 in. w.c.	1.75 in. w.c.
External pressure drop	2.5 in. w.c.	2.0 in. w.c.	2.5 in. w.c.	2.0 in. w.c.
Total static pressure drop	6.0 in. w.c.	5.0 in. w.c.	4.5 in. w.c.	3.75 in. w.c.

Table 6-12 Baseline and Low-Energy Return Fan Total Static Pressure Drop Breakdown

Device	Critical CAV System		Noncritical VAV System	
	Baseline	Low-Energy	Baseline	Low-Energy
Internal pressure drop	0.25 in. w.c.	0.25 in. w.c.	0.25 in. w.c.	0.25 in. w.c.
External pressure drop	1.5 in. w.c.	1.5 in. w.c.	1.5 in. w.c.	1.5 in. w.c.
Total static pressure drop	1.75 in. w.c.	1.75 in. w.c.	1.75 in. w.c.	1.75 in. w.c.

EnergyPlus cannot model a supply and a return fan separately. Therefore, with the approval of the PC, the EnergyPlus models used an "equivalent fan" that represented the combined performance of the supply and return fans. The equivalent fan was assigned a total static pressure drop equal to summation of the supply and return fan total static pressure drop shown in Table 6-13. Yet to capture the performance of the supply and return fans, a special calculation procedure was needed to determine the equivalent fan combined fan-motor-belt efficiency based on the performance characteristics of the supply and return fans. Section 6.3.3 provides an example of the equivalent fan combined efficiency calculation procedure.

Table 6-13 Baseline and Low-Energy Equivalent Fan Total Static Pressure

Device	Critical CAV System		Noncritical VAV System	
	Baseline	Low-Energy	Baseline	Low-Energy
Total static pressure drop	7.75 in. w.c.	6.75 in. w.c.	6.25 in. w.c.	5.50 in. w.c.

6.3.2 Motor-Belt-Fan Efficiency

The combined efficiency is defined by the delivered power to the motor relative to the delivered power to the air and is a function of the motor efficiency, belt-drive efficiency, and fan efficiency. Multiplying all these efficiencies together provides a combined efficiency. The fan performance requirements in ASHRAE 90.1 are stringent, so both the baseline and the low-energy fans had National Electric Manufacturers Association (NEMA) premium efficiency motors. Appendix H.2 shows the NEMA premium efficiency based on the motor size.

The belt-drive losses can be significant, and depend on the type of belt used. A standard V-belt has a wide efficiency range of 90% to 97%. A cogged belt has a tighter efficiency range of 94% to 98%. Fortunately, direct drive motors, even in larger sizes, are becoming more common in healthcare design. Again, because of the stringent requirements of ASHRAE 90.1, the baseline and low-energy fans were modeled as direct drive such that no belt-drive losses were incurred.

The fan efficiencies depend mainly on the fan type and configuration. The PC recommended single-width, single-inlet centrifugal airfoil plenum fans for the supply and return fans. The Loren Cook Compute-A-Fan program (Loren Cook 2009) was used to calculate the supply and return fan static efficiency based on the total static pressure drops in Table 6-11 and Table 6-12.

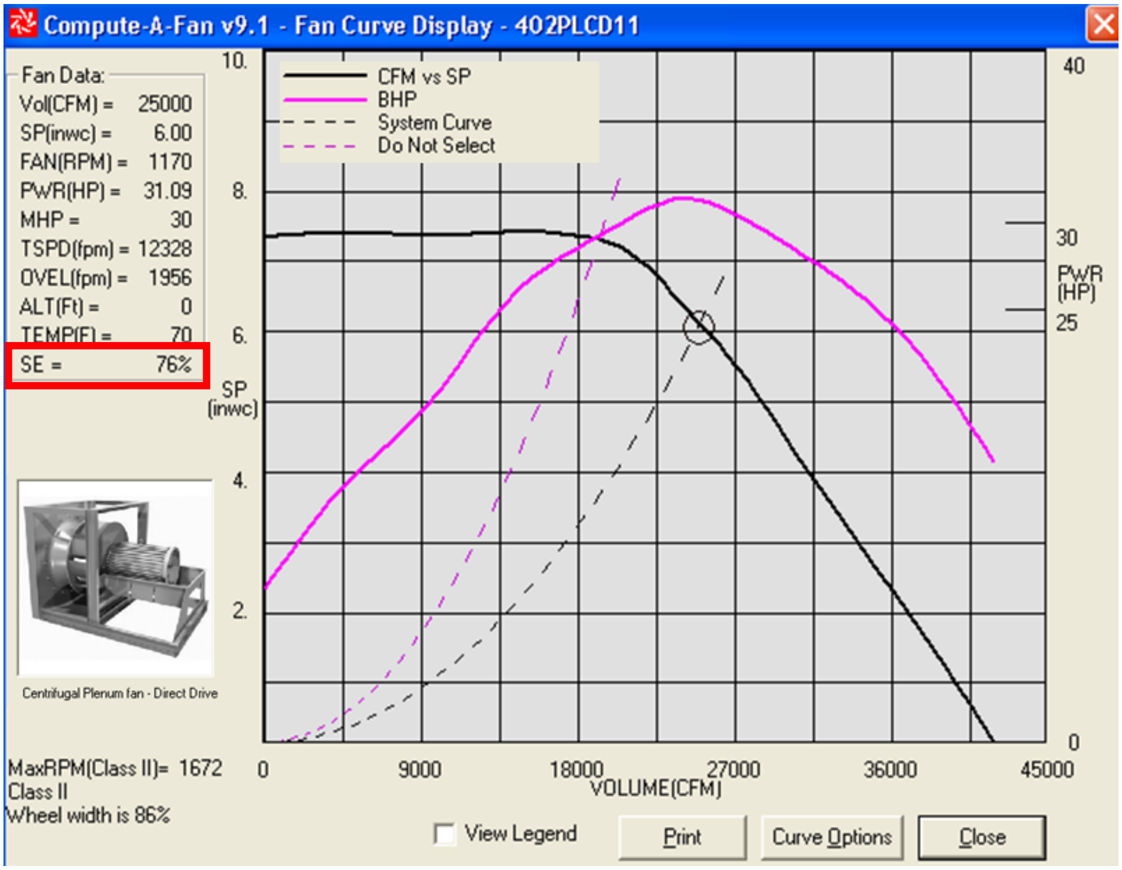
The design flow rates based on the surgery center model are shown in Table 6-14. The surgery center design flow rates were chosen as a typical ratio of supply, return, and dedicated exhaust air flow rate for critical and noncritical systems.

Table 6-14 Surgery Center Design Flow Rates

Device	Critical CAV System			Noncritical VAV System		
	Supply	Return	Exhaust	Supply	Return	Exhaust
Flow rates	25,000 cfm	20,000 cfm	5,000 cfm	20,000 cfm	17,000 cfm	3,000 cfm

Static pressure efficiency was chosen over total pressure efficiency. Space in healthcare mechanical rooms is so limited that an insufficient length of straight duct is provided at the discharge of the fan. Consequently, the velocity pressure does not have sufficient straight duct length to convert to static pressure, also known as static regain. To be on the conservative side, the velocity pressure is assumed to dissipate to heat. This is the reason for using plenum fans, which are designed to maximize static pressure at the fan discharge with minimal velocity pressure. As is typical of programs from most fan manufacturers, the fan selection program provides only the static efficiency, labeled SE in Figure 6-2.

Because ASHRAE 90.1 fan performance requirements are so stringent, the same high static efficiencies were specified for the baseline and low-energy fans (see Table 6-15). Therefore, the low-energy model would realize fan energy savings only through the lower total static pressure drops shown in Table 6-13.



Fan Data:
Vol(CFM) = 25000
SP(inwc) = 6.00
FAN(RPM) = 1170
PWR(HP) = 31.09
MHP = 30
TSPD(fpm) = 12328
OVEL(fpm) = 1956
ALT(Ft) = 0
TEMP(F) = 70
SE = 76%

MaxRPM(Class II)= 1672
Class II
Wheel width is 86%

Figure 6-2 Baseline supply fan selection
Credit: Ian Doebber/NREL

Table 6-15 Baseline and Low-Energy Fan Static Efficiency

Device	**Critical CAV System**		**Noncritical VAV System**	
	Supply	**Return**	**Supply**	**Return**
Fan static efficiency	76%	70%	76%	74%

With the total static pressure drops and motor-belt-fan efficiencies known for the supply and return fans, a combined efficiency was calculated for the equivalent fan. The best way to review the calculation procedure is through an example in Section 6.3.3.

6.3.3 Equivalent Fan Combined Efficiency Example Calculation

Table 6-16 shows an example calculation of the combined efficiency for the surgery center baseline critical CAV system based on the supply and return fan performance characteristics.

Table 6-16 Baseline Critical CAV System Supply and Return Fan Performance Characteristics

Device	Critical CAV System	
	Supply	Return
Design flow rate	25,000 cfm	20,000 cfm
Total static pressure drop	6.0 in. w.c.	1.75 in. w.c.
Fan static efficiency	76%	70%
Motor efficiency	93.6%	91.7%
Belt efficiency	100%	100%

The supply fan performance characteristics in Table 6-16 are used to calculate its power draw (Rabi and Kreider 1994).

$$\dot{W}_{SUPPLY} = \frac{25{,}000\ cfm\ \cdot 6.0\ in.w.c.}{6{,}356 \frac{ft^3 - in.w.c.}{min} \cdot 0.00134 \frac{bhp}{W} \cdot 76\% \cdot 93.6\% \cdot 100\%} = 24{,}758\ W \tag{6-9}$$

The return fan performance characteristics in Table 6-16 are used to calculate its power draw.

$$\dot{W}_{RETURN} = \frac{20{,}000\ cfm\ \cdot 1.75\ in.w.c.}{6{,}356 \frac{ft^3 - in.w.c.}{min} \cdot 0.00134 \frac{bhp}{W} \cdot 70\% \cdot 91.7\% \cdot 100\%} = 6{,}402\ W \tag{6-10}$$

The supply and return fan power draws are summed.

$$\dot{W}_{EQUIVALENT\_FAN} = 24{,}758\ W + 6{,}402\ W = 31{,}160\ W \tag{6-11}$$

The supply and return fan total static pressures are summed.

$$\Delta p_{EQUIVALENT\_FAN} = 6.0\ in.w.c.\ + 1.75\ in.w.c. = 7.75\ in.w.c. \tag{6-12}$$

Using the 25,000 cfm (11,800 L/s) supply flow rate, the total power draw, and the total static pressure of the equivalent fan, the combined efficiency can be calculated.

$$31{,}160\ W = \frac{25{,}000\ cfm\ \cdot 7.75\ in.w.c.}{6{,}356 \frac{ft^3 - in.w.c.}{min} \cdot 0.00134 \frac{bhp}{W} \cdot \eta_{COMBINED}} \tag{6-13}$$

$$\eta_{COMBINED} = 73\% \tag{6-14}$$

Therefore, the equivalent fan modeled with performance characteristics of 25,000 cfm (11,800 L/s), 7.75 in. w.c. (1930 Pa), and 73% combined efficiency will consume the same amount of power as if the supply and return fans were modeled separately. Table 6-17 shows the total static pressure drop and combined efficiency for the equivalent fans used in the baseline and low-energy models.

Table 6-17 Baseline and Low-Energy Equivalent Fan Total Static Pressure

Device	Critical CAV System		Noncritical VAV System	
	Baseline	Low-Energy	Baseline	Low-Energy
Total static pressure drop	7.75 in. w.c.	6.75 in. w.c.	6.25 in. w.c.	5.50 in. w.c.
Fan-motor-belt combined efficiency	73%	73%	73%	73%

6.3.4 Fan Power Part-Load Factor Curve

EnergyPlus does not model a system curve and fan curve to determine the power consumption by the fan at each time step. Instead, it combines the two curves into a single one defined as the PLF curve. This provides a relationship between the fraction of full flow at which a fan operates and the associated fraction of peak power consumption at full flow. This curve is needed for VAV system only, where the flow rate can modulate. CAV systems always maintain maximum flow at maximum power draw.

Although ASHRAE 90.1-2004 specifies a fan power PLF curve in Table G3.1.3.15, a fan power PLF curve based on a 0.5 in. w.c. (125 Pa) static pressure reset was used instead. The PLF curve was obtained from Energy Design Resources (2007). The static pressure reset in ASHRAE 90.1-2004 6.5.3.2.3 stipulates that the static pressure set point will be reset based on the zone requiring the most pressure. In other words, the static pressure is set downward until one terminal box damper is fully open. Figure 6-3 compares the fan power PLF curves, indicating that the 0.5 in. w.c. (125 Pa) static pressure reset curve will provide greater fan savings when the fan operates at 20% to 100% of its flow.

The PLF curve methodology indicates the importance of not having the design flow rate incorrectly oversized (see Table 6-18). For example, assume a VAV AHU is incorrectly sized for a maximum flow rate of 30,000 cfm (14,160 L/s), based on standard sizing methodology. Correctly sized, the maximum design flow rate should have been 27,000 cfm (12,740 L/s); 90% of 30,000 cfm (14,160 L/s). The fan flow fraction at each time step will be artificially low, which in turn will artificially reduce the fan power fraction. Therefore, the fan power at each time step will be artificially low.

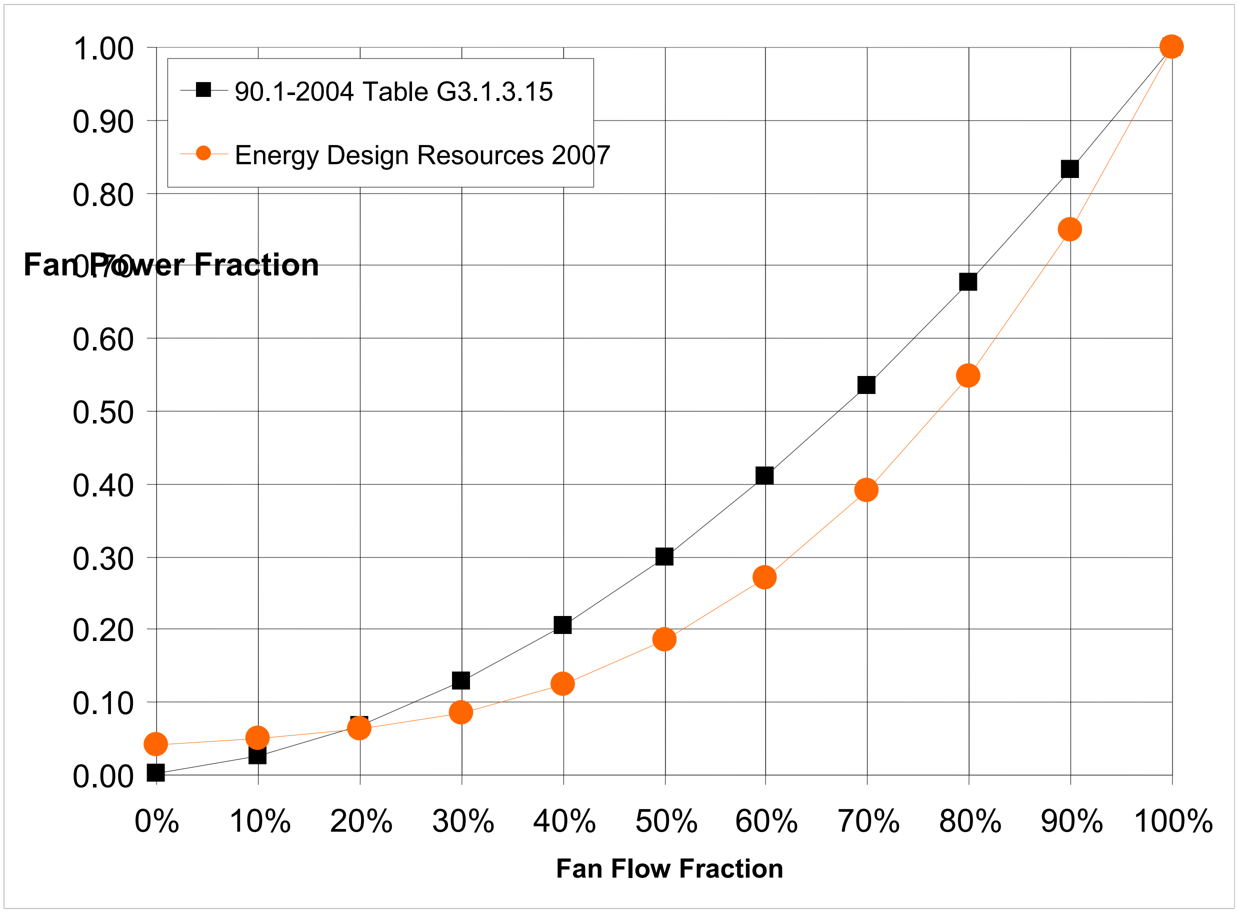


Figure 6-3 Fan power PLF curves
Credit: Ian Doebber/NREL

Table 6-18 Fan Power PLF Curve Coefficients

Coefficients	90.1-2004 Appendix G Table G3.1.3.15 Method 2	Stein/Hydeman "Good SP Reset" (0.5 in. w.c.)
C1	0.0013	0.0408
C2	0.1470	0.0880
C3	0.9506	–0.0729
C4	–0.0998	0.9437

6.3.5 ASHRAE 90.1-2007 Fan Performance

ASHRAE 90.1 fan performance requirements are extremely stringent for healthcare facilities, where fans need to overcome large internal pressure drops from required high efficiency filters. Although ASHRAE 90.1 provides pressure credits for air systems requiring high levels of filtration, the performance requirements still mandate that the mechanical designer reduce internal pressure drop through lower face velocities, reduce external pressure drop through improved duct design, and install high-efficiency motors, belts, and fans. Although the baseline for the AEDG is ASHRAE 90.1-1999, the fan power limitations shown in Table 6-19 are based on ASHRAE 90.1-2007 calculations based on recommendation by the PC. (The AEDG recommendation tables reference the ASHRAE 90.1-2007 (ASHRAE 2007) calculations for fan performance.)

Table 6-19 provides the pressure drop adjustments for the two types of air systems. Then Equations 6-15 through 6-20 calculate the minimum fan performance in bhp per 1000 cfm (470 L/s) using the ASHRAE 90.1-2007 procedure specified in Table 6.5.3.1.1A and the pressure credits from Table 6-19. As shown, the minimum performance requirements are much more stringent for the CAV system than for the VAV system. Table 6-20 compares ASHRAE 90.1-2007 fan performance requirements to those used for the baseline and low-energy systems.

Table 6-19 Fan Power Limitation Pressure Drop Adjustment (90.1-2007 Table 6.5.3.1.1B)

Device	Critical CAV System	Noncritical VAV System
Ducted return credit	0.50 in. w.c.	0.50 in. w.c.
Return dampers credit	0.50 in. w.c.	–
Filter credit	0.90 in. w.c.*	0.50 in. w.c.**
Sound attenuator	0.15 in. w.c.	0.15 in. w.c.
Total	2.05 in. w.c.	1.15 in. w.c.

* Critical care system requires 95% filtration

** Noncritical care system requires 85% filtration

Table 6-20 ASHRAE 90.1-2007 Versus Baseline and Low-Energy Equivalent Fan Performance

Device	Critical CAV System			Noncritical VAV System		
	90.1-2007	Baseline	Low-Energy	90.1-2007	Baseline	Low-Energy
bhp/1000 cfm performance	1.4	1.7	1.4	1.6	1.4	1.2

6.3.5.1.1 Constant Air Volume—Critical Care Fan Power Limitation

$$bhp \leq cfm \cdot 0.00094 + A \qquad 6\text{-}15$$

$$bhp \leq 1000\ cfm \cdot 0.\ 00094 + (2.05 * 1000\ cfm/4{,}131) \qquad 6\text{-}16$$

$$\leq 1.4\ bhp/1000\ cfm \qquad 6\text{-}17$$

6.3.5.1.2 Variable Air Volume—Noncritical Care Fan Power Limitation

$$bhp \leq cfm \cdot 0.0013 + A \qquad 6\text{-}18$$

$$bhp \leq 1000\ cfm \cdot 0.0013 + (1.15 * 1000\ cfm/4{,}131) \qquad 6\text{-}19$$

$$\leq 1.6\ bhp/1000\ cfm \qquad 6\text{-}20$$

6.3.6 Dedicated Exhaust Fan Performance

The dedicated exhaust fan performance characteristics are shown in Table 6-21. The PC recommended a belt-driven, down-blast centrifugal fan as the standard fan type. Like the supply and return fans, the static pressure efficiency was used. The low-energy fan achieves a higher static efficiency because it operates at a more efficient point on its fan curve (see Appendix H.1). There are no efficiency standards for the motors serving these exhaust fans, as they are smaller than 1 hp (745 kW). The baseline motor efficiency was based on the minimum efficiency for a 1-hp motor prior to the Energy Policy Act of 2005. The low-energy motor efficiency was based on the NEMA premium efficiency for a 1-hp (745 kW) motor. The baseline belt efficiency represented a high drive loss; the low-energy belt efficiency represented a low drive loss.

Table 6-21 Dedicated Exhaust Fan Baseline and Low-Energy Performance Characteristics

Performance Characteristics	Baseline	Low-Energy
Total static pressure drop	1.0 in. w.c.	1.0 in. w.c.
Fan static efficiency	47%	60%
Motor efficiency	76.7%	85.5%
Belt efficiency	85%	89%
Combined efficiency	31%	46%

6.4 Pumps

The constant and variable-speed pumps in the baseline and low-energy models were modeled with the performance characteristics in Table 6-22. Brief descriptions about each of these performance characteristics follow.

- Intermittent pump operation means that the pump operates only when there is a load on the plant loop.
- The design pump flow rate is autosized based on the plant loop peak load calculated during the EnergyPlus design day sizing run and the design loop temperature difference, which are stated in Table 6-24 through Table 6-27.
- The rated pump power is autosized based on the design pump flow rate, rated pump head, motor efficiencies, and pump efficiencies stated in Table 6-24 through Table 6-27.
- The minimum pump flow rate is used for variable-speed pumps only.
- The percentage of motor heat transferred to the fluid was specified as 0%, meaning that none of the motor heat affected the fluid temperature leaving the pump.

Table 6-22 Pump Performance Inputs

Performance Characteristics	Baseline and Low-Energy
Pump operation	Intermittent
Design pump flow rate	autosized
Rated pump power	autosized
Minimum pump flow rate	0 gpm
Percentage of motor heat to fluid	0%

The pump power PLF curve in Table 6-23 applies to variable-speed pumps only. The coefficients dictate that the pump motor power varies linearly from 0 to design pump power based on a plant loop flow rate varying from 0 to design pump flow rate.

Table 6-23 Variable-Speed Pump Power PLF Curve Coefficients

Coefficients	Baseline and Low-Energy
C1	0
C2	1
C3	0
C4	0

The following sections specify the pump performance characteristics specific to each loop. The motor efficiency derives from an approximation of a NEMA premium efficiency motor based on an estimation of the motor size.

6.4.1 Heating Hot Water Pumps

In accordance with the specification for facilities smaller than 120,000 ft^2 (11,150 m^2) in ASHRAE 90.1-2004, Appendix G3.1.3.5, the heating hot water (HHW) system comprises a primary only loop with constant speed pumps. Table 6-24 reviews the HHW pump performance characteristics. The pump is constant speed, so the heating hot water return (HHWR) temperature will float based on the heating demand on the loop.

Table 6-24 HHW Pump Performance Characteristics

Performance Characteristics	Baseline and Low-Energy
Capacity modulation	Constant speed
Rated pump head	60 ft w.c.
Motor efficiency	90%
Pump efficiency	100%
Design leaving temperature	180°F
Design return temperature	160°F
Design loop temperature difference	20°F

The low-energy model incorporates a heating hot water supply (HHWS) temperature OA reset schedule (see Figure 6-10). Even though the supply temperature changes, the HHW pump still maintains a constant flow rate. A variable-speed pump would have modulated the flow rate to maintain the constant design loop temperature difference.

6.4.2 Chilled Water Pumps

ASHRAE 90.1-2004, Appendix G3.1.3.10 stipulates that the chilled water system comprise a primary and a secondary loop (see Table 6-25). The PC found that for chilled water plants in the size range for small hospital and healthcare facilities, the design community is shifting toward primary loop only. Therefore, the PC recommended a primary loop only configuration. The primary/secondary loop stipulation has become antiquated, as chiller manufacturers no longer dictate that the chiller water through the chiller evaporator maintain a constant flow rate. Typical minimum flow rate is 40% for a centrifugal chiller and 50% for a scroll or screw chiller. A more aggressive minimum flow rate is possible, but can have negative impacts on chiller operation and maintenance. The design leaving temperature and design return temperature are based on Air-Conditioning and Refrigeration Institute (ARI) Standard 550-590. The variable-speed pump modulates the flow rate to maintain the constant design loop temperature difference.

Table 6-25 Chilled Water Pump Performance Characteristics

Performance Characteristics	Baseline and Low-Energy
Capacity modulation	Variable speed
Rated pump head	60 ft w.c.
Motor efficiency	90%
Pump efficiency	100%
Design leaving temperature	44°F
Design return temperature	56°F
Design loop temperature difference	12°F

6.4.3 Condenser Water Pumps

The capacity modulation of the condenser water pump is not specifically stated in ASHRAE 90.1-2004, Appendix G3.1.3.11. The PC stated that variable-speed condenser pumps are by far the exception because of fears about the control of a cooling tower variable-speed fan and variable-speed condenser pump. Improved chilled water plant controls are now being implemented in conjunction with variable-speed cooling tower fans and condenser pumps that have shown energy savings without controllability or maintenance issues. Despite this proven capability, the PC recommended constant-speed condenser pumps because they are the typical design (see Table 6-26).

Table 6-26 Condenser Water Pump Performance Characteristics

Performance Characteristics	Baseline and Low-Energy
Capacity modulation	Constant speed
Rated pump head	60 ft w.c.
Motor efficiency	87%
Pump efficiency	100%
Design leaving temperature	85°F
Design return temperature	100°F
Design loop temperature difference	15°F

The PC also recommended a 15°F (8°C) condenser design loop temperature difference as the standard design practice for chilled water plants, instead of the 10°F (6°C) condenser loop temperature difference specified in ASHRAE 90.1-2004 Appendix G3.1.3.11. The intent is to reduce the condenser flow rate to reduce the condenser pump power draw, which can be substantial with at least 60 ft (18 m) of head pressure. With a constant-speed pump, all the condenser heat rejection is modulated by the cooling tower variable-speed fan. Section 6.9 reviews the design and operation of the cooling tower fan and condenser pump in further detail.

6.4.4 Domestic Hot Water Pumps

The domestic hot water loop is a primary-only loop served by a VFD pump. Table 6-27 reviews the performance characteristics of the domestic hot water pump. The motor efficiency derives from an approximation of a NEMA premium efficiency motor based on an estimation of the motor size.

Table 6-27 Domestic Hot Water Pump Performance Characteristics

Performance Characteristics	Baseline and Low-Energy
Capacity modulation	Variable speed
Rated pump head	60 ft w.c.
Motor efficiency	90%
Pump efficiency	100%
Design leaving temperature	140°F
Design return temperature	131°F
Design loop temperature difference	9°F

6.5 Economizers

Although ASHRAE 90.1 does not require economizers for systems that include nonparticulate air treatment, the PC recommended that small hospital and healthcare facilities typically incorporate them. Therefore, economizers were included in all climate zones (except those that are exempt in 90.1 because of extremely hot or humid conditions). ASHRAE 90.1-2007, Table 6.5.1 states that climate zones 1A, 1B, 2A, 3A, and 4A are not required to have economizers. Table 6-28 indicates which of the 15 climates included economizers for the critical CAV and noncritical VAV systems. Both the baseline and low-energy models had economizers, climate permitting, with identical control configurations.

Table 6-28 Climates Modeled With Economizers

Location	Climate Zone	Economizer
Miami, Florida	1A	–
Houston, Texas	1A	–
Phoenix, Arizona	2B	Yes
Memphis, Tennessee	3A	–
El Paso, Texas	3B	Yes
San Francisco, California	3C	Yes
Baltimore, Maryland	4A	–
Albuquerque, New Mexico	4B	Yes
Seattle, Washington	4C	Yes
Chicago, Illinois	5A	Yes
Boise, Idaho	5B	Yes
Burlington, Vermont	6A	Yes
Helena, Montana	6B	Yes
Duluth, Minnesota	7A	Yes
Fairbanks, Alaska	8A	Yes

The PC recommended that a fixed dry bulb economizer be used with a 65°F (18°C) change over temperature. Therefore, if the ambient dry bulb temperature exceeds 65°F (18°C), the OA flow rate modulates to the minimum set point. Although the ambient dry bulb temperature is less than or equal to 65°F (18°C), the OA damper will modulate between minimum and full open to try to meet the post-fan supply dry bulb temperatures specified in Table 6-29 before turning on the chilled water or DX cooling coil.

Table 6-29 Critical CAV and Noncritical VAV Supply Dry Bulb Temperatures

	Dry Bulb Temperature
Critical CAV supply	52°F
Noncritical VAV supply	55°F

6.6 Packaged Direct Expansion Systems

The small hospital and healthcare facilities addressed in the AEDG are typically ideal for packaged DX systems because their relatively small overall building sizes and expansive rooftop spaces provide a great deal of flexibility for locating the units. Packaged DX systems are commercially available in a large size range from single-compressor 5-ton (17.6 kW) units to multicompressor units reaching 500 tons (1,760 kW). More common units range from 70 to 150 tons (246 to 528 kW), coinciding with typical peak cooling demand for AHUs serving small hospital and healthcare facilities. This is true even in hot, humid climates such as Miami. Packaged DX units are typically installed in these facilities and therefore represent the baseline for the AEDG. Section 6.6.1 reviews the inputs that define the baseline and low-energy package DX units.

Unlike chilled water systems, which use water as a secondary heat transfer medium, packaged DX systems condition the air directly with an evaporator coil. The term *direct expansion* refers to the absence of a secondary medium. A packaged DX system increases its cooling capacity by adding DX circuits in parallel. Each DX circuit consists of one or more compressors, an evaporator coil in the supply air stream, and a condenser coil that rejects the heat to the ambient environment. Each DX circuit is its own closed loop. The individual evaporator coils are configured in interwoven or stacked arrangements in the supply air stream. Standard packaged DX systems modulate their cooling capacity by cycling on and off compressors depending on the cooling demand. However, improved capacity modulation technologies such as digital compressors—which may provide much greater control over the cooling provided—are beginning to enter the marketplace.

6.6.1 Packaged Direct Expansion Rated Performance Inputs

The packaged DX model in EnergyPlus uses full-load performance information at rated conditions based on ARI Standard 340-360, which specifies the rating conditions for packaged DX equipment up to 250 MBH (73 kW). However, there is no standard for units larger than 250 MBH (73 kW), so ARI Standard 340-360 has become the de facto standard for any packaged DX unit of 65 MBH (19 kW) or larger.

The full load performance information includes the total cooling capacity, sensible heat ratio (SHR), coefficient of performance (COP), and air volume flow rate. The rating conditions are 80°F (27°C) dry bulb and 67°F (19°C) wet bulb air entering the evaporator coil, 95°F (35°C) dry bulb air entering the condenser coil, and an air volume flow rate across the evaporator coil based on 350 cfm per ton (47 L/s per kW) of rated total cooling capacity. The rated air volume flow rate based on ARI Standard 340-360 can range from 300 to 450 cfm/ton (47 (L/s)/kW to 60 (L/s)/kW).

The rated COP is the only performance input that is hard entered into the model. Section 6.6.4 reviews the procedure to determine the rated COP; Section 6.6.5 reviews the rated COP specified in the baseline and low-energy models. The rated total cooling capacity and the air volume flow rate are autosized. The rated SHR is autocalculated based on the user-specified supply air conditions and the ARI Standard 340-360 rated inlet dry bulb and wet bulb temperature conditions.

6.6.2 Packaged Direct Expansion Modifier Curves

Modifier curves are empirical curves, based on manufacturer data, that capture performance at nonrated conditions. Five modifier curves are used to model packaged DX systems in EnergyPlus; the first four provide the actual total cooling capacity and COP based on the air temperature conditions, and air flow rates on the evaporator and condenser coil at each time step. These four curves account for the steady-state performance; a fifth accounts for the transient performance. EnergyPlus models the packages' DX system as having a variable-speed compressor with infinitely variable capacity. In reality, the system cycles on and off a discrete number of compressors to meet the cooling demand. Although EnergyPlus does not capture the over- and undercooling that occurs with cycling compressors to meet a partial load, the last modifier curve attempts to capture the degradation of system performance caused by compressor cycling.

The five curves are:

- The total cooling capacity modifier curve as a function of the wet bulb temperature of the air entering the evaporator coil and the dry bulb temperature of the air entering the condenser coil. The output is multiplied by the rated total cooling capacity to provide the total cooling capacity at the specific evaporator and condenser coil conditions.
- The total cooling capacity modifier curve as a function of the ratio of actual air flow across the evaporator coil to the rated air flow. The output of this curve is multiplied by the rated total cooling capacity to provide the total cooling capacity at the specific air flow rate across the evaporator coil.
- The energy input ratio (EIR, inverse of COP) modifier curve as a function of the wet bulb temperature of the air entering the evaporator coil and the dry bulb temperature of the air entering the condenser coil. The output of this curve is multiplied by the rated EIR to provide the EIR at the specific evaporator and condenser coil conditions.
- The EIR modifier curve as a function of the ratio of actual air flow across the evaporator coil to the rated air flow. The output of this curve is multiplied by the rated EIR to provide the EIR at the specific air flow rate across the evaporator coil.
- The EIR modifier curve as a function of the part-load ratio (PLR) (sensible cooling load divided by the steady-state sensible cooling capacity). The output of this curve is multiplied by the rated EIR to provide the EIR at the specific part-load condition to account for efficiency losses caused by compressor cycling.

Table 6-30 specifies the coefficients for these five modifier curves. These performance coefficients were fit from manufacturer data for a 2-compressor, 10-ton (35-kW) packaged rooftop unit. Although the packaged DX systems installed on small hospital and healthcare facilities are much larger built-up units—easily exceeding 70 tons (246 kW) with at least 4 DX circuits—the detailed manufacturer data necessary to create the empirical curves were not available.

Table 6-30 Packaged DX Rated Conditions Modifier Curves

Coefficients	Cooling Capacity f(Twb1*,Tdb2**)	Cooling Capacity f(FF3***)	EIR f(Twb1,Tdb2)	EIR f(FF3)	PLF f(PLR4****)
Constant	0.42415	0.77136	1.23649	1.20550	0.77100
x	0.04426	0.34053	–0.02431	–0.32953	0.22900
x^2	–0.00042	–0.11088	0.00057	0.12308	
y	0.00333	–	–0.01434	–	
y^2	–0.00008	–	0.00063	–	
xy	–0.00021	–	–0.00063	–	
Min x	17.0	0.75918	17.0	0.75918	0
Max x	22.0	1.13877	22.0	1.13877	1
Min y	13.0	–	13.0	–	–
Max y	46.0	–	46.0	–	–

* Twb1 is the wet bulb temperature of the air entering the evaporator coil
** Tdb2 is the dry bulb temperature of the air entering the condenser coil
*** FF3 is the ratio of the actual air flow rate across the evaporator coil to the rated air flow rate (flow fraction)
**** PLR represents the part-load ratio (sensible cooling load/steady state sensible cooling capacity)

6.6.3 Degradation of Latent Cooling Capacity

Extensive small packaged DX testing at the Florida Solar Energy Center (FSEC) reveals that moisture removed from the air while a compressor is on will cling to the evaporator coil and fins, only to be re-evaporated into the supply when the compressor shuts off (Shirey, 2006). The phenomenon is a transient effect and is called *latent degradation*. Packaged DX systems are much more susceptible to latent degradation, because the thermal capacity of an evaporator coil filled with refrigerant is significantly lower than that of a chilled water coil.

Figure 6-4 shows the sensible versus latent cooling of a DX coil test at FSEC over a 90-minute cycle in which the compressor is on for the first 45 minutes (Shirey et al. 2006). When the refrigeration compressor is on, the evaporator coil is sensibly cooling the incoming air and simultaneously condensing water out of the air, which is collecting on the coil and fin surface area. After 45 minutes, the compressor shuts off, and the supply fan continues to operate, causing the water coating the evaporator fin and coil to re-evaporate into the supply air. This negatively affects the packaged DX unit's performance because it reduces the equipment's ability to maintain proper indoor humidity levels.

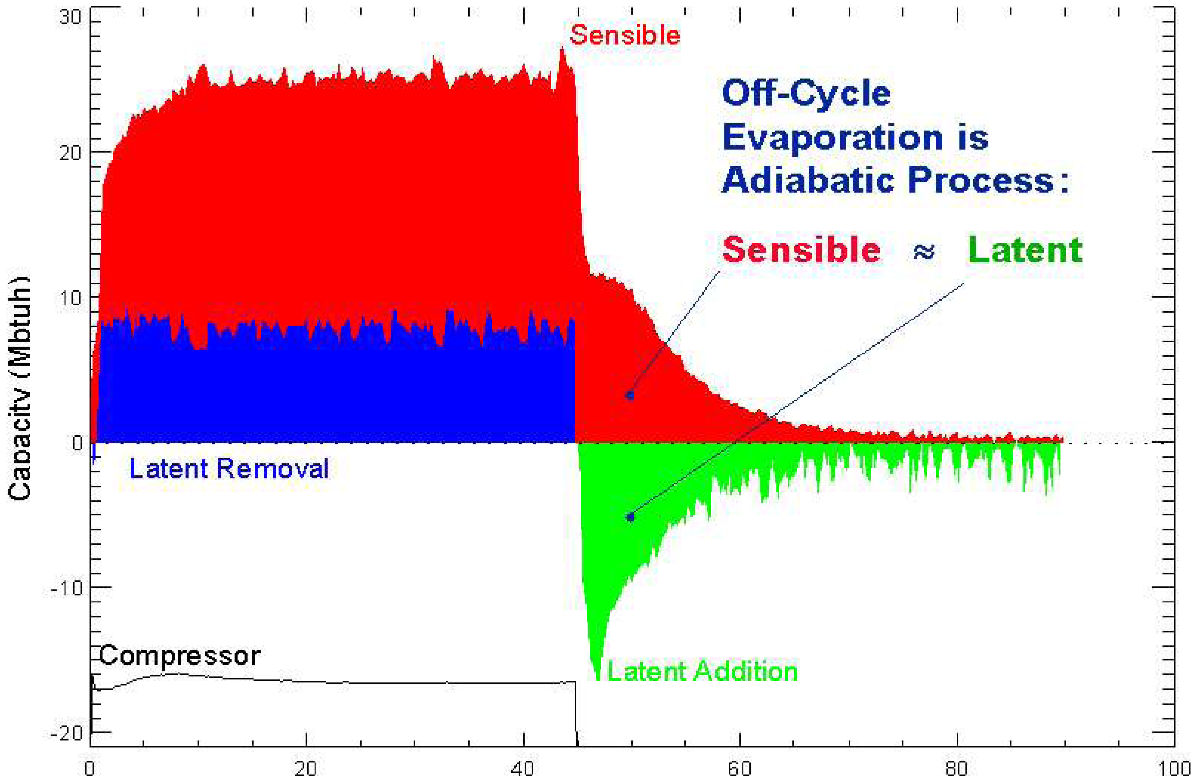


Figure 6-4 **Transient sensible and latent capacity of a cooling coil over an operating cycle**
Credit: EnergyPlus Engineering Reference

FSEC found that latent degradation is exacerbated by excessive cycling of compressors because the more a compressor cycles on and off, the more water is evaporated back into the supply air. Figure 6-5 (from FSEC field data) shows how increased compressor cycling of a single compressor DX unit (represented by runtime fraction on the x-axis) results in increased latent degradation represented by high SHRs (Shirey et al. 2006). Figure 6-5 indicates the importance of latent degradation showing that a runtime fraction less than 0.4 (a compressor that is on less than 40% of the time) provides no latent cooling.

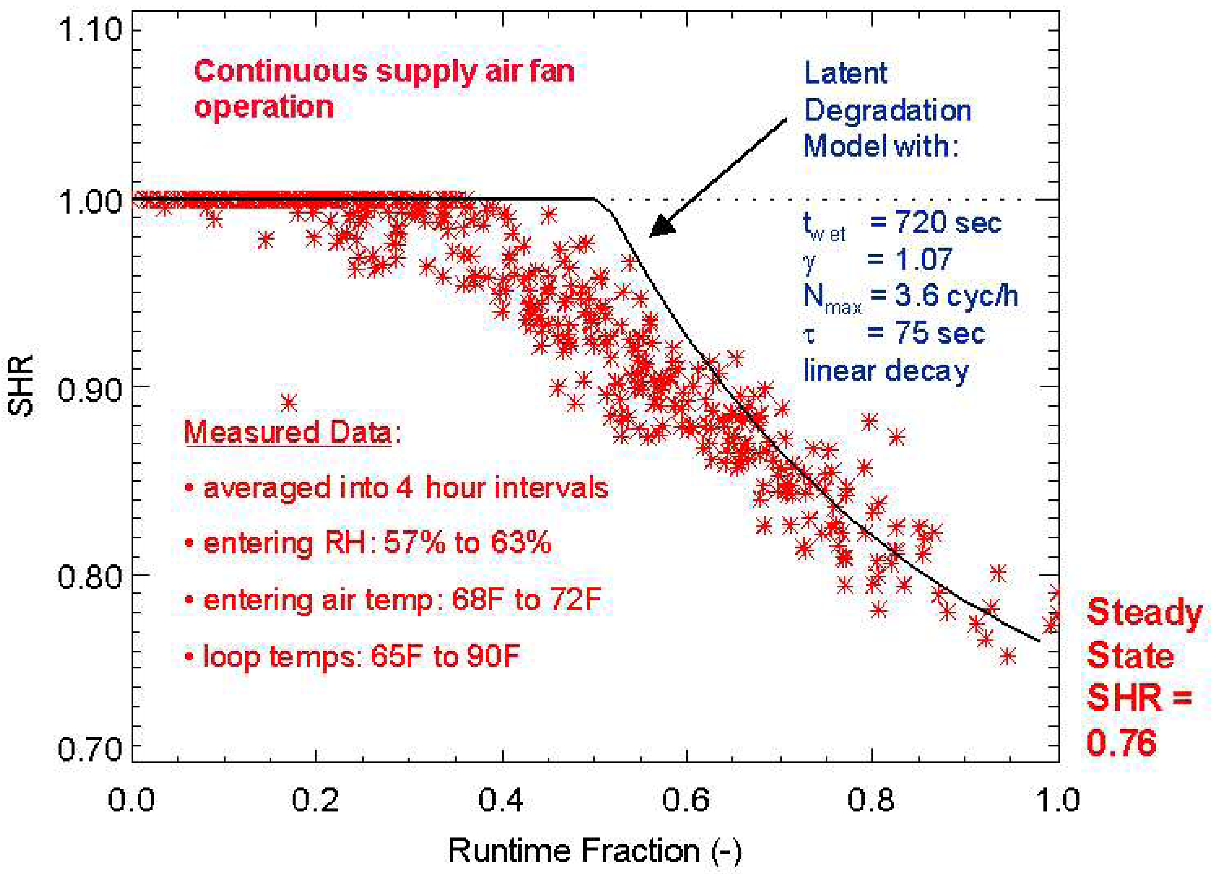


Figure 6-5 **Field data showing the net impact of part-load operation on SHR**
Credit: EnergyPlus Engineering Reference

Latent degradation is a greater problem for smaller packaged DX systems. The larger built-up systems used in small hospital and healthcare facilities are much less susceptible to latent degradation because (1) the units are sized more accurately with the actual cooling demand of the building, which reduces compressor cycling; (2) the controls of these units are more robust, with features such as more optimal time delays to further reduce compressor cycling; and (3) the units have at least four DX circuits in each packaged unit, so they can match the cooling demand more closely, thereby reducing the need for excessive compressor cycling.

Thus, the PC assumed the effect would be negligible and recommended that the packaged DX systems not be modeled with any latent degradation. However, the impact of neglecting latent degradation was not quantified at this time, and future study to verify this assumption is warranted. Further investigations, including testing large built-up units and collecting field data, are necessary to determine whether latent degradation should be considered in designing large DX mechanical systems for small healthcare facilities.

If it is determined that latent degradation should generally be included for small healthcare facilities (or if this effect should be modeled for specific projects), EnergyPlus can capture the degradation of latent cooling capacity. However, it can only do this when the supply air operates continuously while the compressors cycle on and off to meet the cooling load. The final four inputs into the EnergyPlus DX model provide a means of capturing the latent degradation of a DX unit. These inputs are:

- Nominal time for condensate removal defines the time (in seconds) after the startup of a compressor when the water condensing on the evaporator coil begins to drain.
- Ratio of initial moisture evaporation rate and steady-state latent capacity is the ratio of the initial moisture evaporation rate from the cooling coil when the compressor first turns off to the coil's steady-state latent capacity at rated conditions.
- Maximum cycling rate defines the maximum on-off cycling rate of the compressor occurring at a 50% runtime fraction.
- Latent capacity time constant is the time constant for the cooling coils' latent capacity to reach steady state after the compressor starts up.

6.6.4 Decoupling Supply Fan Power From Packaged System Energy Efficiency Ratio

Based on ASHRAE 90.1-1999, packaged systems exceeding 240 kBtu/h (70 kW) of net cooling capacity (gross cooling capacity minus the supply fan heat) must meet minimum efficiency rating requirements of 9.0 energy efficiency ratio (EER) and 9.2 integrated part-load value (IPLV). The EER performance metric includes the power draws of the compressor, the supply fan, and the condenser fan. Yet EnergyPlus models the supply fan separately from the compressor and the condenser fan. With PC guidance, we developed a standard method to calculate the EER of a packaged system that decouples the supply fan power and includes only the compressor and condenser fan power consumption. This method begins by determining the total power draw of the packaged system, including the compressor, the supply fan, and the condenser fan:

$$9.0\ EER = \frac{240{,}000\ Btu/h}{Power_{COMP,SUPPLY\ FAN,COND\ FAN}} \qquad 6\text{-}21$$

$$Power_{COMP,SUPPLY\ FAN,COND\ FAN} = 26{,}667\ W \qquad 6\text{-}22$$

Next, the supply fan power draw is calculated. With the help of the PC, we made assumptions about specifying 2.25 in. w.c. (560 Pa) as a typical internal pressure drop and 50% typical combined fan-motor-belt efficiency for a standard packaged DX unit. The external pressure drop of 0.75 in. w.c. (187 Pa) was based on Table 4 of the ARI Standard 340/360-2000, selecting the value for cooling capacities of 505,000 Btu/h (148 kW) or greater. A 7,000 (3,300 L/s) cfm flow rate was used, assuming 350 cfm/ton (47 (L/s)/kW) for a 240 kBtu/h (70kW) cooling capacity.

$$Power_{SUPPLY\ FAN} = \frac{7{,}000\ cfm\ \cdot (2.25\ in.w.c. + 0.75\ in.w.c.)}{6{,}356 \frac{ft^3 - in.w.c.}{min} \cdot 0.00134 \frac{bhp}{W} \cdot 50\%} \qquad 6\text{-}23$$

$$Power_{SUPPLY\ FAN} = 4{,}931\ W \qquad 6\text{-}24$$

Third, the supply fan power draw was subtracted from the total packaged unit.

$$Power_{COMP,COND\ FAN} = 26{,}667\ W - 4{,}931\ W = 21{,}736\ W \qquad 6\text{-}25$$

Lastly, a new EER was calculated that included only the compressor and condenser fan power draws.

$$EER = \frac{240{,}000\ Btu/h}{21{,}736\ W} = 11.0 \qquad 6\text{-}26$$

EnergyPlus treats the supply fan separately, so the value of 11.0 is the input desired in this case. The EER varies significantly, depending on whether the supply fan is excluded, and an incorrect selection would add error to the simulation results.

6.6.5 *Packaged System Full-Load Performance at Rated Conditions*

The methodology to decouple supply fan power from the packaged system performance was repeated for the low-energy model. Table 6-31 reviews the packaged system EER before and after the supply fan power was decoupled. EnergyPlus uses COP instead of EER to define the packaged system performance at full load, so Table 6-31 also specifies the COP used in the models. Table 6-32 includes the minimum EER and ILPV performance.

Table 6-31 Packaged System Rated Full-Load Performance

Coefficients	Baseline	Low-Energy
EER with supply fan	9.0	10.0
EER without supply fan	11.0	12.6
COP without supply fan	3.24	3.69

Table 6-32 Packaged System Minimum EER and IPLV Performance for ASHRAE 90.1

	ASHRAE 90.1 1999	ASHRAE 90.1 2004	ASHRAE 90.1 2007	ASHRAE 90.1 2010
EER	9.0	9.0	9.0	9.5
IPLV	9.2	9.2	9.2	9.2
Size	> 240,000 Btu/h	> 760,000 Btu/h	> 760,000 Btu/h	> 760,000 Btu/h

6.7 Air-Cooled Chiller Systems

The following sections review the performance and operational characteristics of the air-cooled chiller as one low-energy cooling option. We were able to model scroll and screw chillers. After evaluating several metrics, we chose the scroll air-cooled chiller for the low-energy model because of its higher performance at part-load conditions.

6.7.1 *Scroll Versus Screw Compressors*

The PC indicated that the choice between using a scroll or screw air-cooled chiller typically depends on the cooling capacity required. Commercially available scroll compressors are making inroads into larger systems—some even approaching 400 tons (1,407 kW)—but designers generally specify scroll chillers for systems smaller than 80 tons (281 kW) and screw chillers systems larger than 80 tons (281 kW). However, small healthcare cooling capacities fall in a range overlapped by both chiller types. Table 6-33 shows the typical cooling capacity ranges of commercially available air-cooled scroll and screw chillers. The overlapped range of 80 to 200 tons (281 to 1,407 kW) perfectly coincides with the cooling capacities needed by small hospital and healthcare facilities. Consequently, air-cooled scroll and screw chillers were applicable, so the PC did not have a preference.

Table 6-33 Operational Characteristics of Air-Cooled Scroll and Screw Chillers

	Scroll Chillers	Screw Chillers
Typical size ranges	20–200 tons	80–500 tons
Capacity modulation	Compressor cycling	Slide valve
Minimum PLR	Cycling limitation of a single compressor	15%
Minimum number of compressors	4	2

Cooling capacity was not sufficient to dictate which chiller type to use, so we compared the performance and operational characteristics. Concerning capacity modulation, screw chillers use a slide valve that permits infinitely variable capacity between minimum PLR, typically 15%, and full load. Scroll chillers, on the other hand, modulate capacity identically to packaged DX units by cycling a discrete number of compressors. Yet, compared to DX units, the frequency of cycling and potential for under- or overcooling is significantly mitigated because the chilled water loop has a large thermal capacitance. Designers sometimes add a tank onto the chilled water loop to add thermal capacity and maintain a more constant water temperature. Therefore, the capacity control of the screw chiller was not decisively preferable to that of the scroll chiller.

The air-cooled scroll chiller was chosen because its optimal performance at 30% to 60% PLRs (see Section 6.7.3) coincides with the fact that chillers predominantly operated at PLRs below 80% throughout the year. Air-cooled screw chillers (see Section 6.7.4) experience their optimum performance at 80% to 100% PLR.

6.7.2 Chiller Modifier Curves

The air- and water-cooled chiller models in EnergyPlus are nearly identical. The only difference is that the air-cooled condensing temperature is based on the ambient dry bulb and the water-cooled condensing temperature is based on the condenser water temperature provided from the cooling tower. Similar to the packaged DX model, the chiller model uses empirical curves generated from manufacturer data to modify the cooling capacity and efficiency at rated conditions. The capacity and COP are based on a 44°F (7°C) chilled water supply (CHWS) temperature and 95°F (35°C) ambient dry bulb condenser supply temperature in accordance with ARI Standard 550-590. Curve fits are then used to determine the cooling capacity and efficiency at nonrated conditions. The three curve fits are:

1. The total cooling capacity modifier curve as a function of the exiting chilled water temperature and the entering ambient dry bulb condensing temperature. The output is multiplied by the rated total cooling capacity to provide the total cooling capacity at the specific evaporator and condenser coil conditions.
2. The EIR modifier curve as a function of the exiting chilled water temperature and the entering ambient dry bulb condensing temperature. The output is multiplied by the rated EIR to provide the EIR at the specific evaporator and condenser coil conditions.
3. The EIR modifier curve as a function of the PLR (actual cooling load divided by the chiller’s available cooling capacity). The output is multiplied by the rated EIR to provide the EIR at the specific PLR at which the chiller operates.

Section 6.7.3 reviews the empirical curves used for the scroll chillers; Section 6.7.4 reviews those used for the screw chillers.

6.7.3 Air-Cooled Scroll Chiller Performance

The empirical curves shown in Table 6-34 were developed from the manufacturer's performance data for a 60-ton (211 kW) scroll chiller. Table 6-35 shows the full load and IPLV performance as a result of the scroll chiller empirical curves. With the same full-load 10.0 EER specified in the AEDG recommendation table, the empirical curves produce a 16.1 IPLV, which is much higher than the 11.5 IPLV in the AEDG recommendation table. The higher IPLV indicates that commercially available air-cooled scroll chillers can achieve much greater part-load performance than the PC anticipated. Figure 6-6 shows the scroll chiller performance map based on the empirical curves. The chiller performance map indicates that the scroll chiller performs optimally at 30% to 60% PLR.

Table 6-34 Scroll Air-Cooled Chiller Rated Conditions Modifier Curves

Coefficients	Cooling Capacity f(CHWS*,CWS**)	EIR f(CHWS,CWS)	EIR f(PLR)
Constant	1.05E+00	5.83E-01	4.19E-02
x	3.36E-02	-4.04E-03	6.25E-01
x^2	2.15E-04	4.68E-04	3.23E-01
y	–5.18E-03	–2.24E-04	–
y^2	–4.42E-05	4.81E-04	–
xy	–2.15E-04	–6.82E-04	–
Min x	0.0	0.0	0.0
Max x	20.0	20.0	1.2
Min y	0.0	0.0	–
Max y	50.0	50.0	–

* Chilled water supply

** Condenser water supply

Table 6-35 Scroll Air-Cooled Chiller Performance at ARI Rated Conditions

PLR	CHWS Temperature	Condenser Supply Temperature	Model Performance	AEDG Recommendations
100%	44°F	95°F	10.0 EER	10.0 EER
75%	44°F	80°F	13.7 EER	–
50%	44°F	65°F	17.6 EER	–
25%	44°F	55°F	19.1 EER	–
			16.1 IPLV	11.5 IPLV

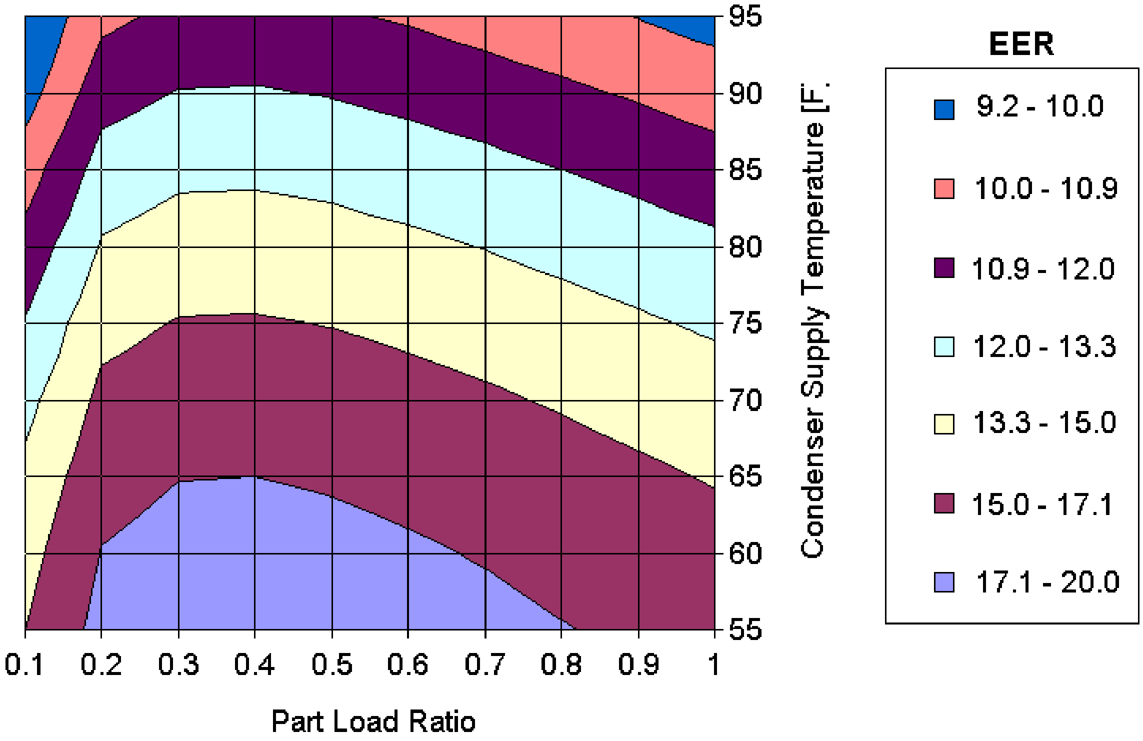


Figure 6-6 Scroll air-cooled chiller performance map with a constant 44°F CHWS

6.7.4 Air-Cooled Screw Chiller Performance

The empirical curves shown in Table 6-36 were developed from the manufacturer's performance data for a 144-ton (506-kW) screw chiller. Table 6-37 shows the full-load and IPLV performance as a result of the screw chiller empirical curves. With the same full-load 10.0 EER specified in the AEDG recommendation table, the empirical curves produce a 12.9 IPLV, which is slightly higher than the 11.5 IPLV in the AEDG recommendation table. Figure 6-7 shows the screw chiller performance map based on the empirical curves. Unlike the scroll chiller, the optimum performance of the screw chiller occurs at 80% to 100% PLR.

Table 6-36 Screw Air-Cooled Chiller Performance at ARI Rated Conditions

PLR	CHWS	CWS	Model Performance	AEDG Recommendations
100%	44°F	95°F	10.0 EER	10.0 EER
75%	44°F	80°F	12.1 EER	–
50%	44°F	65°F	13.6 EER	–
25%	44°F	55°F	13.0 EER	–
			12.9 IPLV	11.5 IPLV

Table 6-37 Screw Air-Cooled Chiller Rated Conditions Modifier Curves

Coefficients	Cooling Capacity f(CHWS,CWS)	EIR f(CHWS,CWS)	EIR f(PLR)
Constant	1.06E+00	5.99E-01	7.27E-02
x	5.07E-02	–1.12E-02	9.53E-01
x^2	–7.70E-05	5.10E-04	–2.66E-02
y	–6.69E-03	3.71E-03	–
y^2	–6.16E-05	3.40E-04	–
xy	–3.60E-04	–4.07E-04	–
Min x	0.0	0.0	0.0
Max x	20.0	20.0	1.2
Min y	0.0	0.0	–
Max y	50.0	50.0	–

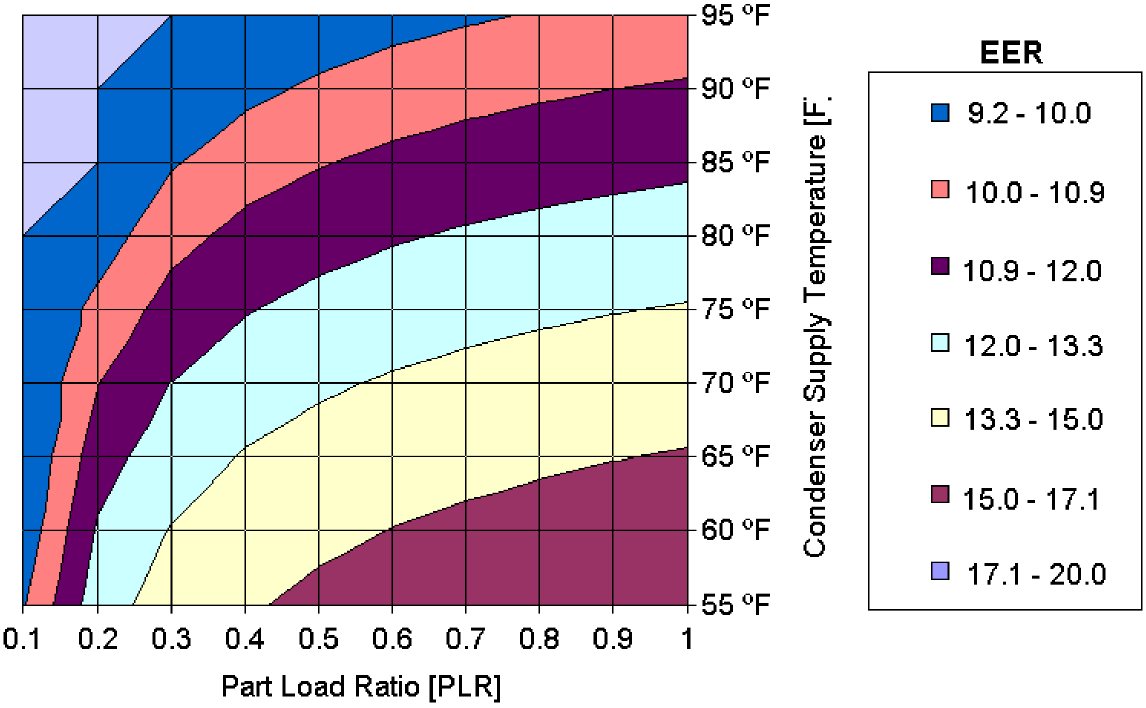


Figure 6-7 Screw air-cooled chiller performance map with a constant 44°F CHWS

6.7.5 ASHRAE 90.1 Minimum Performance Requirements

For reference purposes, Table 6-38 provides the minimum EER and IPLV for air-cooled chillers based on the different versions of ASHRAE 90.1.

Table 6-38 Air-Cooled Chiller Minimum EER and IPLV Performance for ASHRAE 90.1

	ASHRAE 90.1-1999	ASHRAE 90.1-2004	ASHRAE 90.1-2007	ASHRAE 90.1-2010
EER/IPLV*	9.6/9.6	9.6/10.4	9.6/10.4	9.6/10.4
COP/IPLV**	2.80/2.80	2.80/3.05	2.80/3.05	2.80/3.05
Compressor type	Any	Any	Any	Any
Size	All capacities	All capacities	All capacities	All capacities

* EER/IPLV is based on ratio of cooling provided to power draw by the compressors and condenser fans.

** COP/IPLV is a conversion of the EER/IPLV numbers in the previous row.

6.8 Water-Cooled Chiller Systems

The following sections review the performance and operational characteristics of the water-cooled chiller as a low-energy cooling option.

6.8.1 Compressor Type

Water-cooled chillers are available with scroll, screw, and centrifugal compressors. Centrifugal chillers are too large for small hospitals and healthcare facilities, because they have a starting capacity of approximately 170 tons (598 kW). Although scroll and screw chillers fall in the right size range, the PC stated that screw chillers have become the standard for water-cooled chillers in small hospitals and healthcare facilities (see Table 6-39). Therefore, the PC recommended the screw water-cooled chiller.

Table 6-39 Size Range and Operational Characteristics Comparison of Water-Cooled Chillers

	Scroll Chillers	Screw Chillers	Centrifugal Chillers
Typical size ranges	30–200 tons	70–500 tons	170–8500 tons
Capacity modulation	Compressor cycling	Slide valve	Inlet vanes or VFD
Minimum PLR	Cycling limitation of a single compressor	15%	15%
Minimum number of compressors	2	2	1

6.8.2 Water-Cooled Chiller Modifier Curves

The water-cooled chiller model in EnergyPlus is identical to the air-cooled chiller model, except that the condensing temperature of the water-cooled chiller is based on condenser water from a cooling tower rather than the ambient dry bulb. The capacity and COP are based on a 44°F (7°C) CHWS temperature and 85°F (29°C) condenser water supply (CWS) temperature, in accordance with ARI Standard 550-590.

Curve fits are then used to determine the cooling capacity and efficiency at nonrated conditions. The three curve fits are:

- The total cooling capacity modifier curve as a function of the exiting chilled water temperature and the entering condenser water supply temperature. The output is multiplied by the rated total cooling capacity to provide the total cooling capacity at the specific evaporator and condenser coil conditions.
- The EIR modifier curve as a function of the exiting chilled water temperature and the entering condenser water supply temperature. The output is multiplied by the rated EIR to provide the EIR at the specific evaporator and condenser coil conditions.
- The EIR modifier curve as a function of the PLR (actual cooling load divided by the chiller's available cooling capacity). The output is multiplied by the rated EIR to provide the EIR at the specific PLR at which the chiller is operating.

Section 6.8.3 reviews the empirical curves used for the water-cooled screw chiller.

6.8.3 Screw Water-Cooled Chiller Performance

The chiller empirical performance curves in Table 6-41 were obtained from manufacturer's performance data for a 200-ton (703 kW) water-cooled screw chiller. Table 6-42 compares the full load and IPLV performance between the modeled water-cooled chiller and the performance values recommended in the AEDG. Unlike the air-cooled chiller case, for which performance values are recommended for the full load and IPLV, the AEDG recommendation table states that water-cooled chillers must "comply with ASHRAE 90.1." This means the user must meet the more stringent of either the applicable version of Standard 90.1 or the local code requirement. For reference purposes, Table 6-42 provides the full load and IPLV based on an ASHRAE 90.1-2007 water-cooled screw or scroll chiller smaller than 150 tons (528 kW). With the same full-load 15.2 EER, the empirical curves produce a 19.9 IPLV that is slightly higher than the ASHRAE Standard 90.1-2007 IPLV of 17.7.

Table 6-40 Screw Water-Cooled Chiller Rated Conditions Modifier Curves

Coefficients	Cooling Capacity f(CHWS,CWS)	EIR f(CHWS,CWS)	EIR f(PLR)
Constant	1.07E+00	4.68E-01	1.41E-01
x	4.29E-02	–1.38E-02	6.55E-01
x^2	4.17E-04	6.98E-04	2.03E-01
y	–8.10E-03	1.09E-02	–
y^2	–4.02E-05	4.62E-04	–
xy	–3.86E-04	–6.82E-04	–
Min x	0.0	0.0	0.0
Max x	20.0	20.0	1.2
Min y	0.0	0.0	–
Max y	50.0	50.0	–

Table 6-41 Screw Water-Cooled Chiller Performance at ARI Rated Conditions

PLR	CHWS Temperature	CWS Temperature	Model Performance	AEDG Recommendations*
100%	44°F	85°F	15.2	15.2
75%	44°F	75°F	18.5	–
50%	44°F	65°F	21.5	–
25%	44°F	65°F	19.0	–
			19.9	17.7

Figure 6-8 shows the water-cooled screw chiller performance map based on the empirical curves while maintaining a constant 44°F (7°C) CHWS. Figure 6-7 shows that the water-cooled screw chiller performs similarly to the air-cooled screw chiller, achieving optimal performance near full load. Yet the water-cooled screw chiller achieves an optimal performance over a larger PLR range of 60% to 100% and the air-cooled screw chiller reaches its optimal performance over a narrower PLR range of 80% to 100%. A shared disadvantage is that both operate most of the year below their optimal PLR.

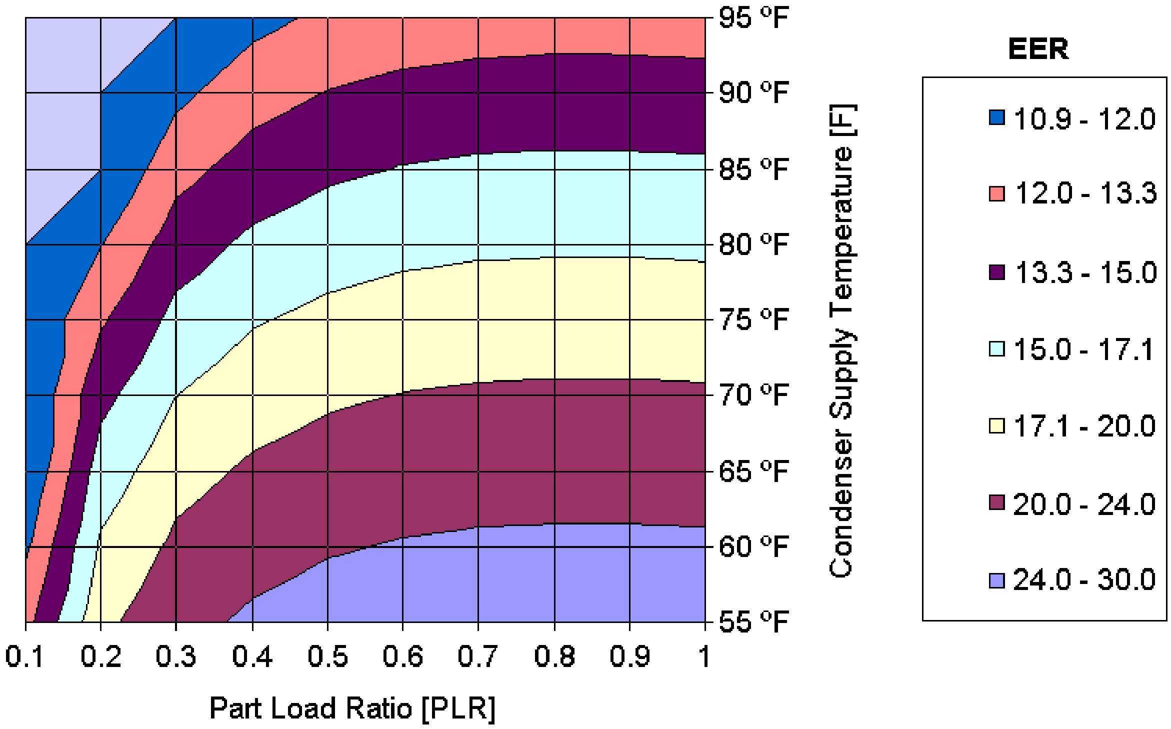


Figure 6-8 **Screw water-cooled chiller performance map with a constant 44°F CHWS**

6.8.4 Water-Cooled Chiller Minimum Energy Efficiency Ratio and Integrated Part-Load Value Performance for ASHRAE 90.1

Table 6-42 provides the minimum EER and IPLV for air-cooled chillers smaller than 150 tons (528 kW); Table 6-43 provides these values for chillers 150 to 300 tons (528 to 1,055 kW), based on the different versions of ASHRAE 90.1.

Table 6-42 **Water-Cooled Screw or Scroll Chiller Minimum EER and IPLV Performance**

	ASHRAE 90.1-1999	ASHRAE 90.1-2004	ASHRAE 90.1-2007	ASHRAE 90.1-2010
EER/IPLV*	15.2/15.4	15.2/17.7	15.2/17.7	15.2/17.8
COP/IPLV**	4.45/4.50	4.45/5.20	4.45/5.20	4.45/5.22
Compressor type	Screw/scroll	Screw/scroll	Screw/scroll	Screw/scroll
Size	< 150 tons	< 150 tons	< 150 tons	< 150 tons

* EER/IPLV is based on ratio of cooling provided to power draw by the compressors and condenser fans.

** COP/IPLV is a conversion of the EER/IPLV numbers in the previous row.

Table 6-43 **Water-Cooled Screw or Scroll Chiller Minimum EER and IPLV Performance for ASHRAE 90.1**

	ASHRAE 90.1-1999	ASHRAE 90.1-2004	ASHRAE 90.1-2007	ASHRAE 90.1-2010
EER/IPLV*	16.7/16.9	16.7/19.1	16.7/19.1	16.7/19.1
COP/IPLV**	4.90/4.95	4.90/5.60	4.90/5.60	4.90/5.60
Compressor type	Screw/scroll	Screw/scroll	Screw/scroll	Screw/scroll
Size	≥ 150 tons and < 300 tons	≥ 150 tons and < 300 tons	≥ 150 tons and < 300 tons	≥ 150 tons and < 300 tons

* EER/IPLV is based on ratio of cooling provided to power draw by the compressors and condenser fans

** COP/IPLV is a conversion of the EER/IPLV numbers in the previous row.

6.9 Cooling Tower Systems

The cooling tower plays an integral role in the performance of the chiller and the entire chilled water plant, as the cooling tower can consume significant energy. Improperly balanced and controlled chilled water plants sometimes consume more energy from the cooling tower than the chiller at lower part loads. Based on the PC recommendation, a single open cooling tower is connected to the chiller. The open configuration provides a lower approach (difference between the cooling tower leaving condenser water temperature and ambient wet bulb temperature) and lower cost (less copper and lighter weight) than those of a closed cooling tower (fluid cooler).

6.9.1 Cooling Tower Design and Operational Criteria

Table 6-44 compares the cooling tower design and operational criteria between ASHRAE 90.1-2004 Appendix G and the AEDG model based on the PC recommendations. The fan modulation—and therefore capacity modulation—of the cooling tower are based on a VFD controlling the fan speed. The ASHRAE 90.1 dual-speed criterion is antiquated, because VFDs provide greater control, are cheaper, and achieve much lower sound pressure levels. The PC recommended that the cooling tower fan be able to ramp down to a 20% minimum air flow ratio. Both ASHRAE 90.1-2004 and the AEDG model use the same sizing strategy: achieve a 7°F (4°C) approach to provide 85°F (29°C) CWS with a 78°F (26°C) ambient wet bulb.

Table 6-44 Comparison of Cooling Tower Design and Operational Criteria

	ASHRAE 90.1 2004	AEDG Recommendations
Configuration	Open tower	Open tower
Fan modulation	Dual speed	VFD
Design CWS set point	85°F	85°F
Design ambient wet bulb	78°F	78°F
Design approach	7°F	7°F
Design cw flow	2.4 gpm/ton	1.6 gpm/ton
Design range	10°F	15°F
CW flow modulation	Constant	Constant
Operational CWS set point	70°F	70°F

Another major deviation from ASHRAE 90.1-2004 was the design condenser water flow rate. The PC recommended a 1.6 gpm/ton (0.03 (L/s)/kW) flow rate (30% lower than the 2.4 gpm/ton (0.04 (L/s)/kW) flow rate specified in ASHRAE 90.1-2004, referenced from ARI Standard 550-590). As a result, the AEDG cooling tower range (difference between the cooling tower entering and exiting condenser water temperatures) is 5°F (3°C) higher than for 90.1-2004. The intent of the AEDG approach is to minimize the condenser pump energy, which can be substantial—especially for an open cooling tower—because an open cooling tower condenser pump must provide sufficient head to overcome the internal pressure drop and the ambient pressure. A typical condenser pump can experience 60 to 75-ft (18 to 23-m) head. Therefore, the condenser pump, which is operated at a constant flow rate, can consume a great deal of energy. By lowering the condenser water flow rate by 30%, however, the PC significantly reduces the condenser pump power draw. Section 6.4 reviews the condenser pump design and operation in more detail.

Although most water-cooled chillers can operate at lower condenser water temperatures (typical minimum is 55°F [13°C]), the PC recommended that the cooling tower operate in a manner that maintains a 70°F (21°C) CWS temperature set point in accordance with ASHRAE 90.1.

Although lower condenser water temperatures would improve the performance of the chiller (see Figure 6-8), condenser water temperatures that are too low would compromise the chiller's ability to maintain the proper pressure differential between its evaporator and condenser sides, resulting in refrigerant back flow.

6.9.2 Cooling Tower Model

The variable-speed cooling tower model in EnergyPlus is similar to the chiller model. The cooling tower performance is specified at design conditions, and empirical curves fits are used to determine the approach temperature and fan power at off-design conditions. Table 6-44 reviews the specified model performance at design conditions, which include the inlet air wet bulb temperature, range, and approach. The cooling tower design water flow rate, air flow rate, and fan power are then auto-calculated using these design conditions. DOE (2009) reviews the calculation procedure for determining the design air flow rate and fan power.

The model accounts for the tower performance in the "free convection" regime, which occurs at low ambient wet bulb conditions where the CWS set point can be achieved while the tower fan is off. The cooling tower model was simulated to switch into the free convection regime once the cooling demand on the tower was less than or equal to 12.5% of its rated capacity. The model can simulate basin water heater operation, but the PC recommended that it be turned off.

The EnergyPlus calculation procedure begins by using the empirical curves to calculate the cooling tower approach for each time step using the following independent variables:

- Air flow rate ratio (actual air flow rate/design air flow rate)
- Water flow rate ratio (actual water flow rate/design water flow rate)
- Cooling tower range
- Ambient wet bulb temperature.

EnergyPlus provides two empirical correlations, CoolTools and YorkCalc. The user can then choose predefined coefficients for the selected empirical correlation or define coefficients based on manufacturer's performance data. We chose the CoolTools empirical correlation, because our contact with one of its authors and the availability of an *ASHRAE Transactions* paper reviewing its methodology (Benton et al. 2002) has provided us considerable understanding of its methodology. The predefined EnergyPlus-embedded CoolTools empirical coefficients were used because the manufacturer's performance data necessary to create a new set of user-defined coefficients was not available. These embedded empirical curve coefficients are published in DOE (2009). The next step in the EnergyPlus calculation procedure is to determine the necessary cooling tower fan speed based on the calculated approach temperature and the CWS set point. Although the cooling tower is sized based on an 85°F (29°C) CWS set point, it is operated in a manner that maintains a 70°F (21°C) CWS set point. DOE 2009 reviews the internal algorithm used to determine the cooling tower fan speed necessary to maintain the CWS temperature at or below 70°F (21°C). If the ambient wet bulb is too high, the cooling tower will operate the fan at full speed, but the CWS temperature will exceed 70°F (21°C).

Table 6-45 shows the fan PLF curve used to calculate the fan power ratio at each time step, based on the cooling tower fan air flow ratio. The resulting fan power ratio is multiplied by the design fan power to give the fan power at each time step.

Table 6-45 Fan PLF Curve

Coefficients	Cooling Tower Fan
C1	–0.0093
C2	0.0512
C3	–0.0838
C4	1.0419

6.10 Boilers

6.10.1 Baseline Model

The baseline heating system consisted of an atmospheric (noncondensing) boiler on a primary-only loop with a variable-speed pump. The HHWS temperature was maintained at a constant 180°F (82°C). The HHWR temperature varied depending on the load, but was not allowed to drop below 150°F (66°C). The 150°F (66°C) minimum HHWR temperature provided a 10°F (6°C) safety factor, ensuring that the boiler would not experience HHWR of 140°F (60°C) or below, at which point flue gases would begin to condense. This would be disastrous to a noncondensing boiler, destroying both the boiler and the flue.

ASHRAE 90.1-1999, Table 6.2.1F mandates that a gas-fired boiler greater than 300,000 Btu/h (88 kW) and less than 2,500,000 Btu/h (733 kW) must have a minimum 80% combustion efficiency (E_c) and 75% E_t, based on the Hydronics Institute Boiler Standard. The E_c accounts for only the flue losses. The E_t accounts for both the flue losses and the losses incurred in the conductive/convective/ radiative heat transfer between the hot combustion gas/flame and the heating hot water. Therefore, E_t was used in the model because it captures the total efficiency of the boiler. In ASHRAE 90.1-2004 Table 6.8.1F, the minimum E_c was eliminated. This left only a minimum 75% E_t requirement and still referenced the Hydronics Institute Boiler Standard.

Based on recommendations of the PC, we modeled the baseline boiler with a 78% E_t at full load. Boiler efficiency is a function of HHWR temperature and PLR. The HHWS temperature was kept constant and the variable-speed pump modulated to maintain a near-constant HHWR temperature, so the part-load E_t was strictly a function of the part-load operation of the boiler. Unfortunately, there is currently no part-load boiler rating standard, which is incredibly important considering that boilers, like other primary systems, operate most of the time well under their fully loaded condition. The ASHRAE Standard 155P committee is currently working to implement a minimum adjusted seasonal boiler system performance into ASHRAE 90.1.

The baseline boiler performance curve as a function of PLR (see Figure 6-9) was obtained from a library of boiler performance curves that are packaged with EnergyPlus. The performance curve was compared against available manufacturers' data and was approved by the PC. Compared with a condensing boiler, the baseline part-load performance curve shows that the E_t degrades at lower part-load operation.

Atmospheric boilers cannot achieve a low part-load operation to prevent condensation. Although the minimum part-load operation varies widely across manufacturers, the PC specified a minimum 0.4 part-load operation. Unfortunately, EnergyPlus cannot model performance degradation caused by cycling. To compensate, the performance curve in EnergyPlus accounts for this degradation by having the E_t degrade quickly under a 0.4 part-load operation (see Figure 6-9). Table 6-46 shows necessary inputs into EnergyPlus used to model the baseline atmospheric boiler.

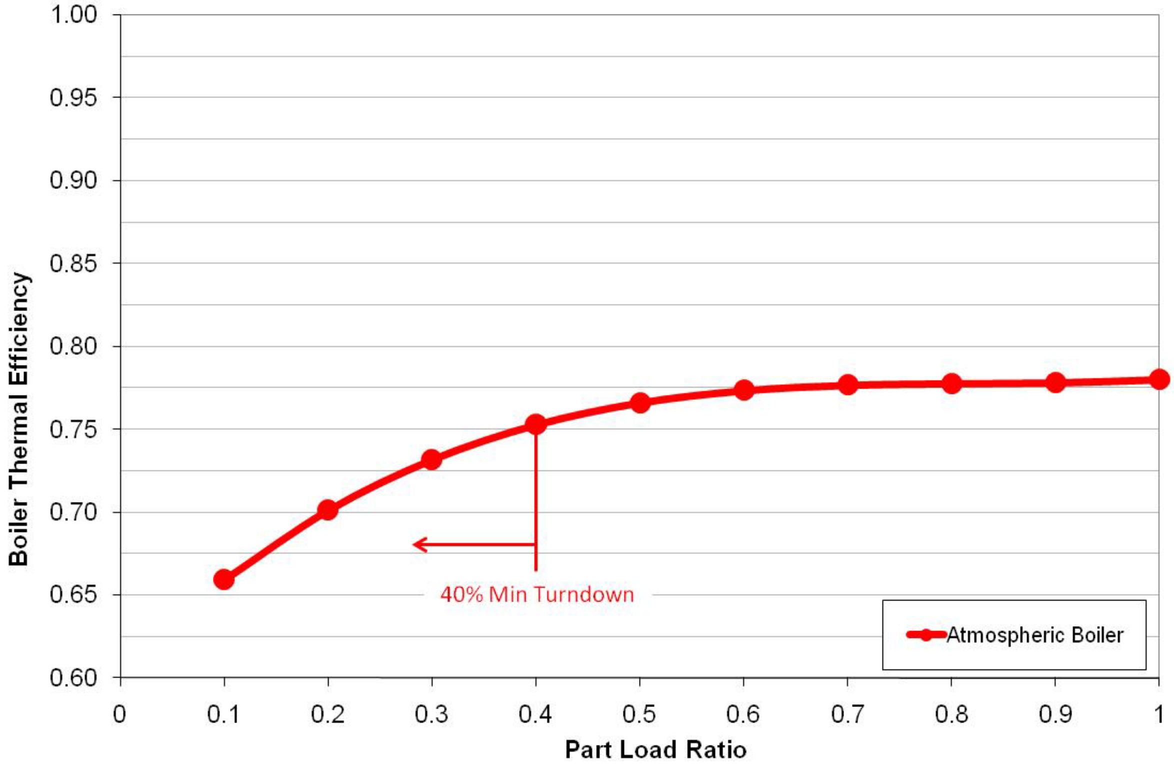


Figure 6-9 Baseline boiler part load curves

Table 6-46 Baseline Boiler EnergyPlus Input Performance Curves

EnergyPlus Input Data	Baseline Boiler
Nominal E_t	0.96
Coefficient 1: Constant	0.6264
Coefficient 2: x	0.6456
Coefficient 3: x^2	–0.7772
Coefficient 4: x^3	0.3138
Minimum PLR	0.1
Maximum PLR	1.0

The Hydronics Institute Boiler Standard official title is *BTS-2000 Testing Standard: Method to Determine Efficiency of Commercial Space Heating Boilers*. It is published by The Hydronics Institute, a division of ARI. The testing standard measures the E_t of the boiler at steady-state operation, fully loaded, and maintains the outlet temperature at 180°F (82°C). Oddly, the testing standard specifies that the inlet water temperature into the boiler be 35° to 80°F (2° to 27°C), which is much lower than the typical HHWR temperature of 150°F (66°C). Consequently, by using colder inlet temperatures, calculations based on the testing standard likely overstate the E_t of a typical boiler. In other words, a noncondensing boiler tested using this standard would most likely condense with such cold HHWR temperatures and artificially overstate its E_t.

Based on various manufacturers' published data, a boiler operating with an 80°F (27°C) HHWR temperature achieves a 10% greater E_t compared with operating at the more typical 150°F (66°C). Additionally, if operating at a 35°F (2°C) return water temperature, the E_t would be boosted even further. Therefore, an item of concern is whether an atmospheric boiler that complies with the ASHRAE 90.1 minimum 75% E_t under BTS-2000 testing conditions would actually operate at 65% or lower thermal under more typical operating conditions.

6.10.2 Low-Energy Model

The low-energy heating system configuration was nearly identical to the baseline with a single boiler in a primary-only loop connected to a variable-speed pump. However, in the low-energy model, a condensing boiler replaced the atmospheric boiler. The two main benefits of a condensing boiler are its significantly higher thermal efficiencies, especially at low part-load operations, and ability to reduce to a lower PLR. Often overlooked, however, is that a condensing boiler will provide higher efficiencies than an atmospheric boiler only when the HHWR temperature drops below 140°F (60°C) and the water begins to condense in the flue.

Although PLR affects boiler performance, the main efficiency gains are realized when the HHWR temperature is aggressively dropped. One way that low HHWR temperatures can be realized by using low HHWS temperature. Yet how low the HHWS temperature can be dropped is limited by the HHW reheat coils in the terminal boxes, which need to maintain a certain log mean temperature difference above the incoming air to provide enough heat. This is especially a concern in perimeter zones where the incoming air sometimes needs to be heated from 55°F (13°C) to at least 95°F (35°C). One solution is to install two-row reheat coils serving perimeter zones to increase the surface area of the coil. For cold locations, a two-row reheat coil is often not enough and the HHWS and HHWR temperatures need to be high, which prevents the condensing boiler from condensing.

One method of allowing the boiler to condense without compromising its ability to sufficiently heat perimeter zones is to implement an OA HHWS temperature reset schedule (see Figure 6-10). The reset schedule maintains a higher HHWS temperature when it is cold ambient dry bulb and the reheat coils need a considerable amount of heat. Then, as the ambient dry bulb warms, the HHWS temperature can slowly decrease, which in turn decreases the HHWR temperature. Once the HHWR temperature drops below 140°F (60°C), the flue gases begin to condense and the E_t of the condensing boiler increases.

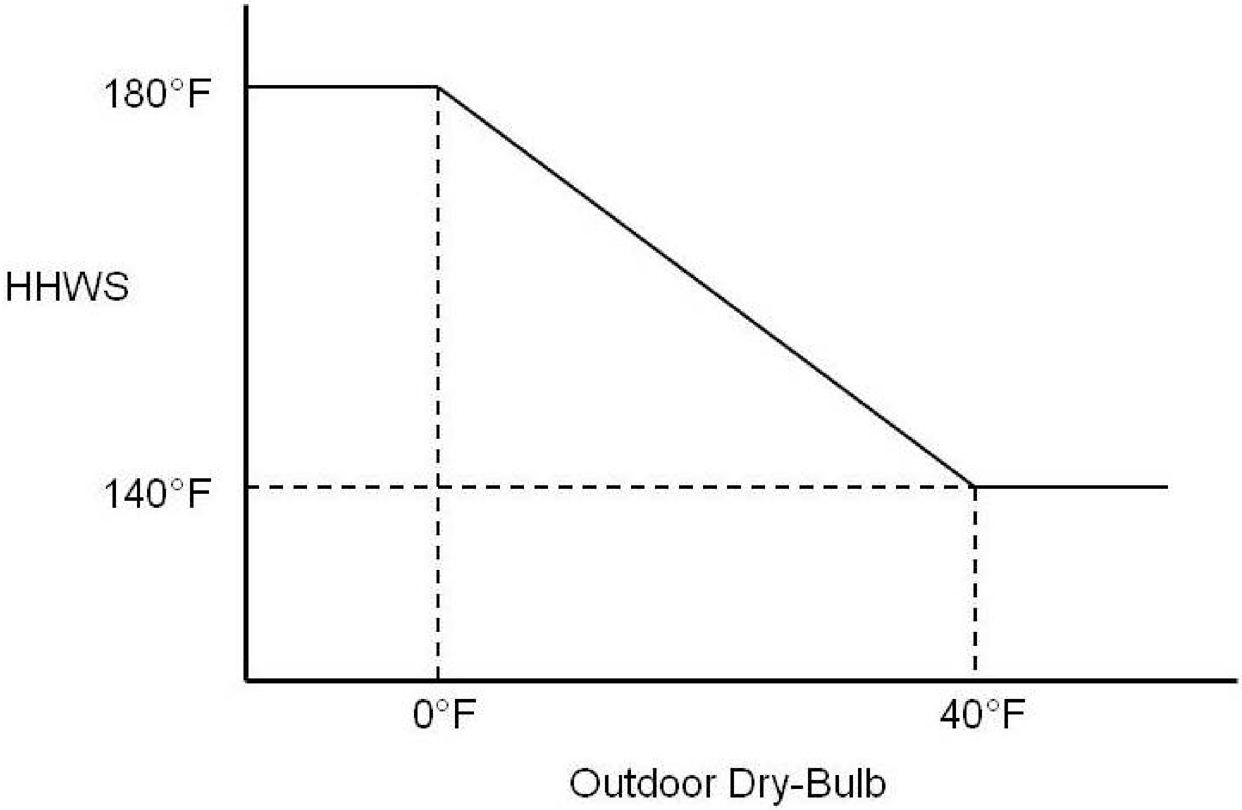


Figure 6-10 Low-energy model HHWS OA reset schedule

In reality, the condensing boiler E_t is a function of both part-load operation and HHWR temperature. Despite EnergyPlus's capability to calculate HHWR temperature and use in the boiler E_t calculation, the PC agreed to model the condensing boiler E_t strictly as a function of part-load operation. To capture the effect of the OA air reset schedule, the PC specified a linear E_t curve. At full load, in most climates, the boiler will achieve full load at a cold ambient temperature only, which demands higher HHWS and HHWR temperatures. Consequently, at full load the boiler will not condense, achieving an atmospheric boiler E_t of 80%. As the ambient temperature increases, the boiler will operate at lower part-load conditions, which in turn will allow lower HHWS and HHWR temperatures. Therefore, the boiler E_t will increase as the part-load operation decreases.

As is the case for atmospheric boilers, the minimum part-load operation of condensing boilers varies widely across manufacturers. The PC agreed to a 20% minimum part-load operation, although some boilers modulate down to 10%. As previously mentioned for the atmospheric boiler, EnergyPlus cannot model performance degradation caused by cycling when operating at part-loads below the minimum turn down. Therefore, the EnergyPlus condensing boiler was specified with a minimum turn down of 0.2. Any operation below this part load would be modeled with a same E_t achieved at 0.2. Figure 6-11 and Table 6-47 show necessary inputs into EnergyPlus used to model the low-energy condensing boiler.

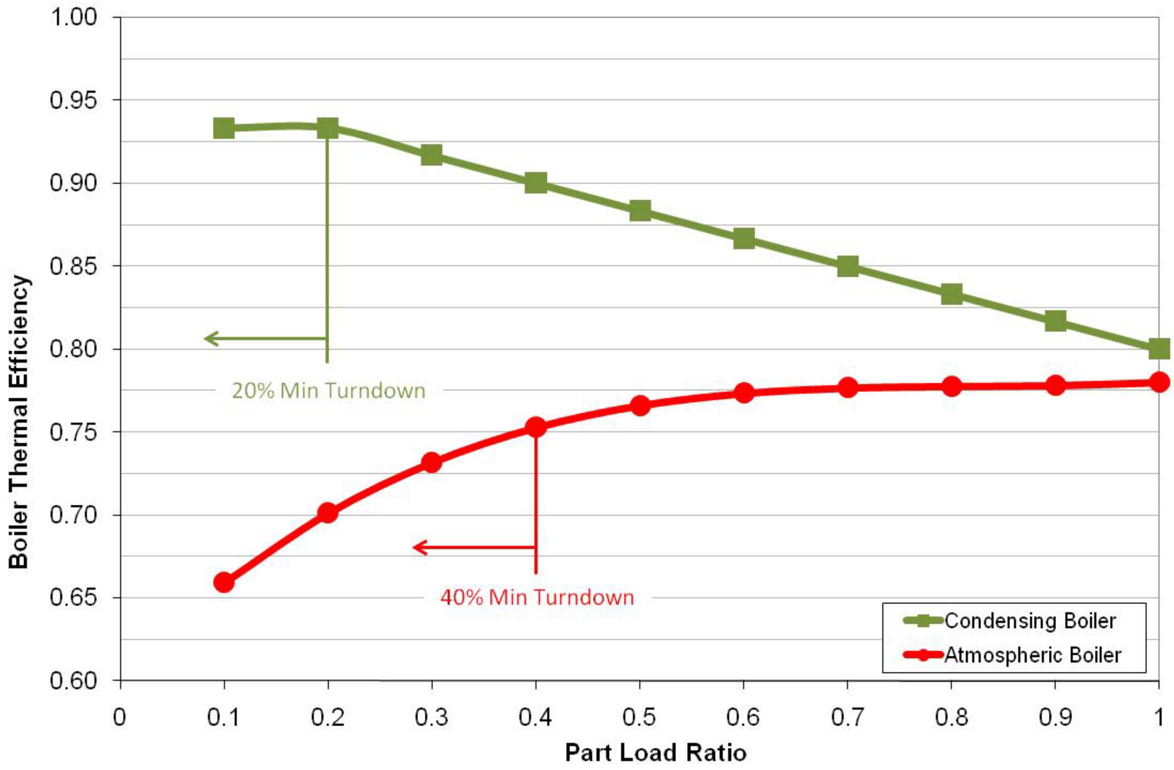


Figure 6-11 Baseline and low-energy boiler part-load curves

Table 6-47 Baseline and Low-Energy Boiler EnergyPlus Input Performance Curves

EnergyPlus Input Data	Baseline Boiler	Low-Energy Boiler
Nominal E_t	0.96	1.00
Coefficient 1: Constant	0.6264	0.9667
Coefficient 2: x	0.6456	–0.1667
Coefficient 3: x^2	–0.7772	0
Coefficient 4: x^3	0.3138	0
Minimum PLR	0.1	0.2
Maximum PLR	1.0	1.0

6.11 Service Water Heaters

SWH objects are components dedicated to heating, storing, and distributing domestic hot water to a building. A well-mixed storage tank water heater was simulated in EnergyPlus for the baseline and low-energy models. EnergyPlus simulates this water heater by analytically solving the differential equation governing the energy balance of the water tank. Conditions are solved separately for when the heater element or burner is on and when it is off. This approach allows ambient losses and parasitic loads to be separated into two cases (on and off) and accounted for in detail. The baseline and low-energy model water heaters are controlled by cycle to meet the demand load. When cycling, the heater element or burner is either on or off. The heater remains fully on while the tank is heated to the set point temperature of 140°F (60°C). When the set point is reached, the heater turns off. The heater remains off until the tank temperature falls below the set point temperature minus the deadband temperature difference of two degrees. The heater continuously cycles on and off to maintain the tank temperature in the dead band. Table 6-48 shows the baseline and low-energy model water heater characteristics.

Table 6-48 Baseline Model Water Heater Characteristics

SWH Characteristic	Baseline Model	Low-Energy Model
Tank volume	800 gal	800 gal
Deadband temperature	2°F	2°F
Set point temperature	140°F	140°F
Control type	Cycle	Cycle
Maximum capacity	288 kBtu/h	288 kBtu/h
Fuel	Natural gas	Natural gas
E_t	80%	90%
Off cycle parasitic heat fraction to tank	0.8	0.9

6.12 Humidifiers

The critical CAV AHUs in the baseline and low-energy models had electric steam humidifiers to maintain the RH in the spaces above 30% based on AIA 2006, which specifies a 30% RH minimum. However, 40% RH was used based on PC recommendations. The PC also recommended that the humidifier be a stand-alone unit in the AHU. Although the humidifiers are controlled to maintain the return air at a 40% minimum RH, EnergyPlus controls the humidifier to maintain a minimum RH set point for one zone served by the AHU. For the community hospital and the surgery center, the operating room was specified as the zone to control the humidifier. Table 6-49 reviews the stand-alone electric humidifier performance characteristics modeled in EnergyPlus. Even though an electric humidifier is essentially 100% efficient—because all the electricity heat is transferred to the water—the 93% resultant efficiency was based on the PC recommendation to account for occasional condensate blowdown.

Table 6-49 Stand-Alone AHU Humidifier EnergyPlus Input

Performance Characteristics	Baseline and Low-Energy
Rated capacity	295 lb/h
Rated power	100 kW
Resultant efficiency	93%

7. Model Validation

Energy modeling of healthcare facilities is difficult because the buildings are complex. Certain PC members were very experienced with these difficulties and scrutinized the energy modeling throughout the development of the Guide. The following sections highlight certain model ideation procedures that were performed to improve the accuracy of the energy model and to prove to the PC that the model was correctly capturing all the intricate energy flows in a small healthcare facility.

7.1 Air Flow Verification

A unique requirement to healthcare facilities stems from AIA 2006. This guide is a reference standard on which many healthcare facilities are constructed. It mandates specific total air flow requirements (in ACH) for particular zone types. In order to correctly model the energy use of a healthcare facility, it was important to incorporate these total air flow requirements into the model, as well as validate their performance. All space types with total air flow requirements can be seen in Table 7-1.

Table 7-1 AIA Total Air Flow Requirements

Space Type	AIA Requirements (ACH)
Anesthesia	8
Clean	4
Conference	–
Corridor	–
Dining	–
Examination room	6
Food preparation center	10
Laboratory	6
Lounge	–
Nurse station	–
Nursery	6
Office	–
Operating room	20*
Patient corridor	2
Patient room	6
Physical therapy	6
Procedure room	15
Radiology	–
Reception area	–
Recovery room	6
Soiled	10
Storage	–
Toilet room	10
Trauma room	15
Triage	12
Utility	–

* This value was changed from the 15 ACH that is listed in AIA 2006, based on PC recommendations.

These total air flow requirements were input into the model. The patient room wing of the community hospital (see Figure 7-1 and Figure 7-2) was chosen to verify that these requirements were being met.

Figure 7-1 Community hospital with patient room wing highlighted
Credit: Eric Bonnema/NREL

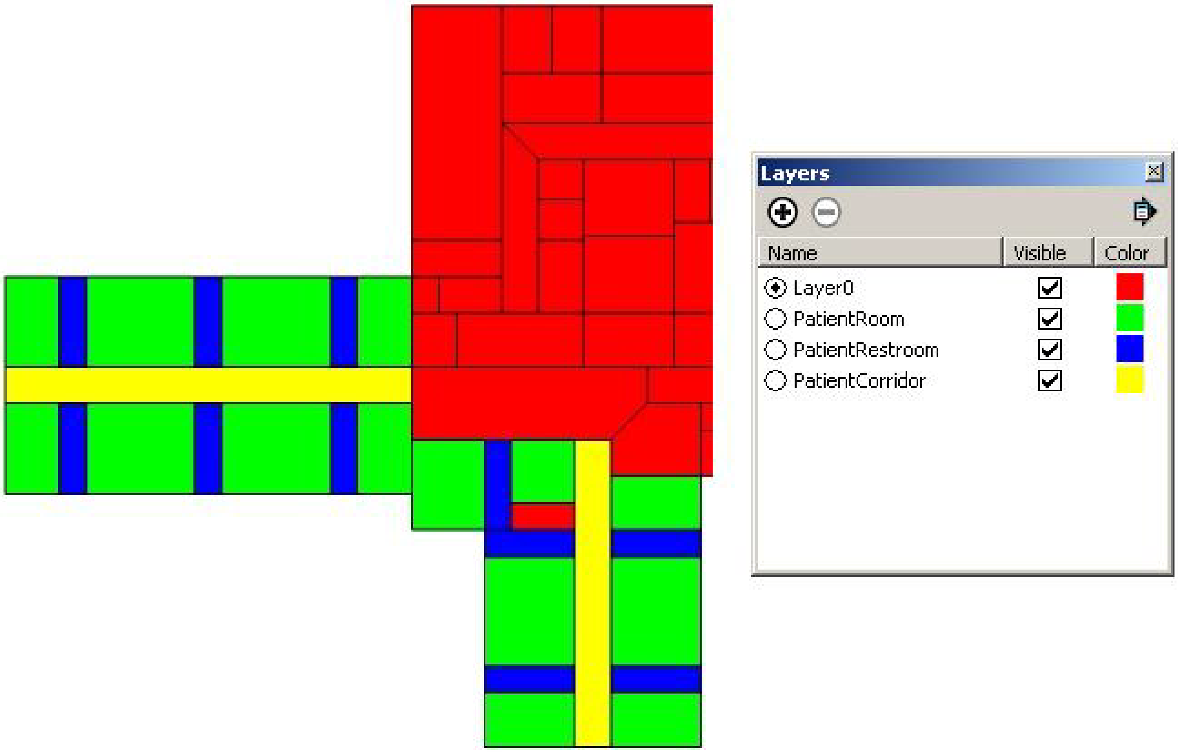


Figure 7-2 Community hospital patient room wing close up
Credit: Eric Bonnema/NREL

As Table 7-1 shows, a patient room requires 6 ACH of total air flow. Detailed hourly air flow data from the simulation was output for the 15 patient room zones in the community hospital. These data were output for three climate zones: 2A (Houston), 5A (Chicago), and 7A (Duluth) for the baseline and low-energy models. The annual minimum total air flow rate values were determined from these detailed hourly data. The patient room floor areas are not consistent (and thus neither are the zone volumes), so the 6 ACH requirement was converted to cubic feet per minute for comparison with the hourly EnergyPlus data. Table 7-2 shows this 6 ACH conversion to cubic feet per minute in red text and the minimum annual total air flow values for each patient room in the three climates for the baseline and low-energy models. As Table 7-2 shows, the 6 ACH requirement is being met for all patient rooms in all locations, demonstrating that the model accurately simulates the total air flow in these AIA mandated zones and furthering confidence in the simulation results.

Table 7-2 Community Hospital Patient Room Air Flow

Zone Name	AIA cfm (equivalent to 6 ACH)	2A – Houston		5A – Chicago		7A – Duluth	
		Baseline Model cfm	Low-Energy Model cfm	Baseline Model cfm	Low-Energy Model cfm	Baseline Model cfm	Low-Energy Model cfm
Patient Rooms 100–101	216	267	218	216	218	215	217
Patient Rooms 103–105	432	436	436	432	436	429	435
Patient Rooms 107–109	432	436	436	432	436	429	435
Patient Room 111	216	218	218	216	218	215	217
Patient Room 120	216	218	218	216	218	215	217
Patient Rooms 122–124	432	436	436	432	436	429	435
Patient Room 126	216	222	218	216	218	215	217
Patient Room 128	216	269	218	263	218	251	217
Patient Rooms 130–132	432	481	436	472	436	457	435
Patient Room 136	176	178	178	177	178	175	177
Patient Room 138	288	291	291	288	291	286	290
Patient Room 140	216	218	218	216	218	215	217
Patient Rooms 142–144	432	436	436	432	436	429	435
Patient Rooms 146–148	432	436	436	432	436	429	435
Patient Rooms 150–151	216	253	218	220	218	215	217

7.2 Utility Bill Comparisons

The community hospital and the surgery center energy models were based on real healthcare facilities. At the time of modeling, the community hospital had been in operation for approximately one year, while the surgery center was still under construction. The community hospital had been open and an entire year of monthly utility (natural gas and electric) bills were available, so comparisons could be made between the community hospital energy model and the community hospital utility bills.

The owners of the community hospital provided the modeling team with a year of monthly utility bills for electrical energy use, electrical demand, and natural gas energy use. Monthly aggregate data were output from the EnergyPlus simulations for electrical and natural gas energy use and monthly maximum data were output for electrical demand. The EnergyPlus output was then plotted with the utility bill for each month. The results of this comparison are shown in Figure 7-3 through Figure 7-5.

Figure 7-3 shows the metered electrical energy use side-by-side with the modeled electrical energy use while Figure 7-4 shows the metered electrical demand side-by-side with the modeled electrical demand. The EnergyPlus modeled electrical energy use and electrical demand are similar to the metered community hospital data. These similarities further increase our confidence in the simulation results.

Figure 7-5 shows the metered natural gas use side-by-side with the modeled natural gas use. The EnergyPlus modeled natural gas use is much lower than the metered community hospital data, although the annual trends are similar. The differences between the metered gas use and the energy model can be attributed to problems encountered in the boiler room of the community hospital.

7.2.1 Electricity Use

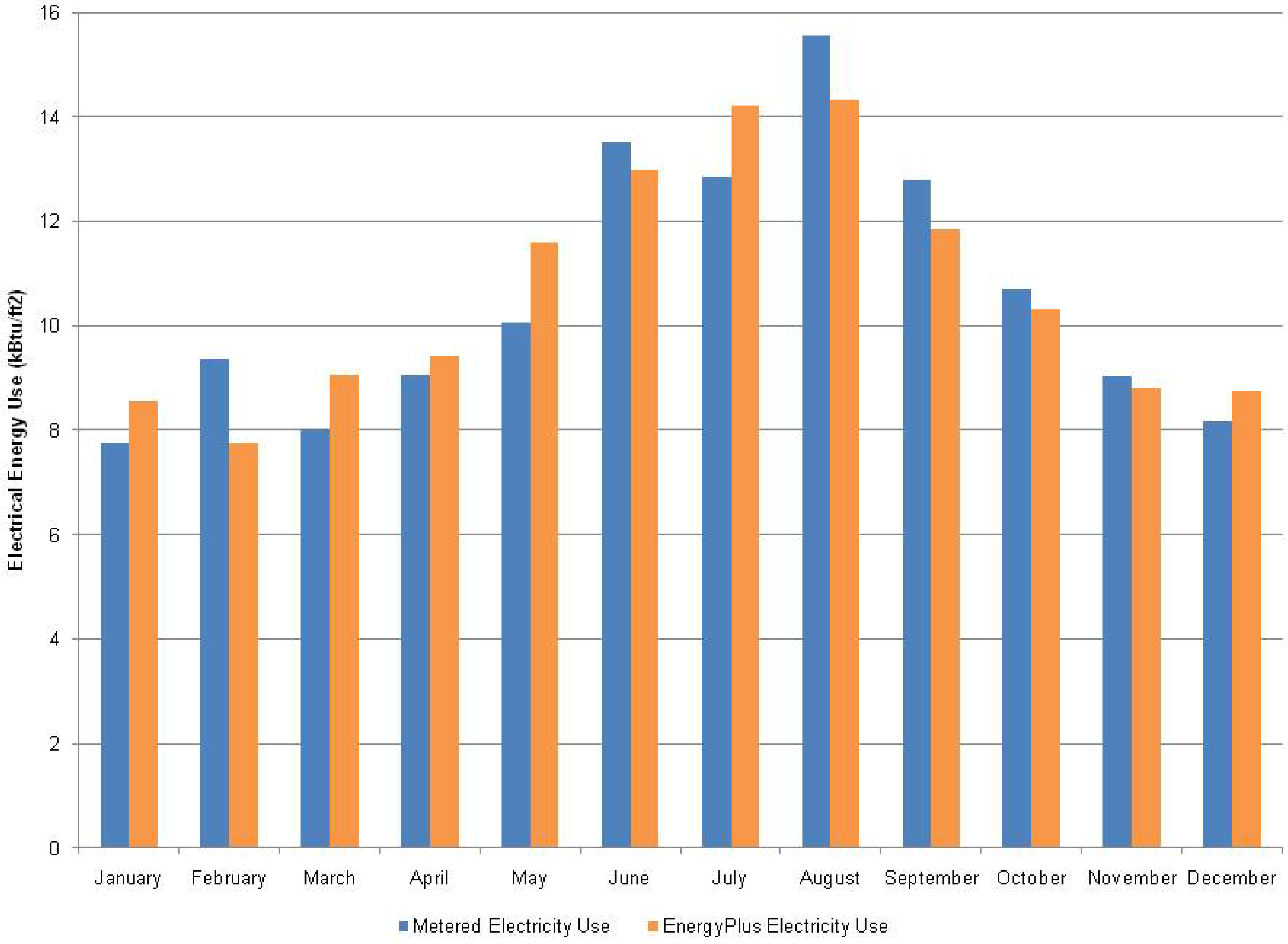


Figure 7-3 Community hospital electrical energy use

7.2.2 Electricity Demand

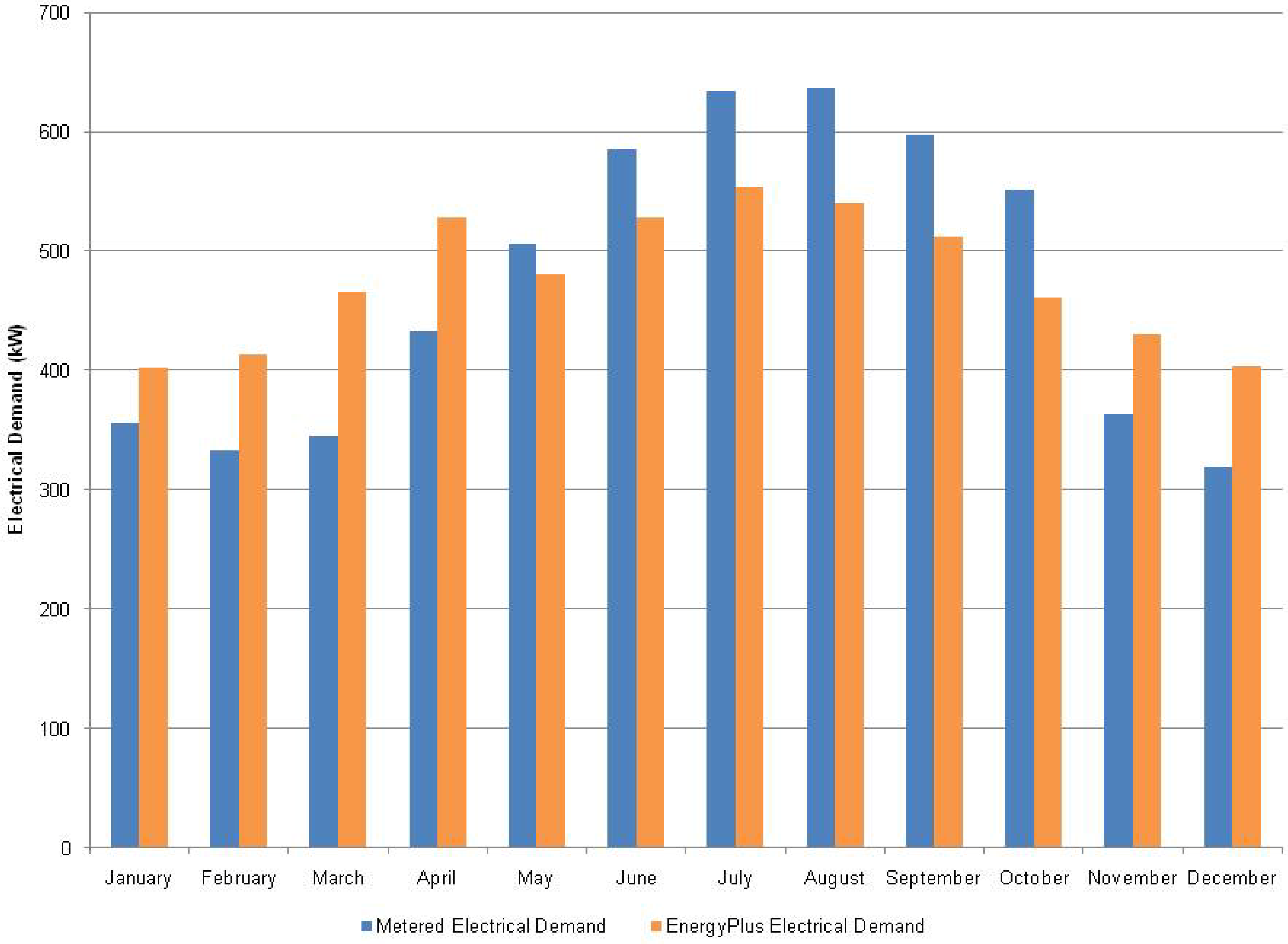


Figure 7-4 Community hospital electrical demand

7.2.3 Natural Gas

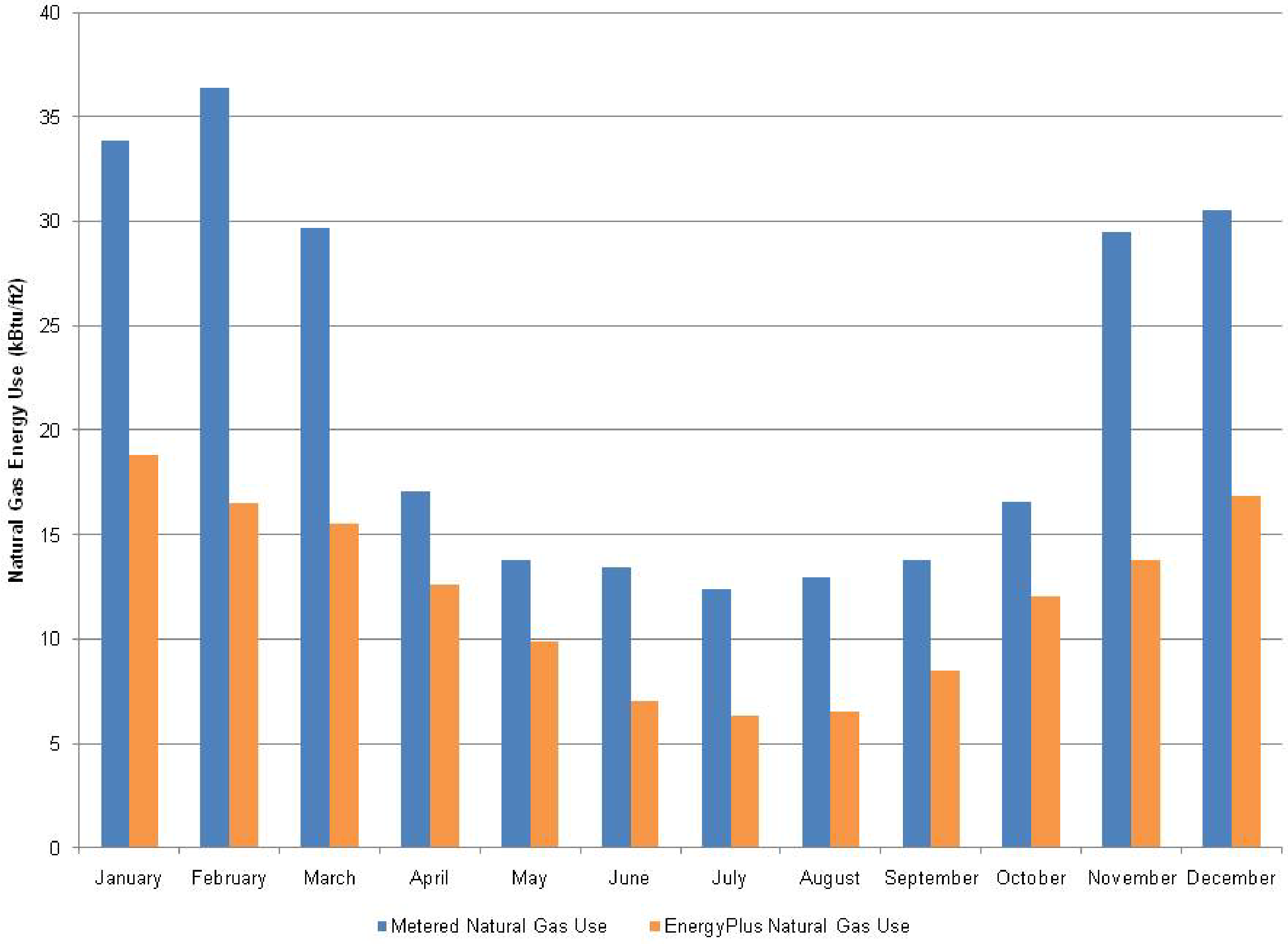


Figure 7-5 **Community hospital natural gas energy use**

8. Evaluation Results

This section contains the modeling results of the recommendations for 30% savings approved by the PC for the SHC-AEDG. Modeling results of the recommendations for 30% savings over ASHRAE 90.1-2004 are also discussed. The energy savings that are achieved as a result of applying these recommendations are presented. Figures of the end use comparisons are provided; the end-use data are presented in tabular format in Appendix E and Appendix G.

The recommendations are applicable for all small healthcare facilities within the scope of the Guide as a means of demonstrating 30% energy savings. The Guide recognizes that there are other ways of achieving 30% energy savings, and offers these recommendations as *some ways, but not the only way* to meet the energy savings target. When a recommendation contains the designation "Comply with Standard 90.1," the Guide provides no recommendation for this component or system. In these cases, the user must meet the more stringent of either the applicable version of Standard 90.1 or the local code requirements.

8.1 Recommendation Tables for 30% Savings

Each recommendation tables presented in the SHC-AEDG includes a set of common items arranged by building subsystem: envelope, daylighting/lighting, HVAC systems, and SWH. Recommendations are included for each item, or subsystem, by component within that subsystem. For some subsystems, recommendations depend on the construction type, HVAC system type, or space type. For example, insulation values are given for mass, steel-framed, and wood-framed wall types. For others, recommendations are given for each attribute. For example, glass recommendations are given for size, thermal transmittance, SHGC, and exterior sun control.

The opaque envelope recommendations are presented for different climate zones by roof, wall, floor, slab, and door types. Recommendations for the thermal characteristics of the vertical fenestration and interior reflectance are also provided.

Daylighting recommendations are provided for specific space types to maximize sidelighting potential. If carefully designed, vertical fenestration and skylights can provide interior illumination without excessive solar heat gain. Electric lighting systems can then be extinguished or dimmed for most daytime hours, saving significant energy and maintenance costs. The key to daylighting is integrated design in which HVAC and electric lighting controls are optimized to take full advantage of and harvest energy savings, and added first costs of fenestration are offset by reduced costs in HVAC equipment. Because of the additional nonenergy benefits from daylighting, a design that uses daylighting should be pursued whenever possible. Proper daylighting design requires an integrated approach and good design skills. If these are possible, lighting and daylighting design can provide predictable and persistent lighting energy savings.

For interior electrical lighting, recommendations are provided that use efficient, state-of-the-art products and lighting design techniques. The recommendations provided in this section include whole-building LPD, light source system efficacy for lighting systems that use the most current energy-efficient lamps and ballasts, and integrated controls. Because lighting energy savings also produce cooling savings, HVAC energy savings of 10% to 15% are also possible in cooling-dominated climates. Moreover, even though the cost of high-performance lighting may be about the same or more than that of a basic solution, the cost of HVAC capacity can also be reduced.

This Guide provides recommendations for one of the following three system types:

- Single-duct VAV air-handling system (indoor or outdoor) with DX cooling or a water chiller and a water boiler
- Water-source heat pump with a dedicated OA ventilation system
- Fan coils with a water chiller, a water boiler, and a dedicated OA ventilation system.

Some system types, however, are not recommended for critical care areas of the healthcare facility. Unique recommendations are included for each HVAC system type, based on practicality of implementation and the 30% energy reduction goal. Unique recommendations for cooling, heating, and fan efficiencies are included for each HVAC system type in the climate-specific recommendations. Economizer use recommendations for each HVAC system type are also included. SWH efficiency recommendations are provided based on electric or gas water heaters, as well as instantaneous or gas storage units.

The recommendation table also lists references to how-to tips for implementing the recommended criteria. The tips are found under separate sections coded for envelope, daylighting, electric lighting, HVAC systems and equipment, and SWH systems and equipment suggestions. Besides design and maintenance suggestions that represent good design practice, these tips include cautions. Each tip is tied to the applicable climate zones. Additional recommendations and strategies are provided for energy savings above and beyond the 30% recommendations contained in the eight climate regions. These savings include plug loads, alternative HVAC systems, and renewable energy systems.

The recommendations presented are either maximum or minimum values. Minimum values include:

- R-values
- Mean lumens per watt
- SRI
- EER
- Integrated energy efficiency ratio (IEER)
- IPLV
- COP
- Effectiveness
- E_c
- E_t
- Energy factor (EF)
- Duct or pipe insulation thickness.

Maximum values include:

- Fenestration U-factors
- Fenestration SHGC
- Total fenestration to gross wall area ratio
- LPD

- Fan brake horsepower
- Fan input power per cfm of supply air flow
- Window-to-wall ratio (WWR).

The recommendations for the SHC-AEDG are shown in Table 8-1 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 1–4 and Table 8-2. The recommendations for 30% energy savings over ASHRAE 90.1-2004 are the same as those for 30% energy savings over ASHRAE 90.1-1999.

Table 8-1 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 1–4

Item		Component	Climate Zone 1 Recommendations	Climate Zone 2 Recommendations	Climate Zone 3 Recommendations	Climate Zone 4 Recommendations
Envelope	**Roofs**	Insulation entirely above deck	R-25 c.i.	R-25 c.i.	R-25 c.i.	R-30 c.i.
		SRI	78	78	78	Comply with 90.1
	Walls	Mass (heat capacity > 7 Btu/ft^2)	R-5.7 c.i.	R-7.6 c.i.	R-11.4 c.i.	R-13.3 c.i.
		Steel-framed	R-13 + R-7.5 c.i.	R-13 + R-7.5 c.i.	R-13 + R-7.5 c.i.	R-13 + R-7.5 c.i.
		Below-grade walls	Comply with 90.1	Comply with 90.1	R-7.5	R-7.5
	Floors	Mass	R-4.2 c.i.	R-10.4 c.i.	R-12.5 c.i.	R-14.6 c.i.
		Steel-framed	R-19	R-30	R-30	R-38
	Slabs	Unheated	Comply with 90.1	Comply with 90.1	Comply with 90.1	R-15 for 24 in.
	Doors	Swinging	U-0.70	U-0.70	U-0.70	U-0.50
		Non-swinging	U-1.45	U-0.50	U-0.50	U-0.50
	Vertical fenestration	Total fenestration to gross wall area	40% max	40% max	40% max	40% max
		Thermal transmittance – all types and orientations	U-0.43	U-0.43	U-0.43	U-0.29
		SHGC – all types and orientations	SHGC-0.26	SHGC-0.26	SHGC-0.26	SHGC-0.34
		Visible transmittance	VT-0.63	VT-0.63	VT-0.63	VT-0.69
		Exterior sun control (S, E, W only)	PF > 0.5	PF > 0.5	PF > 0.5	PF > 0.5
	Skylights	Area (percent of roof area)	3% max	3% max	3% max	3% max
		Thermal transmittance – all types	U-0.75	U-0.75	U-0.75	U-0.60
		SHGC	SHGC-0.35	SHGC-0.35	SHGC-0.35	SHGC-0.40
Lighting/Daylighting	**Interior finishes**	Daylit room interior surface average reflectance	88% > 7 ft 50% < 7 ft	88% > 7 ft 50% < 7 ft	88% > 7 ft 50% < 7 ft	88% > 7 ft 50% < 7 ft
	Interior lighting	LPD	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2
		Lighting system efficacy (linear fluorescent and high-intensity discharge)	90 mean lumens per watt (MLPW) min	90 MLPW min	90 MLPW min	90 MLPW min
		Lighting system efficacy (all other)	50 MLPW min	50 MLPW min	50 MLPW min	50 MLPW min
		Lighting controls – general	Manual on auto off in all zones except patient care areas	Manual on auto off in all zones except patient care areas	Manual on auto off in all zones except patient care areas	Manual on auto off in all zones except patient care areas
		Dimming controls daylight harvesting	Dim fixtures within 15 ft of sidelighting edge, and within 10 ft of toplighting edge	Dim fixtures within 15 ft of sidelighting edge, and within 10 ft of toplighting edge	Dim fixtures within 15 ft of sidelighting edge, and within 10 ft of toplighting edge	Dim fixtures within 15 ft of sidelighting edge, and within 10 ft of toplighting edge

Table 8-1 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 1–4 (con't)

Item			Component	Climate Zone 1 Recommendations	Climate Zone 2 Recommendations	Climate Zone 3 Recommendations	Climate Zone 4 Recommendations
HVAC	**Critical Care Access**	**Central air-handling system**	DX air conditioner (≥ 240 and < 760 kBtu/h)	10.0 EER/10.5 IEER	10.0 EER/10.5 IEER	10.0 EER/10.5 IEER	10.0 EER/10.5 IEER
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	9.7 EER/10.2 IEER	9.7 EER/10.2 IEER	9.7 EER/10.2 IEER
			Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	10.0 EER/11.5 IPLV	10.0 EER/11.5 IPLV	10.0 EER/11.5 IPLV
			Water-cooled chiller efficiency	Comply with 90.1	Comply with 90.1	Comply with 90.1	Comply with 90.1
			Chilled-water pump	VFD and National Electrical Manufacturers Association (NEMA) premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency
			Cooling tower	VFD on tower fan	VFD on tower fan	VFD on tower fan	VFD on tower fan
			Gas boiler	90% E_c at peak water temperature	90% E_c at peak water temperature	90% E_c at peak water temperature	90% E_c at peak water temperature
			Economizer	Comply with 90.1	'A' zones: no 'B' zones: yes	'A' zones: no 'B' & 'C' zones: yes	'A' zones: no 'B' & 'C' zones: yes
			Fans	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors
			Zone air flow setback	Yes	Yes	Yes	Yes
	Noncritical Care Access	**Central VAV air-handling system**	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	10.0 EER/10.5 IEER	10.0 EER/10.5 IEER	10.0 EER/10.5 IEER
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	9.7 EER/10.2 IEER	9.7 EER/10.2 IEER	9.7 EER/10.2 IEER
			Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	10.0 EER/11.5 IPLV	10.0 EER/11.5 IPLV	10.0 EER/11.5 IPLV
			Water-cooled chiller efficiency	Comply with 90.1	Comply with 90.1	Comply with 90.1	Comply with 90.1
			Chilled-water pump	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency
			Cooling tower	VFD on tower fans	VFD on tower fans	VFD on tower fan	VFD on tower fan
			Gas boiler	90% E_c at peak water temperature	90% E_c at peak water temperature	90% E_c at peak water temperature	90% E_c at peak water temperature
			Economizer	Comply with 90.1	'A' zones: no 'B' zones: yes	'A' zones: no 'B' & 'C' zones: yes	'A' zones: no 'B' & 'C' zones: yes
			Fans	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors
			Space temperature setback	Yes	Yes	Yes	Yes

Table 8-1 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 1–4 (con't)

Item			Component	Climate Zone 1 Recommendations	Climate Zone 2 Recommendations	Climate Zone 3 Recommendations	Climate Zone 4 Recommendations
HVAC	Noncritical Care Access	**WSHP system**	Water-source heat pump (< 65 kBtu/h)	CLG: 12 EER 86F HTG: 4.5 COP 68F	CLG: 12 EER 86F HTG: 4.5 COP 68F	CLG: 12 EER 86F HTG: 4.5 COP 68F	CLG: 12 EER 86F HTG: 4.5 COP 68F
			Water-source heat pump (≥ 65 kBtu/h)	CLG: 12 EER 86F HTG: 4.2 COP 68F	CLG: 12 EER 86F HTG: 4.2 COP 68F	CLG: 12 EER 86F HTG: 4.2 COP 68F	CLG: 12 EER 86F HTG: 4.2 COP 68F
			Water pump	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency
			Cooling tower/fluid cooler	VFD on fans	VFD on fans	VFD on fans	VFD on fans
			Gas boiler	90% E_c at peak	90% E_c at peak	90% E_c at peak	90% E_c at peak
			Economizer	Comply with 90.1	Comply with 90.1	Comply with 90.1	Comply with 90.1
			EA energy recovery in dedicated OA system	'A': 50% total; 'B': 50% sensible effectiveness	'A': 50% total; 'B': 50% sensible effectiveness	'A' & 'C': 50% total; 'B': 50% sensible effectiveness	'A' & 'C': 50% total; 'B': 50% sensible effectiveness
			Water source heat pump fans	0.4 W/cfm	0.4 W/cfm	0.4 W/cfm	0.4 W/cfm
			Other fans (dedicated OA system, exhaust)	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors
			Space temperature setback	Yes	Yes	Yes	Yes
		Fan coil and chiller system	Air-cooled chiller efficiency	10.0 EER/11.5 IPLV	10.0 EER/11.5 IPLV	10.0 EER/11.5 IPLV	10.0 EER/11.5 IPLV
			Water-cooled chiller efficiency	Comply with 90.1	Comply with 90.1	Comply with 90.1	Comply with 90.1
			Chilled-water pump	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency
			Cooling tower	VFD on tower fans	VFD on tower fans	VFD on tower fans	VFD on tower fans
			Gas boiler	90% E_c at peak	90% E_c at peak	90% E_c at peak	90% E_c at peak
			Economizer	Comply with 90.1	'A': no 'B': waterside	'A': no 'B' & 'C': waterside	'A': no 'B' & 'C': waterside
			EA energy recovery in dedicated OA system	'A': 50% total; 'B': 50% sensible effectiveness	'A': 50% total; 'B': 50% sensible effectiveness	'A' & 'C': 50% total; 'B': 50% sensible effectiveness	'A' & 'C': 50% total; 'B': 50% sensible effectiveness
			Fan coil units	0.4 W/cfm	0.4 W/cfm	0.4 W/cfm	0.4 W/cfm
			Other fans (dedicated OA system, exhaust)	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors
			Space temperature setback	Yes	Yes	Yes	Yes

Table 8-1 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 1–4 (con't)

Item		Component	Climate Zone 1 Recommendations	Climate Zone 2 Recommendations	Climate Zone 3 Recommendations	Climate Zone 4 Recommendations
HVAC	**Ducts and dampers**	OA damper	Motorized	Motorized	Motorized	Motorized
		Duct seal class	Supply and ducts located outdoors: seal class A; return and exhaust: seal class B	Supply and ducts located outdoors: seal class A; return and exhaust: seal class B	Supply and ducts located outdoors: seal class A; return and exhaust: seal class B	Supply and ducts located outdoors: seal class A; return and exhaust: seal class B
		Insulation level	R-6	R-6	R-6	R-6
SWH	**Service water heating**	Gas storage (≥ 75 kBtu/h)	90% E_t	90% E_t	90% E_t	90% E_t
		Gas instantaneous	0.81 EF or 81% E_t	0.81 EF or 81% E_t	0.81 EF or 81% E_t	0.81 EF or 81% E_t
		Electric (storage or instantaneous)	EF > 0.99-0.0012 × volume	EF > 0.99-0.0012 × volume	EF > 0.99-0.0012 × volume	EF > 0.99-0.0012 × volume
		Pipe insulation (d < 1.5 in./d ≥ 1.5 in.)	1 in./1.5 in.	1 in./1.5 in.	1 in./1.5 in.	1 in./1.5 in.

Table 8-2 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 5–8

Item		Component	Climate Zone 5 Recommendations	Climate Zone 6 Recommendations	Climate Zone 7 Recommendations	Climate Zone 8 Recommendations
Envelope	**Roofs**	Insulation entirely above deck	R-30 c.i.	R-30 c.i.	R-35 c.i.	R-35 c.i.
		SRI	Comply with 90.1	Comply with 90.1	Comply with 90.1	Comply with 90.1
	Walls	Mass (heat capacity > 7 Btu/ft^2)	R-13.3 c.i.	R-19.5 c.i.	R-19.5 c.i.	R-25 c.i.
		Steel-framed	R-13 + R-15.6 c.i.	R-13 + R-18.8 c.i.	R-13 + R-18.8 c.i.	R-13 + R-21.6 c.i.
		Below-grade walls	R-7.5	R-12.5	R-15	R-17.5
	Floors	Mass	R-16.7 c.i.	R-19.5 c.i.	R-20.9 c.i.	R-23 c.i.
		Steel-framed	R-38	R-49	R-60	R-60
	Slabs	Unheated	R-15 for 24 in.	R-20 for 24 in.	R-20 for 24in.	R-20 for 48 in.
	Doors	Swinging	U-0.50	U-0.50	U-0.50	U-0.50
		Nonswinging	U-0.50	U-0.50	U-0.50	U-0.50
	Vertical fenestration	Total fenestration to gross wall area	40% max	40% max	40% max	40% max
		Thermal transmittance – all types and orientations	U-0.29	U-0.29	U-0.29	U-0.20
		SHGC – all types and orientations	SHGC-0.34	SHGC-0.34	SHGC-0.34	SHGC-0.40
		Visible transmittance	VT-0.69	VT-0.69	VT-0.69	VT-0.65
		Exterior sun control (S, E, W only)	PF > 0.5	PF > 0.5	PF > 0.5	PF > 0.5
	Skylights	Area (percent of roof area)	3% max	3% max	3% max	3% max
		Thermal transmittance – all types	U-0.60	U-0.60	U-0.60	U-0.60
		SHGC	SHGC-0.40	SHGC-0.40	Comply with 90.1	Comply with 90.1
Lighting/Daylighting	**Interior finishes**	Daylit room interior surface average reflectance	88% > 7 ft 50% < 7 ft	88% > 7 ft 50% < 7 ft	88% > 7 ft 50% < 7 ft	88% > 7 ft 50% < 7 ft
	Interior lighting	LPD	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2	1.0 W/ft^2
		Lighting system efficacy (linear fluorescent and high-intensity discharge)	90 MLPW min	90 MLPW min	90 MLPW min	90 MLPW min
		Lighting system efficacy (all other)	50 MLPW min	50 MLPW min	50 MLPW min	50 MLPW min
		Lighting controls – general	Manual on auto off in all zones except patient care areas	Manual on auto off in all zones except patient care areas	Manual on auto off in all zones except patient care areas	Manual on auto off in all zones except patient care areas
		Dimming controls daylight harvesting	Dim fixtures within 15 ft of sidelighting edge, and within 10 ft of toplighting edge	Dim fixtures within 15 ft of sidelighting edge, and within 10 ft of toplighting edge	Dim fixtures within 15 ft of sidelighting edge, and within 10 ft of toplighting edge	Dim fixtures within 15 ft of sidelighting edge, and within 10 ft of toplighting edge

Table 8-2 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 5–8 (con't)

Item			Component	Climate Zone 5 Recommendations	Climate Zone 6 Recommendations	Climate Zone 7 Recommendations	Climate Zone 8 Recommendations
HVAC	**Critical Care Access**	**Central air-handling system**	DX air conditioner (≥ 240 and < 760 kBtu/h)	10.0 EER/10.5 IEER	Comply with 90.1	Comply with 90.1	Comply with 90.1
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	Comply with 90.1	Comply with 90.1	Comply with 90.1
			Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	9.6 EER/11.5 IPLV	9.6 EER/11.5 IPLV	9.6 EER/11.5 IPLV
			Water-cooled chiller efficiency	Comply with 90.1	Comply with 90.1	Comply with 90.1	Comply with 90.1
			Chilled-water pump	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency
			Cooling tower	VFD on tower fan	VFD on tower fan	VFD on tower fan	VFD on tower fan
			Gas boiler	90% E_c at peak water temperature	90% E_c at peak water temperature	90% E_c at peak water temperature	90% E_c at peak water temperature
			Economizer	Yes	Yes	Yes	Yes
			Fans	bhp≤ cfm × 0.0012 NEMA premium efficiency motors	bhp≤ cfm × 0.0012 NEMA premium efficiency motors	bhp≤ cfm × 0.0012 NEMA premium efficiency motors	bhp≤ cfm × 0.0012 NEMA premium efficiency motors
			Zone air flow setback	Yes	Yes	Yes	Yes
	Noncritical Care Access	**Central VAV air-handling system**	DX air conditioner (≥ 240 kBtu/h and < 760 kBtu/h)	10.0 EER/10.5 IEER	Comply with 90.1	Comply with 90.1	Comply with 90.1
			DX air conditioner (≥ 760 kBtu/h)	9.7 EER/10.2 IEER	Comply with 90.1	Comply with 90.1	Comply with 90.1
			Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	9.6 EER/11.5 IPLV	9.6 EER/11.5 IPLV	9.6 EER/11.5 IPLV
			Water-cooled chiller efficiency	Comply with 90.1	Comply with 90.1	Comply with 90.1	Comply with 90.1
			Chilled-water pump	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency
			Cooling tower	VFD on tower fan	VFD on tower fan	VFD on tower fan	VFD on tower fan
			Gas boiler	90% E_c at peak water temperature	90% E_c at peak water temperature	90% E_c at peak water temperature	90% E_c at peak water temperature
			Economizer	Yes	Yes	Yes	Yes
			Fans	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors
			Space temperature setback	Yes	Yes	Yes	Yes

Table 8-2 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 5–8 (con't)

Item			Component	Climate Zone 5 Recommendations	Climate Zone 6 Recommendations	Climate Zone 7 Recommendations	Climate Zone 8 Recommendations
HVAC	Noncritical Care Access	WSHP system	Water-source heat pump (< 65 kBtu/h)	CLG: 12 EER 86F HTG: 4.5 COP 68F	CLG: 12 EER 86F HTG: 4.5 COP 68F	CLG: 12 EER 86F HTG: 4.5 COP 68F	CLG: 12 EER 86F HTG: 4.5 COP 68F
			Water-source heat pump (≥ 65 kBtu/h)	CLG: 12 EER 86F HTG: 4.2 COP 68F	CLG: 12 EER 86F HTG: 4.2 COP 68F	CLG: 12 EER 86F HTG: 4.2 COP 68F	CLG: 12 EER 86F HTG: 4.2 COP 68F
			Water pump	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency
			Cooling tower/fluid cooler	VFD on fans	VFD on fans	VFD on fans	VFD on fans
			Gas boiler	90% E_c at peak	90% E_c at peak	90% E_c at peak	90% E_c at peak
			Economizer	Comply with 90.1	Comply with 90.1	Comply with 90.1	Comply with 90.1
			EA energy recovery in dedicated OA system	'A' & 'C': 50% total; 'B': 50% sensible effectiveness	'A': 50% total; 'B': 50% sensible effectiveness	'A': 50% total; 'B': 50% sensible effectiveness	50% sensible effectiveness
			Water-source heat pump fans	0.4 W/cfm	0.4 W/cfm	0.4 W/cfm	0.4 W/cfm
			Other fans (dedicated OA system, exhaust)	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors
			Space temperature setback	Yes	Yes	Yes	Yes
		Fan coil and chiller system	Air-cooled chiller efficiency	9.6 EER/11.5 IPLV	9.6 EER/11.5 IPLV	9.6 EER/11.5 IPLV	9.6 EER/11.5 IPLV
			Water-cooled chiller efficiency	Comply with 90.1	Comply with 90.1	Comply with 90.1	Comply with 90.1
			Chilled-water pump	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency	VFD and NEMA premium efficiency
			Cooling tower	VFD on tower fans	VFD on tower fans	VFD on tower fans	VFD on tower fans
			Gas boiler	90% E_c at peak	90% E_c at peak	90% E_c at peak	90% E_c at peak
			Economizer	Waterside	Waterside	Waterside	Waterside
			EA energy recovery in dedicated OA system	'A' & 'C': 50% total; 'B': 50% sensible effectiveness	'A': 50% total; 'B': 50% sensible effectiveness	'A': 50% total; 'B': 50% sensible effectiveness	50% sensible effectiveness
			Fan coil units	0.4 W/cfm	0.4 W/cfm	0.4 W/cfm	0.4 W/cfm
			Other fans (dedicated OA system, exhaust)	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors	bhp ≤ cfm × 0.0012 NEMA premium efficiency motors
			Space temperature setback	Yes	Yes	Yes	Yes

Table 8-2 SHC-AEDG Recommendations for 30% Savings Over 90.1-1999: Climate Zones 5–8 (con't)

Item		Component	Climate Zone 5 Recommendations	Climate Zone 6 Recommendations	Climate Zone 7 Recommendations	Climate Zone 8 Recommendations
HVAC	**Ducts and dampers**	OA damper	Motorized	Motorized	Motorized	Motorized
		Duct seal class	Supply and ducts located outdoors: seal class A; return and exhaust: seal class B	Supply and ducts located outdoors: seal class A; return and exhaust: seal class B	Supply and ducts located outdoors: seal class A; return and exhaust: seal class B	Supply and ducts located outdoors: seal class A; return and exhaust: seal class B
		Insulation level	R-6	R-6	R-6	R-6
SWH	**Service water heating**	Gas storage (≥ 75 kBtu/h)	90% E_t	90% E_t	90% E_t	90% E_t
		Gas instantaneous	0.81 EF or 81% E_t	0.81 EF or 81% E_t	0.81 EF or 81% E_t	0.81 EF or 81% E_t
		Electric (storage or instantaneous)	EF > 0.99-0.0012 × Volume	EF > 0.99-0.0012 × Volume	EF > 0.99-0.0012 × Volume	EF > 0.99-0.0012 × Volume
		Pipe insulation (d < 1.5 in./d ≥ 1.5 in.)	1 in./1.5 in.	1 in./1.5 in.	1 in./1.5 in.	1 in./1.5 in.

8.2 Discussion of Recommendations

8.2.1 Envelope Recommendations

The envelope recommendations cover the range of assemblies for the opaque and fenestration portions of the building. Opaque elements include the roof, walls, floors and slabs, as well as opaque doors. Fenestration elements include the vertical glazing (including doors). The Guide presents recommendations for a number of components of each building element. In general, the insulation recommendations increase with colder climates. Control of solar loads is more critical in the hotter, sunnier climates, so the SHGC tends to be more stringent (lower) in climate zone 1 and higher in climate zone 8.

8.2.2 Lighting and Daylighting Recommendations

The lighting and daylighting recommendations cover a range of performance characteristics, including LPD, lighting controls, and daylighting fenestration areas. The recommended LPD is 1.0 W/ft^2 (10.8 W/m^2).

A primary difference between ASHRAE 90.1-1999 and ASHRAE 90.1-2004 is the more aggressive limits on LPD. For example, operating room LPD was reduced from 7.6 W/ft^2 to 2.2 W/ft^2 (81.8 W/m^2 to 23.7 W/m^2). Not all low-energy models were still at 30% savings or greater for the ASHRAE 90.1-2004 baseline.

The SHC-AEDG recommends skylights in the top floor of the surgery center only. The surgery center is a three-story building with a relatively small footprint, so most areas can be daylit through sidelighting. The PC felt that direct-beam radiation in community hospitals should be avoided and did not recommend skylights. The community hospital is a single-story building with a relatively large footprint, so to daylight interior zones without introducing direct-beam radiation, the Guide recommends shaded or north-facing clerestories. One benefit of a well-designed daylighting system is that the cooling equipment can be downsized. Often this downsizing can pay for a significant portion of the daylighting system. Therefore, the PC primarily focused on nonskylight daylighting methods that provided good daylighting and could result in downsizing of the cooling systems. This resulted in skylight recommendations for the surgery center only, which would be affected less by direct-beam radiation.

8.2.3 HVAC Systems

Unique recommendations are included for each HVAC system type in the climate-specific recommendation tables. The recommendations are provided based on how ASHRAE 90.1 specifies performance. The packaged rooftop cooling equipment efficiencies for DX and chillers are expressed in EERs. Commercial cooling products have IPLVs that express their performance during part-load operation. Heating efficiencies are expressed as E_t and E_c for furnaces and COPs for heat pumps.

Cooling equipment efficiencies are generally higher in the hotter climates and lower in the colder climates. Boiler efficiencies are the same in all climates; because a significant portion of energy use for all models in all climates is reheat energy.

Unique recommendations are included for each HVAC system type based on practicality of implementation and the goal to achieve 30% energy savings. For example, airside economizers are recommended for rooftop units in all climate zones except 1, 2A, 3A, and 4A, because they are easy to add to the system and save energy. However, higher chiller and boiler efficiencies are recommended for fan-coil systems and economizers are not because airside economizers are less practical for dedicated OA systems.

SWH measures include recommendations for the use of instantaneous water heaters for fuel-fired applications and enhanced efficiencies for storage applications. Recommendations are provided for enhanced pipe insulation values.

8.3 Energy Savings Results

The whole building energy savings results for the recommendations in the SHC-AEDG are shown in Table 8-3. Energy savings are relative to the ASHRAE 90.1-1999 baseline energy use, and include plug loads in the energy use of the baseline and low-energy models. The analysis shows that the recommendations in the SHC-AEDG met the goal of 30% or greater energy savings within a range of HVAC system types. Energy savings are also shown for each community hospital and surgery center prototype. The DX cooling system types performed the best because of the additional pumping power required in chiller systems. The energy savings for a given climate zone were greater in the community hospital than in the surgery center, mainly because of the surgery center's 24-hour operation. The community hospital benefited more from the improved envelope because it has much more building skin than the surgery center.

Table 8-3 Energy Savings: ASHRAE 90.1-1999 Baseline

Location	Climate Zone	Community Hospital			Surgery Center		
		DX	Air-Cooled Chiller	Water-Cooled Chiller	DX	Air-Cooled Chiller	Water-Cooled Chiller
Miami, Florida	1A	38%	36%	36%	39%	36%	34%
Houston, Texas	2A	40%	39%	38%	39%	38%	36%
Phoenix, Arizona	2B	43%	43%	45%	44%	44%	45%
Memphis, Tennessee	3A	39%	39%	37%	38%	38%	35%
El Paso, Texas	3B	41%	43%	43%	44%	45%	45%
San Francisco, California	3C	44%	45%	43%	45%	45%	42%
Baltimore, Maryland	4A	40%	41%	39%	38%	39%	36%
Albuquerque, New Mexico	4B	42%	44%	44%	44%	45%	45%
Seattle, Washington	4C	41%	41%	40%	42%	42%	40%
Chicago, Illinois	5A	41%	40%	40%	40%	40%	38%
Boise, Idaho	5B	42%	43%	43%	43%	43%	43%
Burtlington, Vermont	6A	39%	40%	39%	38%	39%	38%
Helena, Montana	6B	41%	42%	42%	41%	42%	42%
Duluth, Minnesota	7A	39%	39%	39%	37%	37%	36%
Fairbanks, Alaska	8A	33%	33%	33%	33%	33%	32%

The energy savings results for the recommendations in the SHC-AEDG relative to ASHRAE 90.1-2004 are shown in Table 8-4. Energy savings are also shown for each community hospital and surgery center prototype. The Guide recommendations result in 30% or greater energy savings over ASHRAE 90.1-2004 for most climates within a range of cooling system types. In particular, the extremely cold climates (8A) and extremely hot/humid climates (1A, 2A, and 3A) did not achieve 30% savings for all cooling system types for both prototypes. Table 8- shows the specific climates that did not achieve 30% savings over ASHRAE 90.1-2004. If the table cell is blank, the model met or exceeded 30% energy savings; otherwise, the percent savings value less than 30% is shown.

Table 8-4 Energy Savings: ASHRAE 90.1-2004 Baseline

Location	Climate Zone	Community Hospital			Surgery Center		
		DX	Air-Cooled Chiller	Water-Cooled Chiller	DX	Air-Cooled Chiller	Water-Cooled Chiller
Miami, Florida	1A	33%	30%	30%	31%	28%	26%
Houston, Texas	2A	35%	34%	33%	32%	31%	29%
Phoenix, Arizona	2B	39%	38%	40%	38%	38%	39%
Memphis, Tennessee	3A	34%	34%	32%	31%	32%	28%
El Paso, Texas	3B	36%	38%	38%	36%	38%	38%
San Francisco, California	3C	40%	40%	38%	39%	39%	36%
Baltimore, Maryland	4A	35%	36%	34%	32%	33%	30%
Albuquerque, New Mexico	4B	37%	39%	39%	37%	39%	38%
Seattle, Washington	4C	36%	37%	37%	36%	36%	34%
Chicago, Illinois	5A	36%	36%	36%	35%	34%	32%
Boise, Idaho	5B	37%	38%	38%	36%	37%	37%
Burtlington, Vermont	6A	35%	36%	36%	33%	33%	32%
Helena, Montana	6B	36%	37%	37%	34%	36%	35%
Duluth, Minnesota	7A	34%	35%	35%	31%	31%	31%
Fairbanks, Alaska	8A	29%	30%	29%	27%	28%	27%

Table 8-5 Energy Savings: Less Than 30% Over ASHRAE 90.1-2004 Baseline

Location	Climate Zone	Community Hospital			Surgery Center		
		DX	Air-Cooled Chiller	Water-Cooled Chiller	DX	Air-Cooled Chiller	Water-Cooled Chiller
Miami, Florida	1A	–	–	–	–	28%	26%
Houston, Texas	2A	–	–	–	–	–	29%
Phoenix, Arizona	2B	–	–	–	–	–	–
Memphis, Tennessee	3A	–	–	–	–	–	28%
El Paso, Texas	3B	–	–	–	–	–	–
San Francisco, California	3C	–	–	–	–	–	–
Baltimore, Maryland	4A	–	–	–	–	–	–
Albuquerque, New Mexico	4B	–	–	–	–	–	–
Seattle, Washington	4C	–	–	–	–	–	–
Chicago, Illinois	5A	–	–	–	–	–	–
Boise, Idaho	5B	–	–	–	–	–	–
Burtlington, Vermont	6A	–	–	–	–	–	–
Helena, Montana	6B	–	–	–	–	–	–
Duluth, Minnesota	7A	–	–	–	–	–	–
Fairbanks, Alaska	8A	29%	–	29%	27%	28%	27%

The end uses for each ASHRAE 90.1-1999 baseline and low-energy model are shown in Figure 8-1 and Figure 8-2. The end uses for each ASHRAE 90.1-2004 baseline and low-energy model are shown in Figure 8-3 and Figure 8-4.

The end-use data and percent savings for the ASHRAE 90.1-1999 baseline and low-energy models are shown in tabular format in Appendix E. The ASHRAE 90.1-2004 baseline and low-energy model end uses and savings are shown in tabular format in Appendix G.

8.3.1 End Uses for 30% Savings over ASHRAE 90.1-1999

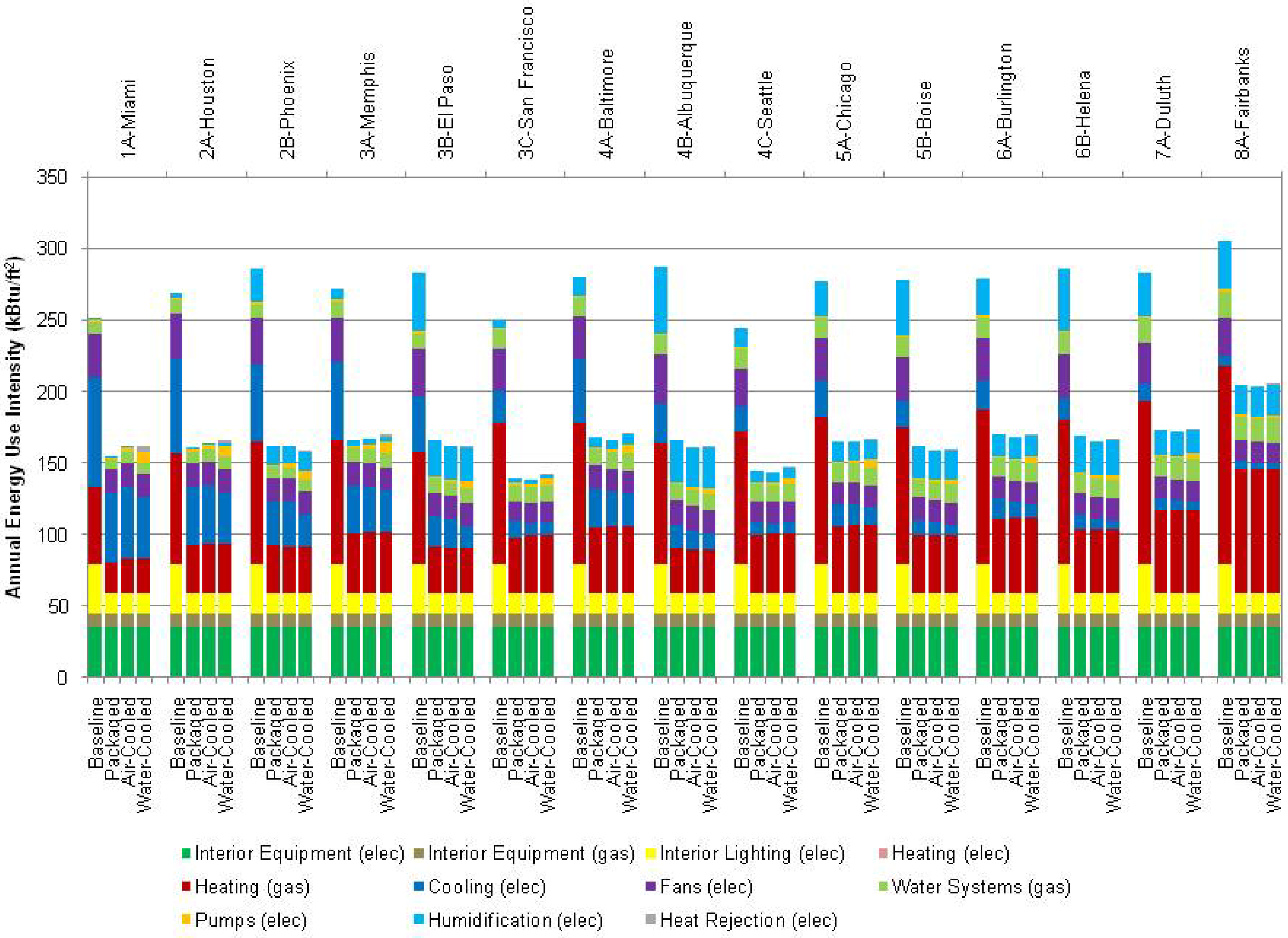


Figure 8-1 Community hospital end uses: ASHRAE 90.1-1999 baseline

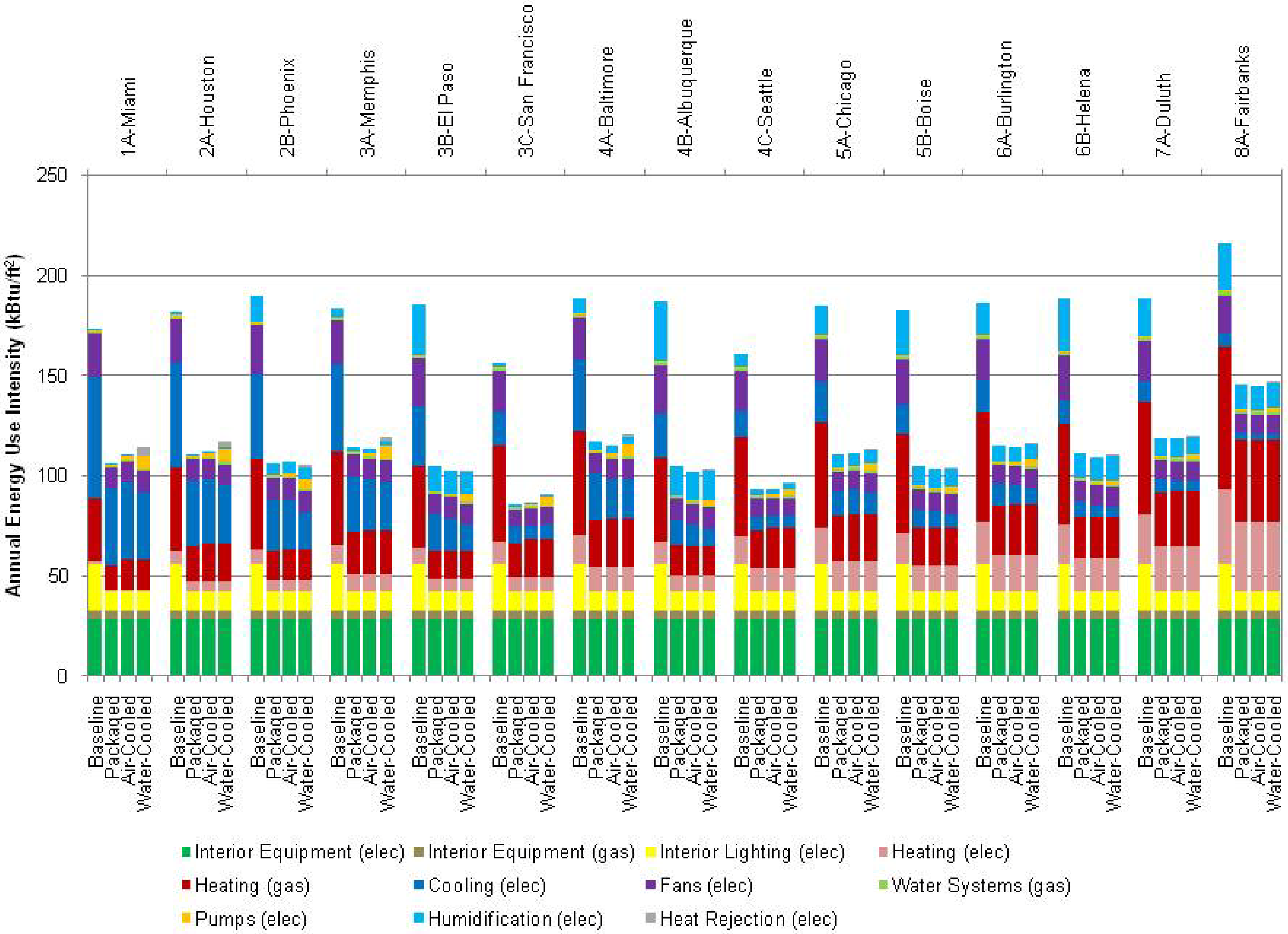


Figure 8-2 **Surgery center end uses: ASHRAE 90.1-1999 baseline**

8.3.2 End Uses for 30% Savings Over ASHRAE 90.1-2004

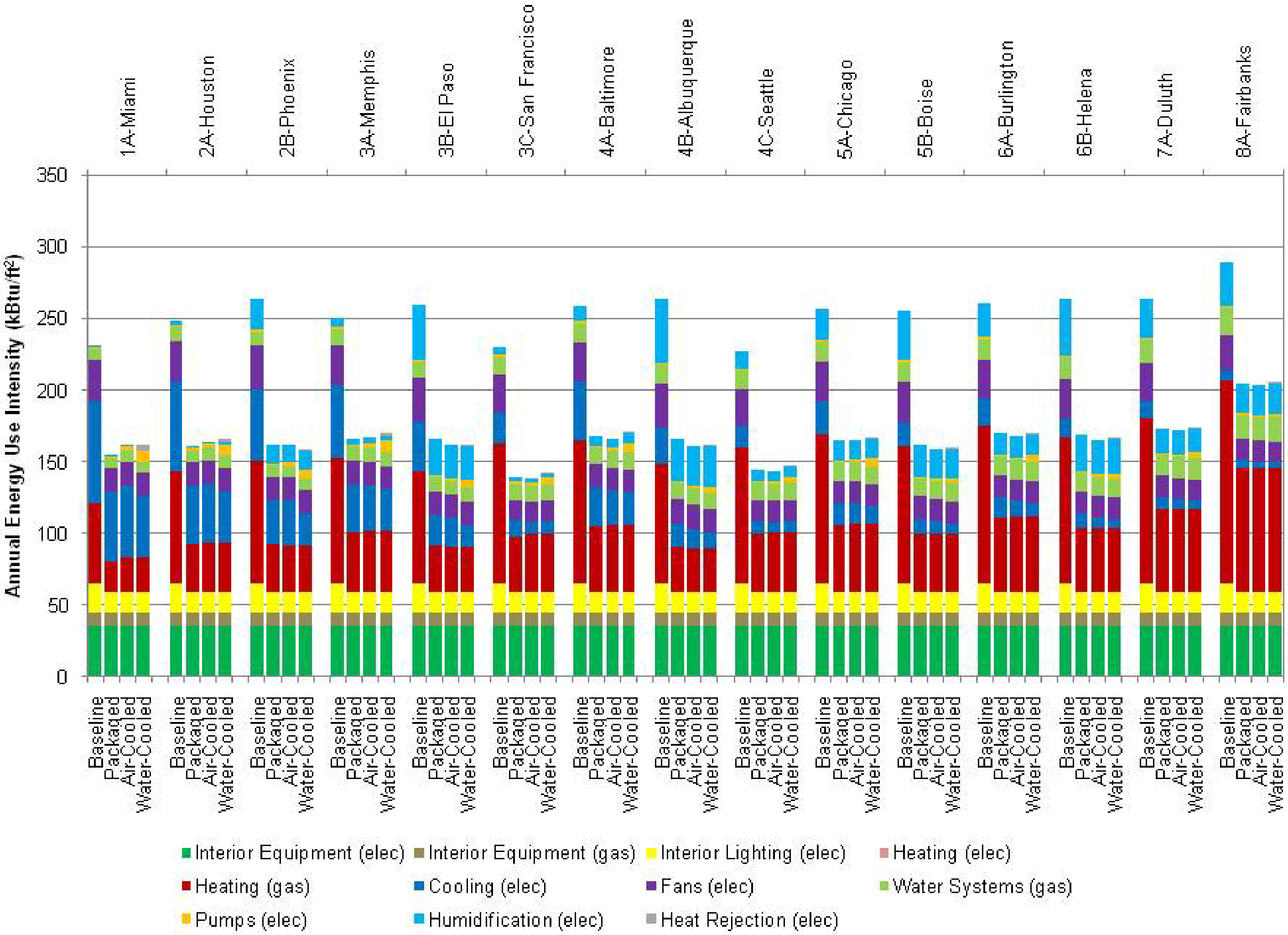


Figure 8-3 Community hospital end uses: ASHRAE 90.1-2004 baseline

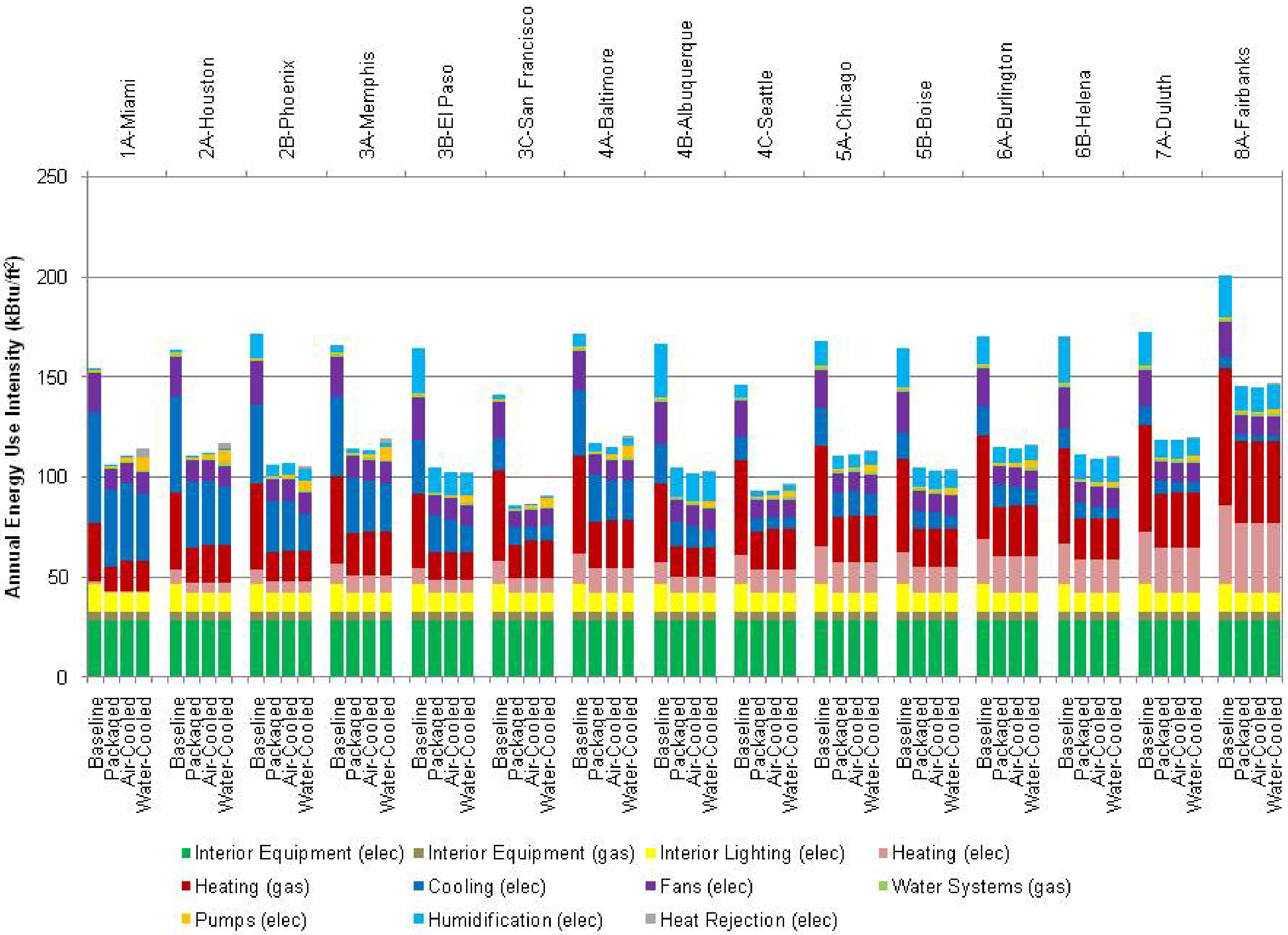


Figure 8-4 Surgery center end uses: ASHRAE 90.1-2004 baseline

8.4 Bundled Energy Efficiency Measure Analysis

During the modeling process, a baseline and a low-energy model are created and compared to provide the percent savings numbers. The low-energy model is created by starting with the baseline model and applying as many of the Guide recommendations as possible. However, it is difficult to determine which recommendations provide the most energy savings, because they were all applied to the baseline model in a single operation. To better understand how each recommendation affects energy performance, we performed a study in which each guide recommendation was incrementally and aggregately applied until the low-energy model was obtained. This study was termed a *bundled energy efficiency measure analysis*, and includes seven steps, chosen in no particular order:

1. Apply the envelope efficiency measures, which included adding overhangs to the south windows, adding skylights to the surgery center, and upgrading the building materials in accordance with the Guide recommendations.
2. Reduce space-by-space LPD.
3. Add daylighting controls to applicable zones.
4. Reduce fan pressure drop and increase fan efficiencies.
5. Improve DX cooling efficiencies.
6. Improve boiler and SWH efficiencies.
7. Implement a zone air flow setback strategy in which the HVAC terminal boxes mimicked CAV boxes during occupied times and VAV boxes during unoccupied times.

Figure 8-5 shows the bundled energy efficiency analysis results by end use for climate zones 1 though 8 (subzone A) for the community hospital; Figure 8-6 shows the results for the surgery center.

The results of this analysis show the biggest energy savers are the LPD reductions and the implementation of a zone air flow setback. Colder climates benefited more from the improved boiler efficiencies and hotter climates benefited more from improved cooling efficiencies. The results also demonstrate the improved envelope makes a greater impact on the community hospital, which can be attributed to its smaller volume-to-skin area ratio. Daylighting made a small impact because it was applied to a small portion of the building. Fan and DX coil efficiency increases made a small effect because the efficiency values varied slightly from the baseline model.

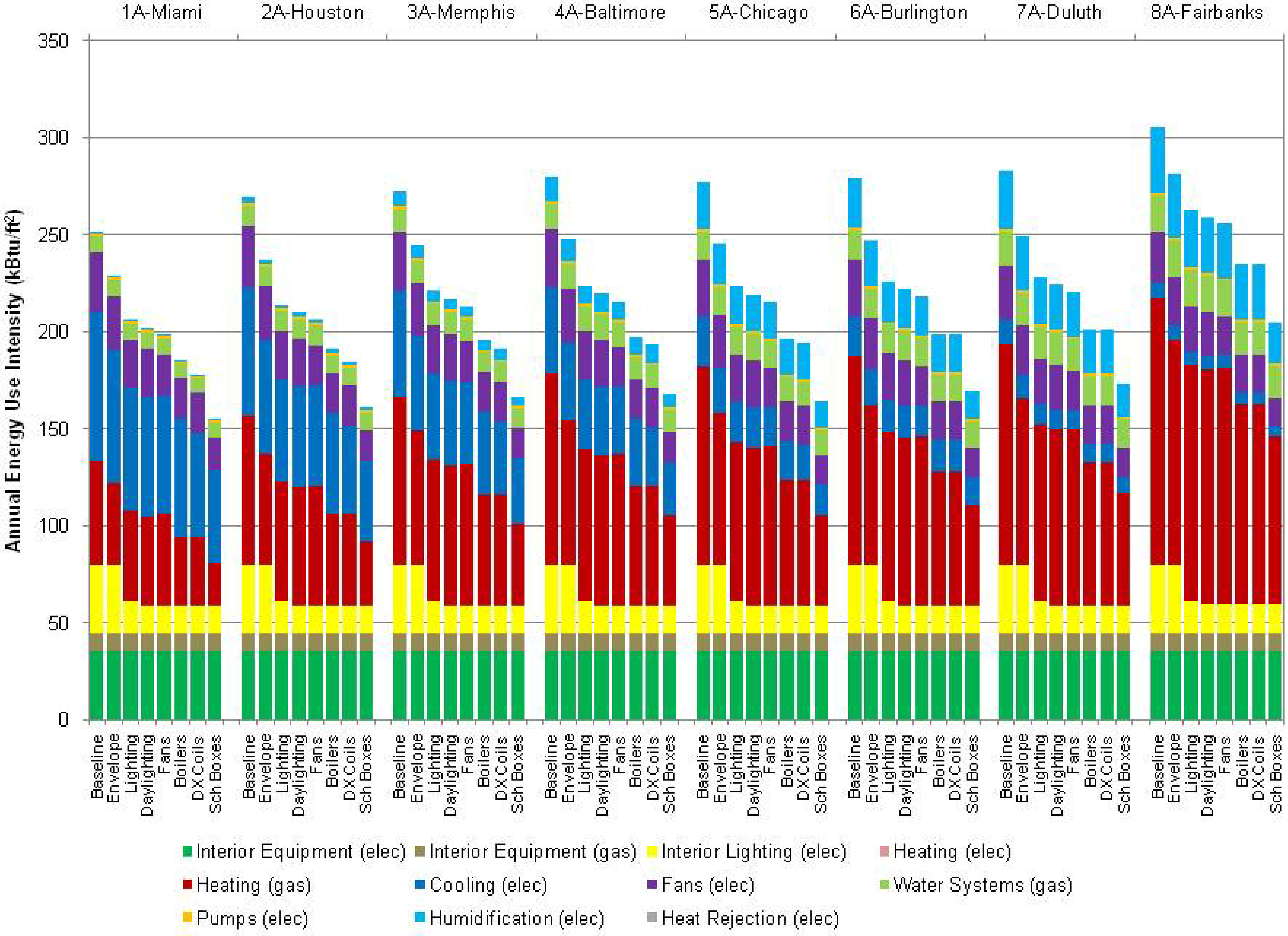


Figure 8-5 Community hospital bundled EEM analysis results for climate zones 1A–8A

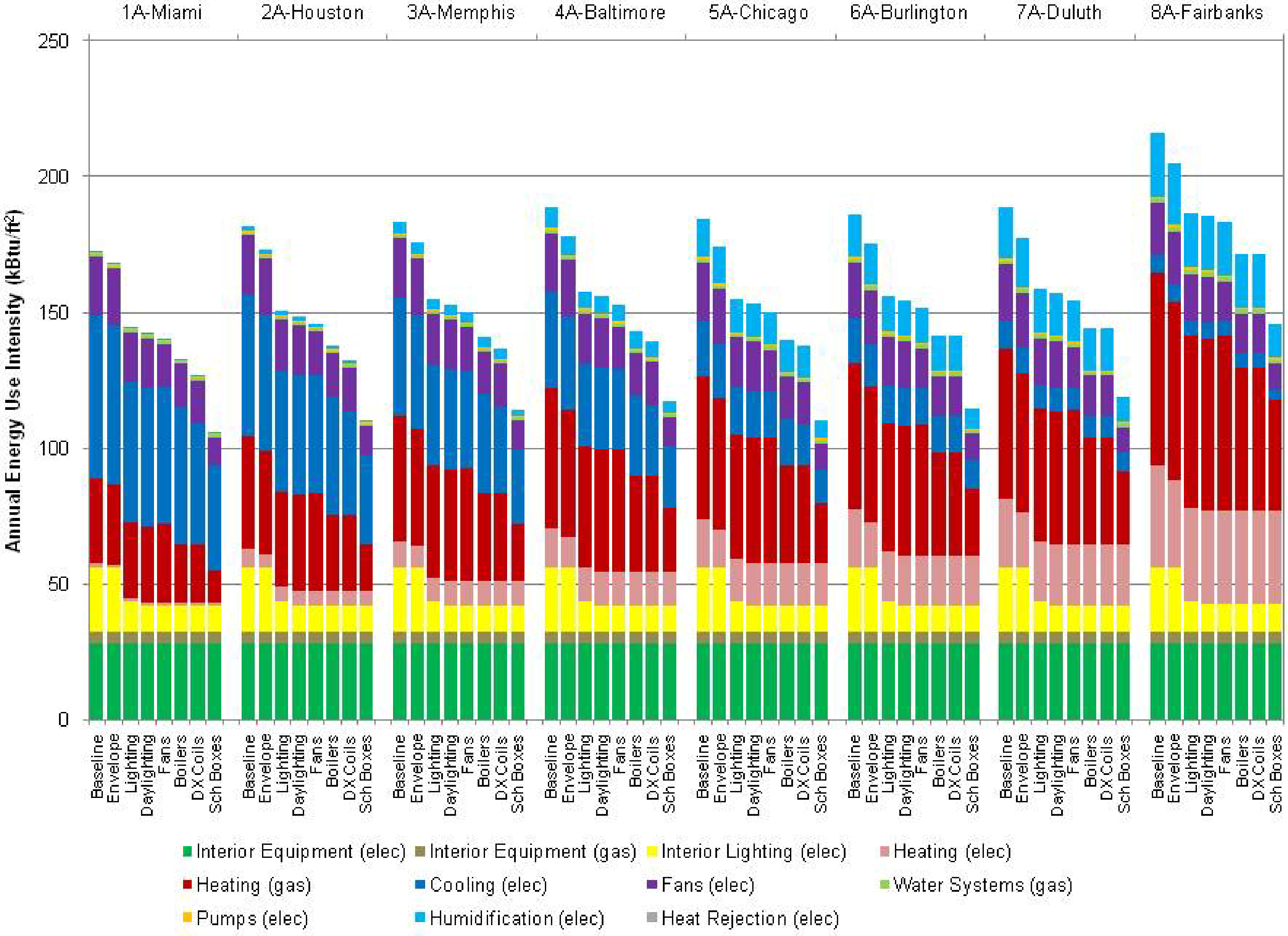


Figure 8-6 **Surgery center bundled EEM analysis results for climate zones 1A–8A**

9. Conclusion

This TSD describes the process and methodology for the development of the SHC-AEDG, which is intended to provide recommendations for achieving 30% whole-building energy savings in small hospitals and healthcare facilities over levels achieved by following Standard 90.1-1999. The SHC-AEDG was developed in collaboration with ASHRAE, AIA, ASHE, IESNA, USGBC, and DOE.

The 30% energy savings target is the first step toward achieving *net-zero energy small hospitals and healthcare facilities*. Net-zero energy facilities are buildings that draw from outside sources less or equal energy than they generate on site from renewable energy sources during a given year. Previous guides in this series include the *Advanced Energy Design Guide for K-12 Schools*, *Advanced Energy Design Guide for Small Office Buildings*, the *Advanced Energy Design Guide for Small Retail Buildings*, and the *Advanced Energy Design Guide for Small Warehouses and Self-Storage Buildings*. Each provides user-friendly design assistance and recommendations to design, architectural, and engineering firms to achieve energy savings. The SHC-AEDG includes prescriptive recommendations by climate zone for designing the building envelope, fenestration lighting systems (including electrical lights and daylighting), HVAC systems, building automation and controls, OA treatment, and SWH. Additional savings recommendations are also included, but are not necessary for 30% savings. These are provided for exterior lighting; electricity distribution; plug, process, and phantom loads; renewable energy systems; combined heat and power; alternative HVAC systems; and other hot water systems. The SHC-AEDG contains recommendations only and is not a code or standard.

As with the previous guides in the series, the SHC-AEDG provides a simple, easy-to-use guide to help the building designer, contractor, or owner identify a clear prescriptive path to 30% energy savings over Standard 90.1-1999. The combination of a set of recommendations contained on a single page, along with numerous how-to tips to help the construction team complete the project successfully, should result in increased energy efficiency in new buildings. Case studies of actual small healthcare applications add to the comprehension of energy-efficiency opportunities.

The ultimate goal of the Advanced Energy Design Guide partner organizations is to achieve net-zero energy buildings, and the 30% savings guides represent the first step in reaching this goal. The SHC-AEDG marks the last in the series of 30% savings design guides. This Guide has furthered similar work in the healthcare energy efficiency field, as it set the stage for development of a large hospital best practices guide and is used in planning the next series of 50% savings Advanced Energy Design Guides. Also, the Guide is starting to be used by the U.S. government healthcare facilities to meet Energy Policy Act 2005 energy efficiency requirements.

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Appendix A Project Committee Meeting Agendas

A.1 Meeting #1 Agenda

Agenda Meeting #1
Advanced Energy Design Healthcare
Project Committee Meeting
ASHRAE Headquarters
1791 Tullie Circle
Atlanta, GA 30329
404-636-8400

Thursday, September 4, 2008, 8:30 am – 5:30 pm
Friday, September 5, 2008, 8:00 am – 2:00 pm

1. Welcome 8:30
2. Introductions
3. Review of Agenda 9:00
4. AEDG Overview 9:10
    a. Organization of AEDG Series
    b. Committee make-up structure/partnering organization
    c. Scoping Document formation
    d. Small healthcare facilities focus
    e. Definition of Project Committee/Focus Group/Resource Group
5. Lessons Learned on the previous Guides 9:40
6. Break 10:00
7. Future Meeting Schedule 10:15
8. Review and Questions on Scoping Document 10:30
    a. Context of the other AEDGs
    b. Goals & Objectives of the Guide
    c. Target Audience
    d. Review of Scoping document
    e. Resolve scope issues:
        i. 100% OA?
        ii. Facility types appropriate?
        iii. Energy Savings Methods (plug or not plugs)
        iv. Process loads
    f. Peer Review Process
9. Lunch 12:30
    a. Review travel expense reimbursement procedures
10. Outline of AEDG 1:30
    a. Review outline of previous Guides
    b. Discuss possible modifications/changes
    c. How will this guide be unique?
11. Analysis Engine 2:30
    a. Modeling experiences from K-12 Schools AEDG
12. Break 3:00
13. Benchmark/Reference Building – How is it defined? 3:15

   a. Define typical parameters to cover facility types in scope
      i. Baseline HVAC system types
      ii. Type/Number/Size of space types in prototypes
      iii. Process and plug loads
14. Development of AEDG-Healthcare 8:00
15. Review outline of previous Guides
   a. Architectural Features
   b. Lighting Criteria
   c. Envelope Criteria
   d. HVAC/Process water heating/cooling
   e. Commissioning
   f. Case Studies
   g. Bonus Savings
   h. Foreword
   i. Other?
16. Break 10:15
17. Development of AEDG-Healthcare (cont.) 10:45
   a. Architectural Features
   b. Lighting Criteria
   c. Envelope Criteria
   d. HVAC/Process water heating/cooling
   e. Commissioning
   f. Case Studies
   g. Bonus Savings
   h. Foreword
   i. Other?
18. Lunch 12:00
19. Finalize Focus Group 1:00
   a. Roster confirmation
   b. Develop draft questions
20. Finalize Resource Group
   a. Roster confirmation
   b. Technical Committees to be represented?
   c. Other representatives?
   d. How utilize this expertise?
21. Additional Issues
22. Review of Action Items 1:30
23. Next Meeting
24. Adjourn 2:00

A.2 Conference Call #1 Agenda

Conference Call 10/15/2008, 12:00pm to 2:00pm EST

Items to discuss:

1. Review of old Action Items
2. Comments on Meeting #1 minutes
3. Who is coming to the focus group meeting? PC Meeting #2?
4. Update from HVAC subcommittee
5. Propose to expand scope:
    a. Included in the scope:
        i. Small Acute Care, Small Inpatient Community Hospital and Outpatient Surgical Center will all be similar and should be included in the scope.
        ii. Small Acute Care Hospitals
        iii. Small Inpatient (Primary Care) Community Hospitals
        iv. Outpatient Surgical Facilities
        v. Primary Care Outpatient Centers
        vi. Small Primary (Neighborhood) Outpatient Facilities
        vii. Freestanding Outpatient Diagnostic and Treatment Facilities
        viii. Freestanding Urgent Care Facilities
        ix. Freestanding Birthing Centers (similar to outpatient surgical facilities)
        x. Medical Offices Buildings?
        xi. Gastrointestinal Endoscopy Facilities (similar to outpatient surgical facilities)
        xii. Renal Dialysis Centers (similar to medical offices buildings)
    b. Excluded:
        i. Facilities over 70,000 sq ft.
        ii. Facilities with central plants or campus plants
        iii. Strip mall doc in a box medical facilities. While non-freestanding facilities are important facilities, they are covered under other guides such as AEDG-SO and AEDG-SR
6. Develop on updated focus group agenda/questions
    a. Items to send to focus group
        i. Agenda/questions (see K-12 focus group questions below)
        ii. Examples from SO and SR guides
        iii. Scoping document
        iv. 35% concept draft/outline?
7. Baseline Determination
    a. Prototype development
        i. Community hospital
        ii. Surgical Facility
8. Review of new Action Items
9. Review of future meeting schedule

A.3 Meeting #2 Agenda

Agenda Meeting #2
Advanced Energy Design Guide-SHC
Project Committee Meeting
ASHRAE Headquarters
1791 Tullie Circle
Atlanta, GA 30329
404-636-8400

Wednesday, October 29, 2008, 8:00 am – 5:30 pm
Thursday, October 30, 2008, 8:00 am – 2:00 pm

1. Welcome 8:00
2. Introductions and Review of Agenda 8:15
3. Meeting Goals (to be done before we leave):
    a. Establish prototypes so NREL can start running simulations
    b. Develop action item list to get to 65% text completion
    c. Determine appropriate set of starting recommendations
4. Review next meeting and call schedule
5. Old Action Items Review 8:45
6. Discuss Results from yesterday's Focus Group 9:00
7. Break 9:30
8. Baseline Discussion 9:45
    a. Review possible prototype model characteristics
        i. Determine typical floor plans for surgery center and small hospital
        ii. "Typical" HVAC systems
9. Lunch 12:00
10. Continue discussion on #8 1:00
11. Begin list of energy efficiency measures (EEMs) 2:00
    a. Required measures vs. suggested measures
    b. Cost and performance data
    c. How do we model the measure?
    d. Starting list of measures to consider for each section:
        i. QAs/Commissioning
        ii. Envelope
        iii. Lighting
        iv. HVAC
        v. SWH
        vi. Medical Equipment, Kitchen, Laundry
        vii. Bonus Savings
12. Break 3:00
13. Development of AEDG-SHC by subcommittee 3:15
    a. Introduction/Foreword
    b. Chapter 1 (Why, Who, How to use guide)
    c. Chapter 2 (Process for Achieving Savings)
    d. Chapter 3 (Recommendation Tables)

    e. Chapter 4 (Case Studies)
    f. Chapter 5 (How to recommendations)
        i. QAs/Commissioning
        ii. Envelope
        iii. Lighting
        iv. HVAC
        v. SWH
        vi. Medical Equipment, Kitchen, Laundry
        vii. Bonus Savings

14. Continue #13 from Thursday 8:30
15. Reconvene as group and discuss draft 10:30
16. Discussion of Cover and other format issues 11:45
17. Lunch 12:00
18. Additional Issues 1:00
19. Review of Action Items 1:30
20. Adjourn 2:00

A.4 Focus Group Agenda and Questions

Focus Group Agenda for the
SHC Advanced Energy Design Guide
ASHRAE Headquarters
1791 Tullie Circle
Atlanta, GA 30329
404-636-8400

October 28, 2008

1. Welcome – Pless
2. Introductions: Give Name/Affiliation and experience in working on energy related issues in Healthcare
3. Review of Agenda – Pless
4. AEDG Overview – Colliver
    a. Organization of AEDG series
    b. Review of scoping document and background
5. Group discussions addressing the below questions:
6. What energy strategies should be addressed in the guide?
    a. Brainstorm energy strategies you would use
    b. Brainstorm additional energy strategies you would consider (pros and cons of each)
    c. Strategies you would not consider and why
    d. Strategies that you would need for a 30% savings small hospital
7. What would an appropriate format look like (show examples and discuss)? What would be most helpful/usable way to present recommendations and results?
8. What makes a valuable case study?
    a. What type of info would you like to see?
    b. How much detail should be provided?
    c. Are photos helpful?
    d. How many case studies are appropriate?
    e. Do you prefer whole building v. individual technology case studies?
    f. Is the level of detail in the past case studies appropriate?
9. Adjourn and discuss outstanding logistical issues (travel reimbursement)

Group discussion questions to consider:

1. For the healthcare facilities that you are involved with, what is common practice relative to the local energy standard or code?
    a. "What energy standard/code?"
    b. "Healthcare facilities are exempt from the local energy standard/code."
    c. "They meet the local energy standard/code."
    d. "They are 10% better than code."
2. How difficult do you think achieving 30% energy savings would be? Do you think the 30% goal is achievable?

3. What energy-saving strategies should be recommended in the guide? What strategies would you not consider and why not? What types of energy efficiency design and operational strategies have you included in your past projects? What systems use the most energy? What systems have the most potential for savings?
    a. Envelope measures
    b. Lighting measures
    c. Daylighting
    d. HVAC measures
    e. Service hot water measures
    f. Medical equipment
    g. Renewables
    h. Combined heat and power
    i. Commissioning
4. What would influence you to design/build a healthcare facility that saved 30% energy? Or not to?
    a. Would you be willing to spend more money to achieve a sustainable building that could be used as a model to the community or nation?
5. Does the scope of this guide include those facility types that would be most beneficial to you? Should the scope cover additional healthcare facility types?
    a. Describe what you consider to be a typical small hospital or surgical facility (size, types of spaces, usage patterns).See the facility types included in our scoping document.
6. What types of HVAC systems are you currently using in your facilities? (consider each facility type included in our scope)
    a. What has been your operational experience (good or bad) with this type of HVAC system?
    b. What has been your maintenance experience (good or bad) with this type of HVAC system?
    c. Would you consider using a different HVAC system type than you typically do?
    d. Would you be willing to consider water-cooled equipment, such as water-cooled chillers?
7. Do you feel recommendations should be individual to specific facility types (small acute care hospital, outpatient surgical facilities, primary care outpatient center, etc.) or generalized?
8. What makes a case study valuable to you?
    a. What type of information should it contain?
    b. How much detail should be provided?
    c. How many case studies are appropriate?
    d. Do you prefer whole building vs. individual technology case studies?
    e. Do you have any whole building or technology specific case studies we can include this guide
9. What would an appropriate recommendation table and guide format look like (see past AEDG examples)? What would be most helpful/usable way to present recommendations and results?

A.5 Meeting #3 Agenda

Agenda Meeting #3
Advanced Energy Design Guide-SHC
Project Committee Meeting
National Renewable Energy Laboratory, TTF Conference Room
1617 Cole Blvd
Golden, CO 80401
303-384-6365 (work)
720-878-5646 (cell)

Wednesday, December 10, 2008, 8:30 am – 5:30 pm
Thursday, December 11, 2008, 8:00 am – 2:00 pm

1. Welcome and submit wireless access paperwork 8:30
2. Introductions: Review of Agenda 8:45
    a. Comments? Adjustments? Additions?
3. Meeting Goals (to be done before we leave):
    a. Establish energy efficiency measures to include in the advanced guide tables by climate zone
    b. Identify holes in draft—determine appropriate scope and depth to each section, and content we can work through while we are here
    c. Develop action item list to get to 65% Draft completed by 12/19/08
4. Next meeting 2/11-2/12 in Atlanta to review and address comments and prepare responses.
    a. Preparation for San Francisco meeting in April?
    b. See future meeting dates in Appendix B
5. Comments on Meeting#2 minutes
6. Old Action Items Review 9:00
7. 65% Review process 9:15
    a. Review notification
    b. Collection of "review remarks"
    c. Assembly of "review remarks"
    d. Response to "review remarks"
8. Break and TTF Lab Tour – Torcellini 9:45
9. Discuss prototype simulation results 10:15
    a. Review prototype model inputs
    b. Review baseline energy performance by climate
    c. Additional prototype model input needs
10. Lunch 12:00
11. Review Status and Comments of each Chapter of current 65% Draft 1:00
    a. Foreword
    b. Chapter 1 (intro)
    c. Chapter 2 (process)
    d. Chapter 3 – Recommendation table structure
        i. Review recommendation table spreadsheet and CZ1 Sample

        ii. Need to determine what type of plug/process loads to include in recommendation table
    e. Chapter 4 – Case Studies
        i. Review current list of case studies later
    f. Chapter 5 – How To Tips
        i. Quality Assurance
        ii. Envelope
        iii. Lighting/Daylighting
        iv. HVAC
        v. SWH
        vi. Bonus savings by strategy type

12. Break 2:45
13. Break into groups to further develop each section 3:00
    a. HVAC
    b. Lighting
    c. Envelope/Daylighting
    d. Case studies
14. Case study review 4:30
    a. Review current list of possible case studies (Pless)
    b. Absolute size limit? Under construction case studies?
    c. What can we include in the 65% draft? Releases?
    d. Others?
15. Return to hotel 5:30
16. Depart to dinner 6:15
17. Meet at Denver West Marriott Lobby for NREL shuttle 7:45
18. Coordinate transportation back to airport 8:00
19. Summarize content and recommendation development status 8:15
    a. Identify what can be done by the end of the day
    b. Identify what can be done by 12/19
20. Break into groups to further develop each section 8:30
    a. HVAC
    b. Lighting
    c. Envelope/Daylighting
    d. Foreword/Intro/Process chapters
21. Break 10:00
22. Continue breakout 10:15
23. Lunch 12:00
24. Review development status and identify additional issues 1:00
    a. Foreword
    b. Chapter 1 (intro)
    c. Chapter 2 (process)
    d. Chapter 3 – Recommendation table structure
        i. Review recommendation table spreadsheet and CZ1 Sample
    e. Chapter 4 – Case Studies
        i. review current list of case studies later
    f. Chapter 5 – How To Tips

i. Quality Assurance
ii. Envelope
iii. Lighting/Daylighting
iv. HVAC
v. SWH
vi. Bonus savings by strategy type

25. Review of Action Items 1:45
26. Adjourn 2:00

A.6 Meeting #4 Agenda

Agenda Meeting #4
Advanced Energy Design Guide-SHC
Project Committee Meeting
ASHRAE Headquarters
1791 Tullie Circle
Atlanta, GA 30329
404-636-8400

Wednesday, February 11, 2009, 8:00 am – 5:30 pm
Thursday, February 12, 2009, 8:00 am – 2:00 pm

1. Welcome 8:00
2. Introductions and Review of Agenda 8:15
3. Meeting Goals (to be done before we leave):
    a. Review simulation results
    b. Address and document responses to remarks.
    c. Identify holes in draft
    d. Develop action item list to get to 90% Draft completed by 5/11/09
4. Review all materials we will be using the next 2 days
    a. PC meeting #4 Agenda
    b. PC meeting #3 Meeting Report
    c. 65% Draft – PDF
    d. 90% Draft – working word draft
    e. 65% Draft Review Remarks Matrix
    f. 65% Draft Review Remarks Matrix-with additional remarks
    g. Proposed case study list
    h. Current recommendations spreadsheet
5. Review next meeting and call schedule 8:30
6. Comments on PC meeting #3 Report and Old Action Items Review
    a. See appendix A for Action Item list and section/chapter assignments
7. Update of related activities in energy efficiency and Healthcare
    a. Standard 189.2
    b. TC 9.6 Energy Subcommittee
    c. Conferences
        i. Healthcare Design
        ii. ASHE
        iii. ASHRAE
8. Discuss simulation results 9:00
    a. Review energy savings calculation process
    b. Prototypes
        i. Surgery Center
        ii. Community hospital
    c. Baseline sweep results
    d. Discuss advanced energy measures currently modeled
        i. Update recommendation spreadsheet

    e. Can we develop a list of possible additional savings measures?
        i. Envelope
        ii. LPDs and daylighting
        iii. EERs, IPLV
        iv. Fan efficiency or pressure drop
        v. ERVs, Economizers, DCV in non-clinical spaces?
    f. Additional model inputs – Doebber to collect during breakout sessions
9. Break 10:30
10. Process for updating 65% review draft 10:45
    a. Address review remark responses and update remark matrix
    b. 65% word draft by section to get a final 90%
11. Review general 65% draft remarks and determine responses 11:00
    a. Overall observations
    b. Problems based on first look?
    c. Major holes in 65% draft?
12. Lunch 12:00
13. Continue discussion on #11 1:00
14. Address outstanding TBD sections of the 65% draft 2:00
15. Case study review 5:00
    a. Review current list of possible case studies
    b. we need to start making decisions on which case studies to include
16. Recap progress addressing review remarks and identify additional work for Thursday
17. Dinner 5:30
18. Further content development and remark responses of by subcommittee 8:00
    a. Introduction/Foreword
    b. Chapter 1 (Why, Who, How to use guide)
    c. Chapter 2 (Process for Achieving Savings)
    d. Chapter 3 (Recommendation Tables)
    e. Chapter 4 (Case Studies)
    f. Chapter 5 (How to recommendations)
        i. QAs/Commissioning
        ii. Envelope
        iii. Lighting
        iv. HVAC
        v. SWH
        vi. Medical Equipment, Kitchen, Laundry
        vii. Bonus Savings
19. Reconvene as group and discuss draft 11:00
20. Discussion of Cover and other format issues 11:45
21. Lunch 12:00
22. Additional Issues 1:00
23. Review of Action Items 1:30
24. Adjourn 2:00

A.7 Meeting #5 Agenda

Agenda Meeting #5
Advanced Energy Design Guide-SHC
Project Committee Meeting
Anshen + Allen Architects (Room TBD)
901 Market Street, Sixth floor
San Francisco, CA 94103

Monday, April 27, 2009, 8:00 am – 5:00 pm
Tuesday, April 28, 2009, 8:00 am – 2:00 pm

1. Welcome 8:00
2. Introductions and Review of Agenda 8:15
3. Meeting Goals (to be done before we leave):
    a. Review simulation results
    b. Identify holes in draft
    c. Develop action item list to get to 90% draft completed by 5/11/09
    d. Evaluate case studies
4. Review next meeting/call schedule
    a. Last meeting in Atlanta?
5. Comments on PC meeting #4 Report and Old Action Items Review
    a. See appendix A for Action Item list and section/chapter assignments
6. Process for drafting 90% review draft 8:30
    a. Process and timing for posting 90% draft
    b. We need to make sure we have addressed review remark responses as we said we would
    c. Summary response document
7. Discuss simulation results 9:00
    a. Review energy savings calculation process
    b. Prototypes
        i. Surgery Center
        ii. Community hospital
    c. Baseline and proposed design sweep results
    d. Discuss advanced energy measures currently modeled
        i. Update recommendation spreadsheet and 90% draft
8. Break 10:30
9. Identify holes in 90% draft 11:00
    a. Assign action items by section
10. Lunch 12:00
11. Address outstanding TBD sections of the 90% draft 1:00
12. Afternoon Break 2:45
13. Continue #11 3:00
14. Case study review and assignments for follow-up 4:00
    a. Riverside Clinic Example In Appendix C
    b. Case study assignment list
        i. Patrick Dollard Health Center (NY)

        ii. Fasseas Cancer Clinic (AZ)
        iii. D'Amour Center for Cancer Care (MA)
        iv. Riverside Medical Clinic (CA)
        v. Rapid City Heart Doctor (SD)
        vi. Valley Health Center at Gilroy & Fair Oaks (AC)
        vii. Contra Costa County (CA)
        viii. North West Option (new)
        ix. Midwest Option (new)
        x. 251 Medical Center (TX)
        xi. Parrish Healthcare Center (FL)
        xii. Queen of Valley Hospital (CA)
        xiii. Oakes Community Hospital – not to be used unless necessary

15. Recap progress in 90% draft and identify additional work for Tuesday 4:45
16. Dinner 5:00
17. Further content development by subcommittee (Break up into groups) 8:00
    a. Introduction/Foreword
    b. Chapter 1 (Why, Who, How to use guide)
    c. Chapter 2 (Process for Achieving Savings)
    d. Chapter 3 (Recommendation Tables)
    e. Chapter 4 (Case Studies)
    f. Chapter 5 (How to recommendations)
        i. QAs/Commissioning
        ii. Envelope
        iii. Lighting
        iv. HVAC
        v. SWH
        vi. Medical Equipment, Kitchen, Laundry
        vii. Bonus Savings
18. Reconvene as group and discuss draft 11:00
19. Discussion of Cover and other format issues 11:45
20. Lunch 12:00
21. Additional Issues 1:00
22. Review of Action Items 1:30
23. Adjourn 2:00
24. Tour of Federal Court House 2:00

A.8 Meeting #6 Agenda

Agenda Meeting #6
Advanced Energy Design Guide-SHC
Project Committee Meeting
Erdman (Room TBD)
1 Erdman Place
Madison, WI 53717

Thursday, June 4, 2009, 8:00 am – 5:00 pm
Friday, June 5, 2009, 8:00 am – 3:00 pm

1. Welcome 8:00
2. Introductions and Review of Agenda 8:15
    a. Erdman building tour?
3. Meeting Goals (to be done before we leave):
    a. Review simulation results
    b. Address 90% review remarks
    c. Develop action item list to get to final draft completed by 6/30/09
    d. Evaluate case studies
4. Review publication schedule
5. Comments on PC meeting #5 Report and Old Action Items Review
    a. See appendix A for Action Item list and section/chapter assignments
6. Review of general 90% review draft remarks 8:30
    a. Summary response document process
7. Identify holes in 90% draft – All 9:00
    a. Items to complete in the next 2 days
    b. Items to complete by June 30
8. Break 10:00
9. Discuss simulation results 10:15
    a. Review energy savings calculation process
    b. Prototypes
        i. Surgery Center
        ii. Community hospital
    c. Baseline and proposed design sweep results
    d. Discuss advanced energy measures currently modeled
        i. Do we need to modify any recommendations?
10. Lunch 12:00
11. Subcommittee breakout to address 90% draft remarks 1:00
12. Afternoon Break 2:45
13. Continue #11 3:00
    a. HVAC subcommittee to review detailed energy model results
14. Review subcommittee progress and identify additional work for Friday 4:45
15. Identify Dinner location 5:00
16. Review status of goals 8:00
17. Case study status and assignments for follow-up 8:15
    a. Case study format and development guidance

   b. Case study assignment list
      i. Patrick Dollard Health Center (NY)
      ii. Fasseas Cancer Clinic (AZ)
      iii. D'Amour Center for Cancer Care (MA)
      iv. Riverside Medical Clinic (CA)
      v. Rapid City Heart Doctor (SD)
      vi. Valley Health Center at Gilroy & Fair Oaks (AC)
      vii. Contra Costa County (CA)
      viii. North West Option (new)
      ix. Midwest Option (new)
      x. 251 Medical Center (TX)
      xi. Parrish Healthcare Center (FL)
      xii. Queen of Valley Hospital (CA)
      xiii. Oakes Community Hospital – not to be used unless necessary

18. Further content development by subcommittee (Break up into groups) 9:00
    a. Introduction/Foreword -
    b. Chapter 1 (Why, Who, How to use guide)
    c. Chapter 2 (Process for Achieving Savings)
    d. Chapter 3 (Recommendation Tables)
    e. Chapter 4 (Case Studies)
    f. Chapter 5 (How to recommendations)
       i. QAs/Commissioning
       ii. Envelope
       iii. Lighting
       iv. HVAC
       v. SWH
       vi. Medical Equipment, Kitchen, Laundry
       vii. Bonus Savings
19. Reconvene as group and discuss draft 11:00
    a. What additional graphics do we need?
    b. What additional side bar technology case studies do we need?
20. Discussion of Cover and other format issues 11:45
21. Lunch 12:00
22. Additional issues and review of action items 1:00
23. Additional breakout as needed 1:30
24. Adjourn 3:00

Appendix B Responses to 65% Draft Review Remarks

SUMMARY RESPONSE TO
PEER REVIEW REMARKS AND RECOMMENDATIONS
RECEIVED ON
65% TECHNICAL REFINEMENT DRAFT OF
ADVANCED ENERGY DESIGN GUIDE:
SMALL HOSPITALS AND HEALTHCARE FACILITIES
April 30, 2009

On January 5, 2009, the Project Committee for the Advanced Energy Design Guide – Small Healthcare (AEDG-SHC) issued a 65% Technical Refinement Draft of the document Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities. Following the review period of January 5-16, 2009, the AEDG-SHC Project Committee met on February 11-12, 2009 to review the recommendations received.

The committee received 137 remarks and review recommendations from 12 reviewers representing AIA, IESNA, USGBC and the ASHRAE membership at large. The following documents the Project Committee's summary response to those remarks and recommendations. Although many of the suggestions dealt with details presented in the draft, this summary includes responses only to significant technical recommendations, especially those in which there was disagreement with what had been written or omitted. The specific and detailed suggestions and remarks have been, and will continue to be, reviewed and digested by the Project Committee as it prepares the next draft of the guide. The review remarks received fall into the following six categories.

General Comments:

1. The intent of the guide is to provide a prescriptive list of measures to achieve 30% savings over Standard 90.1-1999. We emphasize that the guide presents a way, not the only way to achieve 30% energy savings so not all possible strategies will be included, especially specialty items. A balanced, multi-option approach is recommended.
2. Per the direction of the AEDG Steering Committee, the 30% goal is based on site energy use and uses Standard 90.1-1999 as the baseline measurement. This is to be consistent with all the AEDG guides in the series.
3. Criteria used in the advanced case will be no less stringent than Standard 90.1-2007 (including addenda as and at and the metal buildings update for roofs and walls).
4. References will be added as needed and both the references and additional resources list will be updated to include the most recent versions of 90.1 (2007) and the IMC (2009) and to delete unnecessary references.
5. The numbering and in-text references for the figures and tables will be updated and corrected throughout the document prior to publication of the document.
6. The use of acronyms will be standardized in the document and additional definitions will be added as needed.
7. The formatting of the document including headings is handled by ASHRAE publications and will be consistent with all the AEDG guides in the series.

Foreword

1. While the information on revenue in the Foreword will be reworded to include concerns for patient satisfaction, the information on lowering overall cost will remain as the committee feels that this information is crucial to the adoption of the capital costs required.
2. Savings information will be verified and revised as needed.

Introduction (Chapter 1)

1. The addition of energy savings relative to 90.1-2007 is dependent up on available resources and while this comparison will likely be done for future guides, it may or may not be done for this guide.
2. The explanation on site versus source energy will be rewritten for clarity on energy efficiencies and costs.

How to Use an Integrated Design Approach (Chapter 2)

1. Information in this section will be substantiated with references or rewritten as appropriate.
2. The energy modeling graph in Figures 2.1 is a placeholders showing information from a previous guide. Updated graphs will be inserted when the analysis is completed and prior to publication.
3. The tables in this chapter were developed using standard industry practice and terminology and the committee feels that minimal changes are needed. The need for accurate record drawings will be added to Table 2.4 in addition to O&M manuals.
4. The committee feels that the TAB (Testing and Balancing) contractor and the ME (Mechanical Engineer) roles are adequately represented in chapter 2 tables under the subcontractor, designers, and consultants categories. However, additional information on TAB will be added to the commissioning section in the guide. Healthcare experience for these professionals is discussed in Chapter 1.
5. The discussion on drivers for integrated design in the healthcare industry will be rewritten to improve the clarity and accuracy of the information.

Recommendations by Climate (Chapter 3)

1. General
    a. The minimum and maximum value lists in the chapter overview will be updated to reflect the recommendations in the guide.
2. Envelope
    a. The SRI values in climate zones 1-3 will be corrected from decimals to whole numbers.
    b. The c.i. designation will be added where missing in the Recommendation Tables.
    c. The roof insulation recommendations will be changed to R-30 in climate zones 4-6 and to R-35 in climate zones 7 and 8.
    d. The committee notes that floors with solar gains are no different than north walls. Both experience dry bulb temperatures, but the recommended insulation level for floors is less than that for walls. While un-insulated floor over parking garages can provide "free cooling," it is more efficient to use economizer cycles and insulate the floor.
3. Daylighting and Lighting
    a. The 1.1 W/SF is the initial target value (30% off the 90.1-1999), but will be evaluated as per the simulation results and adjusted as needed.

        b. The automatic dimming control recommendation will be clarified to not include patient rooms where occupant control of lights and window shades should govern.
    4. HVAC and SWH
        a. The automatic setback recommendation for critical care areas will be deleted in favor of air flow setback where permissible.
        b. Energy recovery ventilation is only recommended in those systems types where it was needed to reach the 30% savings target.
        c. Since a major use of heating water is reheat, which is required in every zone, the boiler should be high efficiency in all zones. The recommended efficiencies for cooling systems do vary by climate zone.
        d. The exhaust energy recover recommendations in the tables will be corrected to correspond with the information in the Chapter 5 How-to tips.

Technology Examples and Case Studies (Chapter 4)

1. The detail in the case studies is dependent upon the case studies received, but the PC will make every effort to include case studies that reflect the recommendations included in the guide.

How to Implement Recommendations (Chapter 5)

1. Quality Assurance & Commissioning
    a. The importance of reviewing submittals will be added to this section; however, documentation of on-going energy monitoring is beyond the scope of this document.
2. Envelope
    a. The discussion on thermal mass will be modified to include heating loads as well as cooling loads.
    b. Cavity insulation is recommended in EN4 because the exterior sheathing insulation is more expensive and the cavity insulation helps reduce the sheathing thickness and the accompanying attachment issues
    c. The WWR recommendations reflect the values that were modeled. A caution will be added to the WWR discussion regarding potential increase of heating and cooling loads.
    d. NFRC ratings are for the overall fenestration unit including the edge and frame.
    e. The fenestration options in Table 5-3 were analyzed using LCC analysis and shown to be cost effective using the same economic assumptions from 90.1.
    f. The example in EN22 will cite high continuous windows versus punched windows without trying to distinguish vertical windows
3. Daylighting and Lighting
    a. The numbering and organization of the lighting section will be adjusted as needed to reduce redundancy in the information.
    b. The wording on high light output ballasts in EL2 will be modified to clarify the difference between ballast input power and overall system efficacy.
    c. The description of T8 lamps will state that these are one of the more commonly specified lighting systems for healthcare facilities.
    d. User-intuitive controls and ease of maintenance will be emphasized in the discussion on lighting controls; however, the committee feels that a caution about minimizing bulb types is not needed.

    e. The values in Table 5-5 are in ANSI/IES-RP29-2006 and the committee agrees that they are somewhat constrained by the IES lighting design method illuminance categories that do not always adequately address the visual needs in all applications (such as OR's).
    f. While the values in Table 5-8 will be updated, the values are consistent with and apply the same methodology as previous guides.
    g. The influence of EISA 2007 and the effect of tilt factor and lamp performance will be added to the discussion in EL5
    h. While 90.1 does not explicitly allow for control via keyed or timed switch that restricts when higher power usage occurs in low use spaces, the committee will incorporate this methodology into the discussion on general lighting control strategies as an exception to maximum lighting power density.
    i. The discussion on occupancy based control will be updated to include discussion on bypass-off switches, a caution on the use of ultrasonic sensors in mechanical rooms, and the suggestion that lighting sensors can be linked to HVAC controls to eliminate the need for a second sensor system. The use of occupancy sensors in patient care corridors is being reexamined, and patient control of the environment will be emphasized as the overriding concern in patient rooms.
    j. Information on photo cell sensors will be added to the discussion on control of exterior lighting.
    k. While the committee feels that indirect lighting can be an energy efficient option, task-ambient and direct-indirect approaches will be also be included in the discussion in DL18.
    l. Exit lighting is addressed in EL6; however lighting of ATMs which is a limited application and egress lighting which is governed by local codes will not be addressed in the guide.
4. HVAC and SWH
    a. The discussion of flex duct in HV 11 will be expanded to include additional applications.
    b. While hospitals require ducted returns for all patient care areas, some outpatient facilities permit the use of plenum return.
    c. While partially covered already, additional information indicating the energy optimization and minimization potential of effective DDC controls.
    d. The committee feels that the information in this section on economizers, air flow monitors, and reheat is accurate and appropriate.
    e. The committee feels that some of the suggested information on dampers, duct liner, and filter use are relevant to an energy design guide.
5. Bonus/Additional Savings
    a. Exterior Lighting will be addressed as a bonus savings.
    b. Additional information will be added about integrating metering from distribution equipment into a comprehensive building management system; however, no change is needed regarding emergency power. The distribution system derives supply from either the utility or the emergency power supply system, but the entire distribution system is being metered at all times.

Appendix C Community Hospital Baseline Scorecards

Table C-1 Community Hospital Baseline Scorecard: Climate Zones 1A–3B

ASHRAE 90.1-2004 Climate Zone		1A	2A	2B	3A	3B
Program	**Building name**	Community Hospital	Community Hospital	Community Hospital	Community Hospital	Community Hospital
	Location	Miami, Florida	Houston, Texas	Phoenix, Arizona	Memphis, Tennessee	El Paso, Texas
Form	**Total floor area (ft^2 [m^2])**	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]
	Number of floors	1	1	1	1	1
	Window fraction (window to wall ratio)	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26
	Skylight/TDD percent	0.0%	0.0%	0.0%	0.0%	0.0%
	Azimuth	0.00	0.00	0.00	0.00	0.00
Fabric	**Exterior walls**					
	Construction type	Steel-framed	Steel-framed	Steel-framed	Steel-framed	Steel-framed
	Construction description	R-13	R-13	R-13	R-13	R-13
	R-value (ft^2·h·°F/Btu [m^2·K/W])	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]
	Gross dimensions – total area (ft^2 [m^2])	24,061 [2,235]	24,061 [2,235]	24,061 [2,235]	24,061 [2,235]	24,061 [2,235]
	Net dimensions – total area (ft^2 [m^2])	17,638 [1,639]	17,638 [1,639]	17,638 [1,639]	17,638 [1,639]	17,638 [1,639]
	Wall to skin ratio	0.27	0.27	0.27	0.27	0.27
	Tilts and orientation	Vertical	Vertical	Vertical	Vertical	Vertical
	Roof					
	Construction type	IEAD	IEAD	IEAD	IEAD	IEAD
	Construction description	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.
	R-value (ft^2·h·°F/Btu [m^2·K/W])	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]
	Gross dimensions – total area (ft^2 [m^2])	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]
	Net dimensions – total area (ft^2 [m^2])	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]
	Roof to skin ratio	0.73	0.73	0.73	0.73	0.73
	Tilts and orientation	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal

Table C-1 Community Hospital Baseline Scorecard: Climate Zones 1A–3B (con't)

ASHRAE 90.1-2004 Climate Zone		1A	2A	2B	3A	3B
Fabric	**Windows**					
	Dimensions – total area (ft^2 [m^2])	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]
	U-Factor (Btu/h·ft^2·ºF [W/m^2·K])	S: 1.21 [6.88] E: 1.21 [6.88] N: 1.21 [6.88] W: 1.21 [6.88]	S: 1.21 [6.88] E: 1.21 [6.88] N: 1.21 [6.88] W: 1.21 [6.88]	S: 1.21 [6.88] E: 1.21 [6.88] N: 1.21 [6.88] W: 1.21 [6.88]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.57 [3.24] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.57 [3.24] W: 0.57 [3.24]
	SHGC	South: 0.25 East: 0.25 North: 0.33 West: 0.25	South: 0.25 East: 0.25 North: 0.44 West: 0.25	South: 0.25 East: 0.25 North: 0.44 West: 0.25	South: 0.25 East: 0.25 North: 0.26 West: 0.25	South: 0.25 East: 0.25 North: 0.26 West: 0.25
	Visible transmittance	South: 0.25 East: 0.25 North: 0.33 West: 0.25	South: 0.25 East: 0.25 North: 0.44 West: 0.25	South: 0.25 East: 0.25 North: 0.44 West: 0.25	South: 0.25 East: 0.25 North: 0.26 West: 0.25	South: 0.25 East: 0.25 North: 0.26 West: 0.25
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Skylights/TDD					
	Dimensions – total area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	U-Factor (Btu/h·ft^2·ºF [W/m^2·K])	1.21 [6.92]	1.21 [6.92]	1.21 [6.92]	0.69 [3.92]	0.69 [3.92]
	SHGC	0.36	0.36	0.36	0.39	0.39
	Visible transmittance	0.36	0.36	0.36	0.39	0.39
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Foundation					
	Foundation type	Mass floor	Mass floor	Mass floor	Mass floor	Mass floor
	Construction	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation
	R-value (ft^2·h·°F/Btu [m^2·K/W])	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]
	Average min/max under-slab temperatures	Min: 72.5 [22.5] Max: 73.7 [23.1]	Min: 68.6 [20.4] Max: 73.4 [23.0]	Min: 66.6 [19.2] Max: 70.9 [21.6]	Min: 67.8 [19.9] Max: 72.8 [22.7]	Min: 66.6 [19.2] Max: 71.4 [21.9]
	Dimensions	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]

Table C-1 Community Hospital Baseline Scorecard: Climate Zones 1A–3B (con't)

ASHRAE 90.1-2004 Climate Zone		1A	2A	2B	3A	3B
Fabric	**Interior Partitions**					
	Construction	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board
	Dimensions – total area (ft^2 [m^2])	61,137 [5,680]	61,137 [5,680]	61,137 [5,680]	61,137 [5,680]	61,137 [5,680]
	Internal Mass					
	Construction	6-in. wood	6-in. wood	6-in. wood	6-in. wood	6-in. wood
	Dimensions – total area (ft^2 [m^2])	128,651 [11,952]	128,651 [11,952]	128,651 [11,952]	128,651 [11,952]	128,651 [11,952]
	Thermal properties (lb/ft^2 [kg/m^2])	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]
HVAC	**Heating Type**	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
	Cooling Type	DX	DX	DX	DX	DX
	HVAC Autosizing					
	Air-conditioning (tons [kW])	241.9 [850.8]	246.4 [866.6]	237.3 [834.6]	244.6 [860.3]	210.2 [739.3]
	Heating (kBtu/h [kW])	2,103.6 [616.5]	2,055.6 [602.4]	2,117.1 [620.5]	2,044.4 [599.1]	1,944.7 [569.9]
	HVAC Efficiency					
	Air-conditioning (COP)	3.24	3.24	3.24	3.24	3.24
	Heating efficiency (%)	80	80	80	80	80
	HVAC Control					
	Economizer	No	No	Yes	No	Yes
	Fan and pump loads					
	Supply fan volumetric flow rate (cfm [m^3/s])	80,812.9 [38.1]	83,570.6 [39.4]	90,601.2 [42.8]	82,580.8 [39.0]	91,106.6 [43.0]
	Service water heating					
	SWH type	NG Storage Tank	NG Storage Tank	NG Storage Tank	NG Storage Tank	NG Storage Tank
	E_t (%)	80	80	80	80	80
Internal Loads and Schedules	**Lighting**					
	Average power density (W/ft^2 [W/m^2])	1.85 [19.90]	1.85 [19.90]	1.85 [19.90]	1.85 [19.90]	1.85 [19.90]
	Schedule	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5
	Plug Loads					
	Average power density (W/ft^2 [W/m^2])	2.06 [22.20]	2.06 [22.20]	2.06 [22.20]	2.06 [22.20]	2.06 [22.20]
	Schedule	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8
	Occupancy					
	Average people (#/1000 ft^2 [#/100 m^2])	10.48 [11.29]	10.48 [11.29]	10.48 [11.29]	10.48 [11.29]	10.48 [11.29]
	Schedule	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9

Table C-2 Community Hospital Baseline Scorecard: Climate Zones 3C–5A

ASHRAE 90.1-2004 Climate Zone		3C	4A	4B	4C	5A
Program	**Building name**	Community hospital	Community hospital	Community hospital	Community hospital	Community hospital
	Location	San Francisco, California	Baltimore, Maryland	Albuquerque, New Mexico	Seattle, Washington	Chicago, Illinois
Form	**Total floor area (ft^2 [m^2])**	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]
	Number of floors	1	1	1	1	1
	Window fraction (window to wall ratio)	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26
	Skylight/TDD percent	0.0%	0.0%	0.0%	0.0%	0.0%
	Azimuth	0.00	0.00	0.00	0.00	0.00
Fabric	**Exterior Walls**					
	Construction type	Steel-framed	Steel-framed	Steel-framed	Steel-framed	Steel-framed
	Construction description	R-13	R-13	R-13	R-13	R-13 + R-3.8 c.i.
	R-value (ft^2·h·°F/Btu [m^2·K/W])	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]	11.06 [1.95]
	Gross dimensions – total area (ft^2 [m^2])	24,061 [2,235]	24,061 [2,235]	24,061 [2,235]	24,061 [2,235]	24,061 [2,235]
	Net dimensions – total area (ft^2 [m^2])	17,638 [1,639]	17,638 [1,639]	17,638 [1,639]	17,638 [1,639]	17,638 [1,639]
	Wall to skin ratio	0.27	0.27	0.27	0.27	0.27
	Tilts and orientation	Vertical	Vertical	Vertical	Vertical	Vertical
	Roof					
	Construction type	IEAD	IEAD	IEAD	IEAD	IEAD
	Construction description	R-10 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.
	R-value (ft^2·h·°F/Btu [m^2·K/W])	9.69 [1.71]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]
	Gross dimensions – total area (ft^2 [m^2])	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]
	Net dimensions – total area (ft^2 [m^2])	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]
	Roof to skin ratio	0.73	0.73	0.73	0.73	0.73
	Tilts and orientation	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal

Table C-2 Community Hospital Baseline Scorecard: Climate Zones 3C–5A (con't)

ASHRAE 90.1-2004 Climate Zone		3C	4A	4B	4C	5A
Fabric	**Windows**					
	Dimensions – total area (ft^2 [m^2])	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]
	U-factor (Btu/h·ft^2·°F [W/m^2·K])	S: 1.21 [6.88] E: 1.21 [6.88] N: 0.73 [4.15] W: 1.21 [6.88]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]
	SHGC	South: 0.61 East: 0.61 North: 0.61 West: 0.61	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39
	Visible transmittance	South: 0.61 East: 0.61 North: 0.61 West: 0.61	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Skylights/TDD					
	Dimensions – total area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	U-factor (Btu/h·ft^2·°F [W/m^2·K])	1.21 [6.92]	0.69 [3.92]	0.69 [3.92]	0.69 [3.92]	0.69 [3.92]
	SHGC	0.61	0.49	0.49	0.49	0.49
	Visible transmittance	0.61	0.49	0.49	0.49	0.49
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Foundation					
	Foundation type	Mass floor	Mass floor	Mass floor	Mass floor	Mass floor
	Construction	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation
	R-value (ft^2·h·°F/Btu [m^2·K/W])	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]
	Average min/max underslab temperatures	Min: 67.8 [19.9] Max: 68.8 [20.4]	Min: 67.4 [19.7] Max: 72.6 [22.6]	Min: 66.5 [19.2] Max: 71.3 [21.8]	Min: 67.5 [19.7] Max: 70.0 [21.1]	Min: 67.1 [19.5] Max: 72.3 [22.4]
	Dimensions	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]

Table C-2 Community Hospital Baseline Scorecard: Climate Zones 3C–5A (con't)

ASHRAE 90.1-2004 Climate Zone		3C	4A	4B	4C	5A
Fabric	**Interior Partions**					
	Construction	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board
	Dimensions – total area (ft^2 [m^2])	61,137 [5,680]	61,137 [5,680]	61,137 [5,680]	61,137 [5,680]	61,137 [5,680]
	Internal Mass					
	Construction	6-in. wood	6-in. wood	6-in. wood	6-in. wood	6-in. wood
	Dimensions – total area (ft^2 [m^2])	128,651 [11,952]	128,651 [11,952]	128,651 [11,952]	128,651 [11,952]	128,651 [11,952]
	Thermal properties (lb/ft^2 [kg/m^2])	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]
HVAC	**Heating Type**	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
	Cooling Type	DX	DX	DX	DX	DX
	HVAC Autosizing					
	Air-conditioning (tons [kW])	194.3 [683.4]	232.9 [819.1]	206.9 [727.7]	182.9 [643.3]	226.0 [794.8]
	Heating (kBtu/h [kW])	1,789.7 [524.5]	2,026.0 [593.8]	1,875.9 [549.8]	1,847.3 [541.4]	2,002.0 [586.7]
	HVAC Efficiency					
	Air-conditioning (COP)	3.24	3.24	3.24	3.24	3.24
	Heating efficiency (%)	80	80	80	80	80
	HVAC Control					
	Economizer	Yes	No	Yes	Yes	Yes
	Fan and Pump Loads					
	Supply fan volumetric flow rate (cfm [m^3/s])	70,999.3 [33.5]	81,894.0 [38.7]	93,177.2 [44.0]	74,576.9 [35.2]	80,202.8 [37.9]
	Service Water Heating					
	SWH type	NG storage tank	NG storage tank	NG storage Tank	NG storage tank	NG storage tank
	E_t (%)	80	80	80	80	80
Internal Loads and Schedules	**Lighting**					
	Average power density (W/ft^2 [W/m^2])	1.85 [19.90]	1.85 [19.90]	1.85 [19.90]	1.85 [19.90]	1.85 [19.90]
	Schedule	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5
	Plug Loads					
	Average power density (W/ft^2 [W/m^2])	2.06 [22.20]	2.06 [22.20]	2.06 [22.20]	2.06 [22.20]	2.06 [22.20]
	Schedule	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8
	Occupancy					
	Average people (#/1000 ft^2 [#/100 m^2])	10.48 [11.29]	10.48 [11.29]	10.48 [11.29]	10.48 [11.29]	10.48 [11.29]
	Schedule	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9

Table C-3 Community Hospital Baseline Scorecard: Climate Zones 5B–8A

ASHRAE 90.1-2004 Climate Zone		5B	6A	6B	7A	8A
Program	**Building name**	Community Hospital	Community Hospital	Community Hospital	Community Hospital	Community Hospital
	Location	Boise, Idaho	Burlington, Vermont	Helena, Montana	Duluth, Minnesota	Fairbanks, Alaska
Form	**Total floor area (ft^2 [m^2])**	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]
	Number of floors	1	1	1	1	1
	Window fraction (window to wall ratio)	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26	South: 0.19 East: 0.12 North: 0.42 West: 0.16 Total: 0.26
	Skylight/TDD percent	0.0%	0.0%	0.0%	0.0%	0.0%
	Azimuth	0.00	0.00	0.00	0.00	0.00
Fabric	**Exterior Walls**					
	Construction type	Steel-framed	Steel-framed	Steel-framed	Steel-framed	Steel-framed
	Construction description	R-13 + R-3.8 c.i.	R-13 + R-3.8 c.i.	R-13 + R-3.8 c.i.	R-13 + R-7.5 c.i.	R-13 + R-7.5 c.i.
	R-value ($ft^2 \cdot h \cdot °F/Btu$ [$m^2 \cdot K/W$])	11.06 [1.95]	11.06 [1.95]	11.06 [1.95]	14.76 [2.60]	14.76 [2.60]
	Gross dimensions – total area (ft^2 [m^2])	24,061 [2,235]	24,061 [2,235]	24,061 [2,235]	24,061 [2,235]	24,061 [2,235]
	Net dimensions – total area (ft^2 [m^2])	17,638 [1,639]	17,638 [1,639]	17,638 [1,639]	17,638 [1,639]	17,638 [1,639]
	Wall to skin ratio	0.27	0.27	0.27	0.27	0.27
	Tilts and orientation	Vertical	Vertical	Vertical	Vertical	Vertical
	Roof					
	Construction type	IEAD	IEAD	IEAD	IEAD	IEAD
	Construction description	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-20 c.i.
	R-value ($ft^2 \cdot h \cdot °F/Btu$ [$m^2 \cdot K/W$])	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	19.76 [3.48]
	Gross dimensions – total area (ft^2 [m^2])	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]
	Net dimensions – total area (ft^2 [m^2])	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]	64,752 [6,016]
	Roof to skin ratio	0.73	0.73	0.73	0.73	0.73
	Tilts and orientation	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal

Table C-3 Community Hospital Baseline Scorecard: Climate Zones 5B–8A (con't)

ASHRAE 90.1-2004 Climate Zone		**5B**	**6A**	**6B**	**7A**	**8A**
Fabric	**Windows**					
	Dimensions – total area (ft^2 [m^2])	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]	S: 1,060 [98] E: 572 [53] N: 3,449 [320] W: 1,069 [99] Total: 6149 [571]
	U-factor (Btu/h·ft^2·°F [W/m^2·K])	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.46 [2.61] E: 0.46 [2.61] N: 0.35 [1.99] W: 0.46 [2.61]
	SHGC	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.49 West: 0.39	South: 0.39 East: 0.39 North: 0.49 West: 0.39	South: 0.49 East: 0.49 North: 0.64 West: 0.49	South: 0.46 East: 0.46 North: 0.46 West: 0.46
	Visible transmittance	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.49 West: 0.39	South: 0.39 East: 0.39 North: 0.49 West: 0.39	South: 0.49 East: 0.49 North: 0.64 West: 0.49	South: 0.46 East: 0.46 North: 0.46 West: 0.46
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Skylights/TDD					
	Dimensions – total area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	U-factor (Btu/h·ft^2·°F [W/m^2·K])	0.69 [3.92]	0.69 [3.92]	0.69 [3.92]	0.69 [3.92]	0.58 [3.29]
	SHGC	0.49	0.49	0.49	0.68	0.49
	Visible transmittance	0.49	0.49	0.49	0.68	0.49
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Foundation					
	Foundation type	Mass floor	Mass floor	Mass floor	Mass floor	Mass floor
	Construction	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation
	R-value (ft^2·h·°F/Btu [m^2·K/W])	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]
	Average min/max underslab temperatures	Min: 66.7 [19.3] Max: 706 [21.5]	Min: 66.9 [19.4] Max: 71.4 [21.9]	Min: 66.4 [19.1] Max: 70.4 [21.3]	Min: 66.5 [19.1] Max: 69.7 [20.9]	Min: 65.1 [18.4] Max: 67.3 [19.6]
	Dimensions	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]	64,326 [5,976]

Table C-3 Community Hospital Baseline Scorecard: Climate Zones 5B–8A (con't)

ASHRAE 90.1-2004 Climate Zone		5B	6A	6B	7A	8A
Fabric	**Interior Partitions**					
	Construction	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board
	Dimensions – total area (ft^2 [m^2])	61,137 [5,680]	61,137 [5,680]	61,137 [5,680]	61,137 [5,680]	61,137 [5,680]
	Internal Mass					
	Construction	6-in. wood	6-in. wood	6-in. wood	6-in. wood	6-in. wood
	Dimensions – total area (ft^2 [m^2])	128,651 [11,952]	128,651 [11,952]	128,651 [11,952]	128,651 [11,952]	128,651 [11,952]
	Thermal properties (lb/ft^2 [kg/m^2])	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]
HVAC	**Heating Type**	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
	Cooling Type	DX	DX	DX	DX	DX
	HVAC Autosizing					
	Air-conditioning (tons [kW])	195.0 [685.8]	208.3 [732.6]	189.5 [666.5]	194.0 [682.3]	158.9 [558.9]
	Heating (kBtu/h [kW])	1,905.2 [558.4]	1,988.8 [582.9]	1,878.2 [550.4]	1,943.1 [569.5]	2,032.9 [595.8]
	HVAC Efficiency					
	Air-conditioning (COP)	3.24	3.24	3.24	3.24	3.24
	Heating efficiency (%)	80	80	80	80	80
	HVAC Control					
	Economizer	Yes	Yes	Yes	Yes	Yes
	Fan and Pump Loads					
	Supply fan volumetric flow rate (cfm [m^3/s])	85,044.1 [40.1]	77,199.0 [36.4]	83,860.1 [39.6]	76,140.0 [35.9]	68,894.8 [32.5]
	Service Water Heating					
	SWH type	NG storage tank	NG storage tank	NG storage tank	NG storage tank	NG storage tank
	E_t (%)	80	80	80	80	80
Internal Loads and Schedules	**Lighting**					
	Average power density (W/ft^2 [W/m^2])	1.85 [19.90]	1.85 [19.90]	1.85 [19.90]	1.85 [19.90]	1.85 [19.90]
	Schedule	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5
	Plug Loads					
	Average power density (W/ft^2 [W/m^2])	2.06 [22.20]	2.06 [22.20]	2.06 [22.20]	2.06 [22.20]	2.06 [22.20]
	Schedule	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8
	Occupancy					
	Average people (#/1000 ft^2 [#/100 m^2])	10.48 [11.29]	10.48 [11.29]	10.48 [11.29]	10.48 [11.29]	10.48 [11.29]
	Schedule	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9

Appendix D Surgery Center Baseline Scorecard

Table D-1 Surgery Center Baseline Scorecard: Climate Zones 1A–3B

ASHRAE 90.1-2004 Climate Zone		1A	2A	2B	3A	3B
Program	**Building name**	Surgery Center	Surgery Center	Surgery Center	Surgery Center	Surgery Center
	Location	Miami, Florida	Houston, Texas	Phoenix, Arizona	Memphis, Tennessee	El Paso, Texas
Form	**Total floor area (ft^2 [m^2])**	40,946 [3,804]	40,946 [3,804]	40,946 [3,804]	40,946 [3,804]	40,946 [3,804]
	Number of floors	3	3	3	3	3
	Window fraction (window to wall ratio)	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20
	Skylight/TDD percent	0.00	0.00	0.00	0.00	0.00
	Azimuth	0.00	0.00	0.00	0.00	0.00
Fabric	**Exterior Walls**					
	Construction type	Steel-framed	Steel-framed	Steel-framed	Steel-framed	Steel-framed
	Construction description	R-13	R-13	R-13	R-13	R-13
	R-value (ft^2·h·°F/Btu [m^2·K/W])	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]
	Gross dimensions – total area (ft^2 [m^2])	16,720 [1,553]	16,720 [1,553]	16,720 [1,553]	16,720 [1,553]	16,720 [1,553]
	Net dimensions – total area (ft^2 [m^2])	13,178 [1,224]	13,178 [1,224]	13,178 [1,224]	13,178 [1,224]	13,178 [1,224]
	Wall to skin ratio	0.53	0.53	0.53	0.53	0.53
	Tilts and orientation	Vertical	Vertical	Vertical	Vertical	Vertical
	Roof					
	Construction type	IEAD	IEAD	IEAD	IEAD	IEAD
	Construction description	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.
	R-value (ft^2·h·°F/Btu [m^2·K/W])	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]
	Gross dimensions – total area (ft^2 [m^2])	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]
	Net dimensions – total area (ft^2 [m^2])	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]
	Roof to skin ratio	0.47	0.47	0.47	0.47	0.47
	Tilts and orientation	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal

Table D-1 Surgery Center Baseline Scorecard: Climate Zones 1A–3B (con't)

ASHRAE 90.1-2004 Climate Zone		1A	2A	2B	3A	3B
Fabric	**Windows**					
	Dimensions – total area (ft^2 [m^2])	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]
	U-factor (Btu/h·ft^2·°F [W/m^2·K])	S: 1.21 [6.88] E: 1.21 [6.88] N: 1.21 [6.88] W: 1.21 [6.88]	S: 1.21 [6.88] E: 1.21 [6.88] N: 1.21 [6.88] W: 1.21 [6.88]	S: 1.21 [6.88] E: 1.21 [6.88] N: 1.21 [6.88] W: 1.21 [6.88]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.57 [3.24] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.57 [3.24] W: 0.57 [3.24]
	SHGC	South: 0.25 East: 0.25 North: 0.33 West: 0.25	South: 0.25 East: 0.25 North: 0.44 West: 0.25	South: 0.25 East: 0.25 North: 0.44 West: 0.25	South: 0.25 East: 0.25 North: 0.26 West: 0.25	South: 0.25 East: 0.25 North: 0.26 West: 0.25
	Visible transmittance	South: 0.25 East: 0.25 North: 0.33 West: 0.25	South: 0.25 East: 0.25 North: 0.44 West: 0.25	South: 0.25 East: 0.25 North: 0.44 West: 0.25	South: 0.25 East: 0.25 North: 0.26 West: 0.25	South: 0.25 East: 0.25 North: 0.26 West: 0.25
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Skylights/TDD					
	Dimensions – total area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	U-factor (Btu/h·ft^2·°F [W/m^2·K])	1.21 [6.92]	1.21 [6.92]	1.21 [6.92]	0.69 [3.92]	0.69 [3.92]
	SHGC	0.36	0.36	0.36	0.39	0.39
	Visible transmittance	0.36	0.36	0.36	0.39	0.39
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Foundation					
	Foundation type	Mass floor	Mass floor	Mass floor	Mass floor	Mass floor
	Construction	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation
	R-value (ft^2·h·°F/Btu [m^2·K/W])	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]
	Average min/max under-slab temperatures	Min: 72.5 [22.5] Max: 73.7 [23.1]	Min: 68.6 [20.4] Max: 73.4 [23.0]	Min: 66.6 [19.2] Max: 70.9 [21.6]	Min: 67.8 [19.9] Max: 72.8 [22.7]	Min: 66.6 [19.2] Max: 71.4 [21.9]
	Dimensions	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]

Table D-1 Surgery Center Baseline Scorecard: Climate Zones 1A–3B (con't)

ASHRAE 90.1-2004 Climate Zone		**1A**	**2A**	**2B**	**3A**	**3B**
Fabric	**Interior Partitions**					
	Construction	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board
	Dimensions – total area (ft^2 [m^2])	39,960 [3,712]	39,960 [3,712]	39,960 [3,712]	39,960 [3,712]	39,960 [3,712]
	Internal Mass					
	Construction	6-in. wood	6-in. wood	6-in. wood	6-in. wood	6-in. wood
	Dimensions – total area (ft^2 [m^2])	81,304 [7,553]	81,304 [7,553]	81,304 [7,553]	81,304 [7,553]	81,304 [7,553]
	Thermal properties (lb/ft^2 [kg/m^2])	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]
HVAC	**Heating type**	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
	Cooling type	DX	DX	DX	DX	DX
	HVAC Autosizing					
	Air-conditioning (tons [kW])	148.9 [523.7]	153.5 [539.8]	147.8 [520.0]	154.3 542.8]	133.2 [468.4]
	Heating (kBtu/h [kW])	1,101.2 [322.7]	1,133.51 [332.2]	1,206.7 [353.7]	1,141.0 [334.4]	1,089.9 [319.4]
	HVAC Efficiency					
	Air-conditioning (COP)	3.24	3.24	3.24	3.24	3.24
	Heating efficiency (%)	80	80	80	80	80
	HVAC Control					
	Economizer	No	No	Yes	No	Yes
	Fan and Pump Loads					
	Supply fan volumetric flow rate (cfm [m^3/s])	49,491.8 [23.4]	52,085.7 [24.6]	59,809.4 [28.2]	52,208.9 [24.6]	58,355.0 [27.5]
	Service Water Heating					
	SWH type	NG Storage Tank	NG Storage Tank	NG Storage Tank	NG Storage Tank	NG Storage Tank
	E_t (%)	80	80	80	80	80
Internal Loads and Schedules	**Lighting**					
	Average power density (W/ft^2 [W/m^2])	1.86 [19.97]	1.86 [19.97]	1.86 [19.97]	1.86 [19.97]	1.86 [19.97]
	Schedule	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5
	Plug Loads					
	Average power density (W/ft^2 [W/m^2])	1.80 [19.42]	1.80 [19.42]	1.80 [19.42]	1.80 [19.42]	1.80 [19.42]
	Schedule	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8
	Occupancy					
	Average people (#/1000 ft^2 [#/100 m^2])	10.13 [10.90]	10.13 [10.90]	10.13 [10.90]	10.13 [10.90]	10.13 [10.90]
	Schedule	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9

Table D-2 Surgery Center Scorecard: Climate Zones 3C–5A

	ASHRAE 90.1-2004 Climate Zone	3C	4A	4B	4C	5A
Program	**Building name**	Surgery Center	Surgery Center	Surgery Center	Surgery Center	Surgery Center
	Location	San Francisco, California	Baltimore, Maryland	Albuquerque, New Mexico	Seattle, Washington	Chicago, Illinois
Form	**Total floor area (ft^2 [m^2])**	40,946 [3,804]	40,946 [3,804]	40,946 [3,804]	40,946 [3,804]	40,946 [3,804]
	Number of floors	3	3	3	3	3
	Window fraction (window to wall ratio)	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20
	Skylight/TDD percent	0.0%	0.0%	0.0%	0.0%	0.0%
	Azimuth	0.00	0.00	0.00	0.00	0.00
Fabric	**Exterior Walls**					
	Construction type	Steel-framed	Steel-framed	Steel-framed	Steel-framed	Steel-framed
	Construction description	R-13	R-13	R-13	R-13	R-13 + R-3.8 c.i.
	R-value (ft^2·h·°F/Btu [m^2·K/W])	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]	7.22 [1.27]	11.06 [1.95]
	Gross dimensions – total area (ft^2 [m^2])	16,720 [1,553]	16,720 [1,553]	16,720 [1,553]	16,720 [1,553]	16,720 [1,553]
	Net dimensions – total area (ft^2 [m^2])	13,178 [1,224]	13,178 [1,224]	13,178 [1,224]	13,178 [1,224]	13,178 [1,224]
	Wall to skin ratio	0.53	0.53	0.53	0.53	0.53
	Tilts and orientation	Vertical	Vertical	Vertical	Vertical	Vertical
	Roof					
	Construction type	IEAD	IEAD	IEAD	IEAD	IEAD
	Construction description	R-10 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.
	R-value (ft^2·h·°F/Btu [m^2·K/W])	9.69 [1.71]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]
	Gross Dimensions – total area (ft^2 [m^2])	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]
	Net Dimensions – total area (ft^2 [m^2])	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]
	Roof to skin ratio	0.47	0.47	0.47	0.47	0.47
	Tilts and orientation	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal

Table D-2 Surgery Center Baseline Scorecard: Climate Zones 3C–5A (con't)

	ASHRAE 90.1-2004 Climate Zone	3C	4A	4B	4C	5A
Fabric	**Windows**					
	Dimensions – total area (ft^2 [m^2])	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]
	U-factor (Btu/h·ft^2·°F [W/m^2·K])	S: 1.21 [6.88] E: 1.21 [6.88] N: 0.73 [4.15] W: 1.21 [6.88]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]
	SHGC	South: 0.61 East: 0.61 North: 0.61 West: 0.61	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39
	Visible transmittance	South: 0.61 East: 0.61 North: 0.61 West: 0.61	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.36 West: 0.39
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Skylights/TDD					
	Dimensions – total area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	U-factor (Btu/h·ft^2·°F [W/m^2·K])	1.21 [6.92]	0.69 [3.92]	0.69 [3.92]	0.69 [3.92]	0.69 [3.92]
	SHGC	0.61	0.49	0.49	0.49	0.49
	Visible transmittance	0.61	0.49	0.49	0.49	0.49
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Foundation					
	Foundation type	Mass floor	Mass floor	Mass floor	Mass floor	Mass floor
	Construction	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation
	R-value (ft^2·h·°F/Btu [m^2·K/W])	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]
	Average min/max under-slab temperatures	Min: 67.8 [19.9] Max: 68.8 [20.4]	Min: 67.4 [19.7] Max: 72.6 [22.6]	Min: 66.5 [19.2] Max: 71.3 [21.8]	Min: 67.5 [19.7] Max: 70.0 [21.1]	Min: 67.1 [19.5] Max: 72.3 [22.4]
	Dimensions	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]

Table D-2 Surgery Center Baseline Scorecard: Climate Zones 3C–5A (con't)

ASHRAE 90.1-2004 Climate Zone		3C	4A	4B	4C	5A
Fabric	**Interior Partitions**					
	Construction	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board
	Dimensions – total area (ft^2 [m^2])	39,960 [3,712]	39,960 [3,712]	39,960 [3,712]	39,960 [3,712]	39,960 [3,712]
	Internal Mass					
	Construction	6-in. wood	6-in. wood	6-in. wood	6-in. wood	6-in. wood
	Dimensions – total area (ft^2 [m^2])	81,304 [7,553]	81,304 [7,553]	81,304 [7,553]	81,304 [7,553]	81,304 [7,553]
	Thermal properties (lb/ft^2 [kg/m^2])	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]
HVAC	**Heating Type**	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
	Cooling Type	DX	DX	DX	DX	DX
	HVAC Autosizing					
	Air-conditioning (tons [kW])	115.1 [404.9]	147.8 [519.9]	131.1 [461.1]	114.0 [400.9]	143.4 [504.4]
	Heating (kBtu/h [kW])	1,002.5 [293.8]	1,156.3 [338.9]	1,062.3 [311.3]	1,059.6 [310.5]	1,165.2 [341.5]
	HVAC Efficiency					
	Air-conditioning (COP)	3.24	3.24	3.24	3.24	3.24
	Heating efficiency (%)	80	80	80	80	80
	HVAC Control					
	Economizer	Yes	No	Yes	Yes	Yes
	Fan and Pump Loads					
	Supply fan volumetric flow rate (cfm [m^3/s])	45,676.7 [21.6]	51,755.6 [24.4]	59,264.3 [28.0]	47,907.5 [22.6]	50,235.6 [23.7]
	Service Water Heating					
	SWH type	NG Storage Tank	NG Storage Tank	NG Storage Tank	NG Storage Tank	NG Storage Tank
	E_t (%)	80	80	80	80	80
Internal Loads and Schedules	**Lighting**					
	Average power density (W/ft^2 [W/m^2])	1.86 [19.97]	1.86 [19.97]	1.86 [19.97]	1.86 [19.97]	1.86 [19.97]
	Schedule	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5
	Plug Loads					
	Average power density (W/ft^2 [W/m^2])	1.80 [19.42]	1.80 [19.42]	1.80 [19.42]	1.80 [19.42]	1.80 [19.42]
	Schedule	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8
	Occupancy					
	Average people (#/1000 ft^2 [#/100 m^2])	10.13 [10.90]	10.13 [10.90]	10.13 [10.90]	10.13 [10.90]	10.13 [10.90]
	Schedule	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9

Table D-3 Supply Center Baseline Scorecard: Climate Zones 5B–8A

ASHRAE 90.1-2004 Climate Zone		5B	6A	6B	7A	8A
Program	**Building name**	Surgery Center	Surgery Center	Surgery Center	Surgery Center	Surgery Center
	Location	Boise, Idaho	Burlington, Vermont	Helena, Montana	Duluth, Minnesota	Fairbanks, Alaska
Form	**Total floor area (ft^2 [m^2])**	40,946 [3,804]	40,946 [3,804]	40,946 [3,804]	40,946 [3,804]	40,946 [3,804]
	Number of floors	3	3	3	3	3
	Window fraction (window to wall ratio)	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20	South: 0.24 East: 0.19 North: 0.21 West: 0.13 Total: 0.20
	Skylight/TDD percent	0.0%	0.0%	0.0%	0.0%	0.0%
	Azimuth	0.00	0.00	0.00	0.00	0.00
Fabric	**Exterior Walls**					
	Construction type	Steel-framed	Steel-framed	Steel-framed	Steel-framed	Steel-framed
	Construction description	R-13 + R-3.8 c.i.	R-13 + R-3.8 c.i.	R-13 + R-3.8 c.i.	R-13 + R-7.5 c.i.	R-13 + R-7.5 c.i.
	R-value (ft^2·h·°F/Btu [m^2·K/W])	11.06 [1.95]	11.06 [1.95]	11.06 [1.95]	14.76 [2.60]	14.76 [2.60]
	Gross dimensions – total area (ft^2 [m^2])	16,720 [1,553]	16,720 [1,553]	16,720 [1,553]	16,720 [1,553]	16,720 [1,553]
	Net dimensions – total area (ft^2 [m^2])	13,178 [1,224]	13,178 [1,224]	13,178 [1,224]	13,178 [1,224]	13,178 [1,224]
	Wall to skin ratio	0.53	0.53	0.53	0.53	0.53
	Tilts and orientation	Vertical	Vertical	Vertical	Vertical	Vertical
	Roof					
	Construction type	IEAD	IEAD	IEAD	IEAD	IEAD
	Construction description	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-15 c.i.	R-20 c.i.
	R-value (ft^2·h·°F/Btu [m^2·K/W])	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	14.82 [2.61]	19.76 [3.48]
	Gross dimensions – total area (ft^2 [m^2])	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]
	Net dimensions – total area (ft^2 [m^2])	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]
	Roof to skin ratio	0.47	0.47	0.47	0.47	0.47
	Tilts and orientation	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal

Table D-3 Surgery Center Baseline Scorecard: Climate Zones 5B–8A (con't)

ASHRAE 90.1-2004 Climate Zone		5B	6A	6B	7A	8A
Fabric	**Windows**					
	Dimensions – total area (ft^2 [m^2])	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]	S: 1,228 [114] E: 624 [58] N: 1,046 [97] W: 420 [39] Total: 3,318 [308]
	U-Factor (Btu/h·ft^2·ºF [W/m^2·K])	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.57 [3.24] E: 0.57 [3.24] N: 0.46 [2.61] W: 0.57 [3.24]	S: 0.46 [2.61] E: 0.46 [2.61] N: 0.35 [1.99] W: 0.46 [2.61]
	SHGC	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.49 West: 0.39	South: 0.39 East: 0.39 North: 0.49 West: 0.39	South: 0.49 East: 0.49 North: 0.64 West: 0.49	South: 0.46 East: 0.46 North: 0.46 West: 0.46
	Visible transmittance	South: 0.39 East: 0.39 North: 0.36 West: 0.39	South: 0.39 East: 0.39 North: 0.49 West: 0.39	South: 0.39 East: 0.39 North: 0.49 West: 0.39	South: 0.49 East: 0.49 North: 0.64 West: 0.49	South: 0.46 East: 0.46 North: 0.46 West: 0.46
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Skylights/TDD					
	Dimensions – total area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	U-Factor (Btu/h·ft^2·ºF [W/m^2·K])	0.69 [3.92]	0.69 [3.92]	0.69 [3.92]	0.69 [3.92]	0.58 [3.29]
	SHGC	0.49	0.49	0.49	0.68	0.49
	Visible transmittance	0.49	0.49	0.49	0.68	0.49
	Operable area (ft^2 [m^2])	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]	0.0 [0.0]
	Foundation					
	Foundation type	Mass floor	Mass floor	Mass floor	Mass floor	Mass floor
	Construction	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation	Carpet over heavy concrete and insulation
	R-value (ft^2·h·°F/Btu [m^2·K/W])	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]	2.11 [0.37]
	Average min/max under-slab temperatures	Min: 66.7 [19.3] Max: 706 [21.5]	Min: 66.9 [19.4] Max: 71.4 [21.9]	Min: 66.4 [19.1] Max: 70.4 [21.3]	Min: 66.5 [19.1] Max: 69.7 [20.9]	Min: 65.1 [18.4] Max: 67.3 [19.6]
	Dimensions	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]	14,782 [1,373]

Table D-3 Surgery Center Baseline Scorecard: Climate Zones 5B–8A (con't)

	ASHRAE 90.1-2004 Climate Zone	5B	6A	6B	7A	8A
Fabric	**Interior Partitions**					
	Construction	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board	2 × 4 steel frame gypsum board
	Dimensions – total area (ft^2 [m^2])	39,960 [3,712]	39,960 [3,712]	39,960 [3,712]	39,960 [3,712]	39,960 [3,712]
	Internal mass					
	Construction	6-in. wood	6-in. wood	6-in. wood	6-in. wood	6-in. wood
	Dimensions – total area (ft^2 [m^2])	81,304 [7,553]	81,304 [7,553]	81,304 [7,553]	81,304 [7,553]	81,304 [7,553]
	Thermal properties (lb/ft^2 [kg/m^2])	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]	16.6 [81.0]
HVAC	**Heating Type**	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
	Cooling Type	DX	DX	DX	DX	DX
	HVAC Autosizing					
	Air-conditioning (tons [kW])	125.7 [442.1]	127.5 [448.4]	119.0 [418.4]	118.7 [417.3]	104.2 [366.5]
	Heating (kBtu/h [kW])	1,125.8 [330.0]	1,173.1 [343.8]	1,140.5 [334.3]	1,175.2 [344.4]	1,307.1 [383.1]
	HVAC Efficiency					
	Air-conditioning (COP)	3.24	3.24	3.24	3.24	3.24
	Heating efficiency (%)	80	80	80	80	80
	HVAC Control					
	Economizer	Yes	Yes	Yes	Yes	Yes
	Fan and pump loads					
	Supply fan volumetric flow rate (cfm [m^3/s])	55,105.1 [26.0]	48,439.9 [22.9]	53,801.7 [25.4]	47,888.7 [22.6]	45,863.0 [21.6]
	Service Water Heating					
	SWH type	NG Storage Tank	NG Storage Tank	NG Storage Tank	NG Storage Tank	NG Storage Tank
	E_t (%)	80	80	80	80	80
Internal Loads and Schedules	**Lighting**					
	Average power density (W/ft^2 [W/m^2])	1.86 [19.97]	1.86 [19.97]	1.86 [19.97]	1.86 [19.97]	1.86 [19.97]
	Schedule	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5	See Figure 5-5
	Plug Loads					
	Average power density (W/ft^2 [W/m^2])	1.80 [19.42]	1.80 [19.42]	1.80 [19.42]	1.80 [19.42]	1.80 [19.42]
	Schedule	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8	See Figure 5-8
	Occupancy					
	Average people (#/1000 ft^2 [#/100 m^2])	10.13 [10.90]	10.13 [10.90]	10.13 [10.90]	10.13 [10.90]	10.13 [10.90]
	Schedule	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9	See Figure 5-9

Appendix E Determining Plug Loads for Small Healthcare Facilities

Table E-1 provides information about plug loads for small healthcare facilities.

Table E-1 Plug Loads for Small Healthcare Facilities

Zone	Green Guide for Healthcare (W/ft^2)	Savings by Design (W/ft^2)	Surgery Center Prototype Model (W/ft^2)	Measured Data	Final (W/ft^2)	Comments
Anesthesia	1.0	–	1.9	–	2.0	Many numbers used because the space is small and there is potential for computers, task lighting, and an anesthesia machine.
Clean	2.0	2.0	0.1	–	2.0	The equipment is variable. Using the more conservative 2.0 W/ft^2 specified by Savings by Design (the only room where something other than 1.0 W/ft^2 for a hospital-related zone type was specified).
Conference	0.1	0.1	0.4	–	1.0	Contains significant electrical equipment such as projectors, computers, and televisions. Standby power could be improved.
Corridor	0.1	0.1	0.2	–	0.4	The need has increased because electrical equipment is frequently used here. Corridors require significant square footage, which will increase total kWh. This has limited effect on total cfm, which is already 0.9 cfm/ft^2, as the load density is relatively low. The requirement is 2 ACH, which meets ~20 Btu/h-ft^2 [5.7 W/ft^2].
Dining	0.1	0.1	NA	–	1.0	Using the lower number because laptop computers are being used increasingly in dining halls, and vending machines consume considerable energy with no standby capability.
Emergency room	4.0	–	NA	–	1.5	Requires a great deal of equipment, but it is spread out, so the load is slightly lower than the anesthesia room.
Examination room	1.0	–	1.0	–	1.1	Similar to an office with a computer and probably task lighting. Will use 1.1 W/ft^2 (same as an office).
Food preparation center	3.0	1.0	4.5	–	4.0	Uses task lighting, ovens, microwaves, ice machines, and refrigerators. Will use a number between the Green Guide (3 W/ft^2) and Issaquah (4.5 W/ft^2) recommendations.
Laboratory	4.0	1.0	NA	–	3.0	Reduced from 5 W/ft^2, which was much too high; 3 W/ft^2 is reasonable.
Lobby	1.0	–	0.0	–	0.4	Similar to a typical corridor without equipment.

Table E-1 Plug Loads for Small Healthcare Facilities

Zone	Green Guide for Healthcare (W/ft^2)	Savings by Design (W/ft^2)	Surgery Center Prototype Model (W/ft^2)	Measured Data	Final (W/ft^2)	Comments
Lounge	1.0	–	4.5	–	3.0	These typically have vending machines, TVs, refrigerators, coffee machines, task lights, etc. Some diversity will be added, but will remain high.
Nurse station	0.25	0.3	3.0	–	2.00	The Issaquah model showed numerous computers and task lights in this relatively small space. However, it is open to the corridor, so the flow rate is lower because some heat will transfer out.
Nursery	1.5	1.0	NA	–	1.0	Seems quite close to office loads.
Office	1.0	–	1.3	–	1.1	The most well-established load.
Operating room	4.0	1.0	0.7	1.5 kW	4.0	Based on Vernon's measurement of an OR in San Francisco, the mean load was 1.6 kW; spikes reached 11 kW. Using 1.6 kW divided by Issaquah has ~450 ft^2 per OR and Bremen is ~700 ft^2 per OR. Green Guide states 4 W.
Patient room	1.0	1.0	0.0		2.0	Has a lot of equipment in a small space and probably does not have a standby mode. However, 4 is high, so 2 will be used.
Pharmacy	1.0	1.0	NA		1.0	Number seems reasonable, as a pharmacy has little electrical equipment.
Physical therapy	1.0	1.0	0.6		1.5	Higher than office because of exercise equipment.
Procedure room	1.0	1.0	0.1		3.0	Numbers seem reasonable because of considerable equipment. Even at 5 W/ft^2, it is still under the ACH requirement.
Radiology	9.0	1.0	8.4	5.9 kW	10.0	Michael Metyer sent file showing heat gain of 5 MRIs. Lowest was 20 kBtu/h for 600 ft^2 resulting in 30 Btu/h-ft^2. Therefore using 10 W/ft^2.
Reception area	1.0	–	0.3		1.1	Same as office.
Recovery room	1.0	1.0	5.4		3.0	Has a lot of monitoring equipment in a small space.
Soiled	2.0	1.0	2.3		2.0	Has a washer that uses considerable electrical energy to heat water, but much is wasted.
Storage	0.1	–	0.0		0.1	There is a difference between active and passive storage. Passive storage is assumed, so 0.1 W/ft^2 suffices.
Toilet room	0.1	–	0.0		0.4	People use many appliances in these bathrooms, so this seems reasonable.
Trauma room	4.0	1.0	NA		2.0	Similar to anesthesia room.
Triage	4.0	–	NA		2.0	Similar to anesthesia room.

Table E-1 Plug Loads for Small Healthcare Facilities

Zone	Green Guide for Healthcare (W/ft^2)	Savings by Design (W/ft^2)	Surgery Center Prototype Model (W/ft^2)	Measured Data	Final (W/ft^2)	Comments
Utility	0.1	0.1	20.5		5.0	Same number as for an electricity room, as many utility rooms have transformers or are elevator rooms.
Peak power	42,672 W	–	60,456 W	–	60,468 W	CBECS hospital data assume plug loads remain constant over 24 h use 1.7 W/ft^2. The 2.5–3.0 W/ft^2 figure includes all electricity.
	1.0 W/ft^2	–	1.5 W/ft^2	–	1.5 W/ft^2	
Annual energy	274,723 kWh	–	389,216 kWh	–	389,295 kWh	CBECS data present approximately 50 kBtu/ft^2 for plug loads ,which equates to 14.6 kW·h/ft^2
	6.7 kW-h/ft^2	–	9.5 kWh/ft^2	–	9.5 kWh/ft^2	
	22.9 kBtu/ft^2	–	32.4 kBtu/ft^2	–	32.4 kBtu/ft^2	

Appendix F Energy Savings End Use Tables: ASHRAE 90.1-1999 Baseline

Table F-1 Community Hospital End Uses: Climate Zones 1A–4A

Climate	Model	Electricity (kBtu/ft^2)							Gas (kBtu/ft^2)			Total End Uses	Percent Savings
		Heating	Cooling	Lights	Equip	Fans	Pumps	Humid	Heating	Equip	Water Systems		
1A	Baseline	0.0	76.5	34.8	35.8	30.9	1.6	0.2	53.9	9.0	8.4	250.8	N/A
	DX	0.0	48.3	14.3	35.8	16.3	1.3	0.1	21.7	9.0	7.4	154.3	38.5%
	AC	0.0	50.0	14.3	35.8	16.3	3.2	0.1	24.6	9.0	7.4	160.7	35.9%
	WC	0.0	46.0	14.3	35.8	16.3	8.0	0.1	24.6	9.0	7.4	161.5	35.6%
2A	Baseline	0.0	66.5	34.8	35.8	31.4	1.6	3.1	76.9	9.0	10.0	269.2	N/A
	DX	0.0	40.9	14.3	35.8	16.2	1.3	1.6	33.0	9.0	8.9	161.1	40.2%
	AC	0.0	40.6	14.3	35.8	16.2	2.9	1.5	34.8	9.0	8.9	164.0	39.1%
	WC	0.0	38.2	14.3	35.8	16.2	7.6	1.5	34.8	9.0	8.9	166.3	38.2%
2B	Baseline	0.0	53.7	34.8	35.8	33.5	1.7	23.5	85.1	9.0	9.1	286.2	N/A
	DX	0.0	30.8	14.3	35.8	16.3	1.3	13.3	33.1	9.0	8.1	162.0	43.4%
	AC	0.0	30.8	14.3	35.8	16.3	2.4	12.9	32.7	9.0	8.1	162.3	43.3%
	WC	0.0	23.4	14.3	35.8	16.3	6.1	12.9	32.8	9.0	8.1	158.7	44.6%
3A	Baseline	0.0	54.9	34.8	35.8	30.1	1.6	7.5	86.4	9.0	11.3	272.1	N/A
	DX	0.0	33.7	14.3	35.8	16.1	1.3	4.1	41.7	9.0	10.1	166.1	39.0%
	AC	0.0	31.8	14.3	35.8	16.1	2.7	3.9	42.8	9.0	10.1	166.5	38.8%
	WC	0.0	30.9	14.3	35.8	16.1	7.4	3.9	42.8	9.0	10.1	170.4	37.4%
3B	Baseline	0.0	38.0	34.8	35.8	33.6	1.5	41.0	78.3	9.0	10.9	283.1	N/A
	DX	0.0	21.9	14.3	35.8	16.5	1.2	25.3	32.2	9.0	9.7	166.0	41.4%
	AC	0.0	20.1	14.3	35.8	16.5	2.1	23.4	31.2	9.0	9.7	162.0	42.8%
	WC	0.0	16.5	14.3	35.8	16.5	4.8	23.4	31.2	9.0	9.7	161.2	43.1%
3C	Baseline	0.0	23.0	34.8	35.8	29.2	1.5	6.1	98.4	9.0	12.7	250.6	N/A
	DX	0.0	11.7	14.3	35.8	13.9	1.2	3.4	38.6	9.0	11.3	139.3	44.4%
	AC	0.0	8.9	14.3	35.8	13.9	1.9	3.0	40.3	9.0	11.3	138.5	44.7%
	WC	0.0	9.8	14.3	35.8	13.9	4.8	3.0	40.3	9.0	11.3	142.2	43.2%
4A	Baseline	0.0	44.5	34.8	35.8	30.0	1.6	12.6	98.5	9.0	12.9	279.9	N/A
	DX	0.0	27.2	14.3	35.8	16.0	1.3	7.0	46.0	9.0	11.5	168.2	39.9%
	AC	0.0	24.1	14.3	35.8	16.0	2.5	6.4	46.5	9.0	11.5	166.2	40.6%
	WC	0.0	24.6	14.3	35.8	16.0	6.9	6.4	46.5	9.0	11.5	171.1	38.9%

Table F-2 Community Hospital End Uses: Climate Zones 4B–8A

Climate	Model	Electricity (kBtu/ft^2)							Gas (kBtu/ft^2)			Total End Uses	Percent Savings
		Heating	Cooling	Lights	Equip	Fans	Pumps	Humid	Heating	Equip	Water Systems		
4B	Baseline	0.0	27.9	34.8	35.8	34.2	1.5	47.3	84.3	9.0	12.7	287.5	N/A
	DX	0.0	15.9	14.3	35.8	16.9	1.2	29.9	31.7	9.0	11.3	166.1	42.2%
	AC	0.0	13.4	14.3	35.8	16.9	1.9	28.2	30.3	9.0	11.3	161.2	43.9%
	WC	0.0	11.3	14.3	35.8	16.9	4.8	28.2	30.3	9.0	11.3	161.1	44.0%
4C	Baseline	0.0	16.4	34.8	35.8	27.4	1.5	13.3	92.9	9.0	13.6	244.7	N/A
	DX	0.0	9.4	14.3	35.8	14.4	1.2	7.9	40.4	9.0	12.1	144.6	40.9%
	AC	0.0	7.5	14.3	35.8	14.4	1.7	7.5	41.5	9.0	12.1	144.0	41.2%
	WC	0.0	7.9	14.3	35.8	14.4	4.3	7.5	41.5	9.0	12.1	146.9	39.9%
5A	Baseline	0.0	25.8	34.8	35.8	29.5	1.6	24.3	102.2	9.0	14.0	277.0	N/A
	DX	0.0	15.6	14.3	35.8	15.3	1.3	14.0	46.7	9.0	12.5	164.5	40.6%
	AC	0.0	14.9	14.3	35.8	15.3	2.0	13.9	47.3	9.0	12.5	165.1	40.4%
	WC	0.0	13.6	14.3	35.8	15.3	5.3	13.9	47.3	9.0	12.5	167.1	39.7%
5B	Baseline	0.0	18.4	34.8	35.8	30.9	1.5	38.3	95.2	9.0	13.8	277.8	N/A
	DX	0.0	10.6	14.3	35.8	15.6	1.2	22.4	40.3	9.0	12.3	161.7	41.8%
	AC	0.0	9.4	14.3	35.8	15.6	1.7	20.6	40.1	9.0	12.3	159.1	42.8%
	WC	0.0	7.9	14.3	35.8	15.6	3.7	20.6	40.1	9.0	12.3	159.5	42.6%
6A	Baseline	0.0	20.4	34.8	35.8	28.7	1.6	25.8	107.9	9.0	15.1	279.2	N/A
	DX	0.0	14.0	14.3	35.8	15.0	1.4	14.9	51.9	9.0	13.4	169.6	39.2%
	AC	0.0	11.4	14.3	35.8	15.0	1.9	14.8	52.4	9.0	13.4	167.9	39.9%
	WC	0.0	10.6	14.3	35.8	15.0	4.5	14.8	52.4	9.0	13.4	169.8	39.2%
6B	Baseline	0.0	14.5	34.8	35.8	30.9	1.5	43.4	100.9	9.0	15.2	286.1	N/A
	DX	0.0	9.5	14.3	35.8	15.7	1.3	25.3	44.8	9.0	13.5	169.2	40.9%
	AC	0.0	6.9	14.3	35.8	15.7	1.6	23.9	44.4	9.0	13.5	165.2	42.3%
	WC	0.0	6.0	14.3	35.8	15.7	3.1	23.9	44.4	9.0	13.5	165.8	42.1%
7A	Baseline	0.0	12.8	34.8	35.8	28.5	1.5	30.5	113.4	9.0	46.6	283.1	N/A
	DX	0.0	8.6	14.3	35.8	14.7	1.3	17.2	57.5	9.0	14.8	173.4	38.7%
	AC	0.0	6.6	14.3	35.8	14.7	1.7	17.1	57.9	9.0	14.8	172.0	39.2%
	WC	0.0	6.4	14.3	35.8	14.7	3.7	17.1	57.9	9.0	14.8	123.8	38.6%
8A	Baseline	0.0	7.7	34.8	35.8	26.1	1.6	34.0	138.0	9.0	18.5	305.6	N/A
	DX	0.0	5.4	14.3	35.8	14.7	1.5	21.3	46.3	9.0	16.5	205.1	32.9%
	AC	0.0	3.9	14.3	35.8	14.7	1.7	21.0	46.5	9.0	16.5	203.7	33.3%
	WC	0.0	3.8	14.3	35.8	14.7	2.8	21.0	46.5	9.0	16.5	204.8	33.0%

Table F-3 Surgery Center End Uses: Climate Zones 1A–4A

Climate	Model	Electricity (kBtu/ft^2)							Gas (kBtu/ft^2)			Total End Uses	Percent Savings
		Heating	Cooling	Lights	Equip	Fans	Pumps	Humid	Heating	Equip	Water Systems		
1A	Baseline	1.3	60.1	23.9	28.0	21.8	0.8	0.1	31.2	4.4	0.8	172.4	N/A
	DX	1.1	38.4	9.7	28.0	10.5	0.6	0.0	11.9	4.4	0.7	105.5	38.8%
	AC	1.1	38.7	9.7	28.0	10.5	2.1	0.0	14.7	4.4	0.7	109.9	36.2%
	WC	1.1	37.8	9.7	28.0	10.5	6.9	0.0	14.7	4.4	0.7	113.9	33.9%
2A	Baseline	6.6	52.2	23.9	28.0	22.0	0.8	1.6	41.3	4.4	0.9	181.7	N/A
	DX	5.2	33.1	9.7	28.0	10.5	0.7	0.9	17.0	4.4	0.8	110.4	39.2%
	AC	5.3	31.8	9.7	28.0	10.5	1.9	0.7	18.9	4.4	0.8	112.0	38.3%
	WC	5.3	31.7	9.7	28.0	10.5	6.7	0.7	18.9	4.4	0.8	116.7	35.7%
2B	Baseline	7.1	42.8	23.9	28.0	24.2	0.8	13.1	44.6	4.4	0.9	189.7	N/A
	DX	5.5	25.4	9.7	28.0	10.8	0.6	6.0	15.2	4.4	0.8	106.4	43.9%
	AC	5.5	24.9	9.7	28.0	10.8	1.5	5.7	15.3	4.4	0.8	106.6	43.8%
	WC	5.5	19.8	9.7	28.0	10.7	5.2	5.7	15.3	4.4	0.8	105.1	44.6%
3A	Baseline	9.5	43.6	23.9	28.0	21.8	0.8	4.5	46.2	4.4	1.0	183.6	N/A
	DX	8.9	27.8	9.7	28.0	10.5	0.7	2.4	20.8	4.4	0.9	114.2	37.8%
	AC	8.9	25.4	9.7	28.0	10.5	1.7	2.1	21.7	4.4	0.9	113.4	38.2%
	WC	8.9	26.1	9.7	28.0	10.5	6.6	2.1	21.7	4.4	0.9	119.0	35.2%
3B	Baseline	7.5	30.0	23.9	28.0	23.9	0.7	25.5	40.6	4.4	1.0	185.5	N/A
	DX	6.5	17.8	9.7	28.0	10.6	0.5	12.1	14.1	4.4	0.9	104.6	43.6%
	AC	6.5	16.1	9.7	28.0	10.6	1.2	11.2	13.7	4.4	0.9	402.4	44.8%
	WC	6.5	13.8	9.7	28.0	10.6	3.9	11.2	13.7	4.4	0.9	102.7	44.6%
3C	Baseline	10.8	17.0	23.9	28.0	20.1	0.7	2.6	47.8	4.4	1.1	156.5	N/A
	DX	7.2	8.7	9.7	28.0	8.5	0.6	1.1	16.6	4.4	1.0	85.7	45.2%
	AC	7.2	6.9	9.7	28.0	8.5	1.2	1.0	18.9	4.4	1.0	86.8	44.5%
	WC	7.2	7.8	9.7	28.0	8.5	3.9	1.0	18.9	4.4	1.0	90.4	42.2%
4A	Baseline	14.2	35.6	23.9	28.0	21.6	0.8	7.5	51.4	4.4	1.2	188.6	N/A
	DX	12.2	22.8	9.7	28.0	10.4	0.7	4.0	23.8	4.4	1.0	117.0	37.9%
	AC	12.2	19.5	9.7	28.0	10.4	1.5	3.6	24.1	4.4	1.0	114.6	39.2%
	WC	12.2	21.0	9.7	28.0	10.4	6.1	3.6	24.1	4.4	1.0	120.6	36.0%

Table F-4 Surgery Center End Uses: Climate Zones 4B–8A

Climate	Model	Electricity (kBtu/ft^2)							Gas (kBtu/ft^2)			Total End Uses	Percent Savings
		Heating	Cooling	Lights	Equip	Fans	Pumps	Humid	Heating	Equip	Water Systems		
4B	Baseline	10.4	21.9	23.9	28.0	24.4	0.7	29.9	42.2	4.4	1.1	186.9	N/A
	DX	8.3	12.8	9.7	28.0	10.8	0.6	14.6	14.8	4.4	1.0	105.0	43.8%
	AC	8.3	10.8	9.7	28.0	10.9	1.0	13.9	14.0	4.4	1.0	102.1	45.4%
	WC	8.3	9.4	9.7	28.0	10.8	3.0	13.9	14.0	4.4	1.0	102.6	45.1%
4C	Baseline	13.6	13.0	23.9	28.0	20.0	0.7	6.8	49.5	4.4	1.2	161.0	N/A
	DX	11.2	7.1	9.7	28.0	8.9	0.6	2.7	19.0	4.4	1.1	92.9	42.3%
	AC	11.2	5.8	9.7	28.0	8.9	1.0	2.6	20.4	4.4	1.1	93.2	42.1%
	WC	11.2	6.2	9.7	28.0	8.9	3.2	2.6	20.4	4.4	1.1	95.9	40.4%
5A	Baseline	17.7	20.6	23.9	28.0	21.3	0.8	14.3	52.3	4.4	1.2	184.5	N/A
	DX	15.4	12.4	9.7	28.0	9.7	0.7	6.6	22.2	4.4	1.1	110.3	40.2%
	AC	15.4	11.9	9.7	28.0	9.7	1.3	6.6	23.4	4.4	1.1	111.5	39.6%
	WC	15.4	11.4	9.7	28.0	9.7	4.0	6.6	23.4	4.4	1.1	113.6	38.4%
5B	Baseline	15.3	14.8	23.9	28.0	22.5	0.8	22.3	49.2	4.4	1.2	182.4	N/A
	DX	12.9	8.6	9.7	28.0	10.1	0.6	9.9	19.4	4.4	1.1	104.8	42.6%
	AC	12.9	7.6	9.7	28.0	10.1	1.0	9.2	19.2	4.4	1.1	103.2	43.4%
	WC	12.9	6.5	9.7	28.0	10.1	2.6	9.2	19.2	4.4	1.1	103.8	43.1%
6A	Baseline	21.0	16.3	23.9	28.0	20.6	0.8	15.6	54.1	4.4	1.3	186.0	N/A
	DX	18.1	11.0	9.7	28.0	9.4	0.7	7.5	24.7	4.4	1.2	114.7	38.3%
	AC	18.1	9.0	9.7	28.0	9.4	1.2	7.5	25.7	4.4	1.2	114.2	38.6%
	WC	18.1	8.7	9.7	28.0	9.4	3.4	7.5	25.7	4.4	1.2	116.1	37.6%
6B	Baseline	19.6	11.6	23.9	28.0	22.4	0.8	26.5	50.3	4.4	1.3	188.7	N/A
	DX	16.4	4.6	9.7	28.0	10.1	0.7	12.4	21.0	4.4	1.2	111.5	40.9%
	AC	16.4	5.6	9.7	28.0	10.1	1.0	11.9	20.9	4.4	1.2	109.1	42.2%
	WC	16.4	5.0	9.7	28.0	10.1	2.2	11.9	20.9	4.4	1.2	109.7	41.8%
7A	Baseline	24.8	10.3	23.9	28.0	20.5	0.8	18.9	55.7	4.4	1.4	188.6	N/A
	DX	22.2	6.8	9.7	28.0	9.3	0.7	9.0	27.3	4.4	1.3	118.8	37.0%
	AC	22.2	5.3	9.7	28.0	9.3	1.0	8.9	28.0	4.4	1.3	118.3	37.3%
	WC	22.2	5.3	9.7	28.0	9.3	2.6	8.9	28.0	4.4	1.3	119.9	36.5%
8A	Baseline	37.2	6.3	23.9	28.0	19.4	0.9	23.2	71.1	4.4	1.6	215.9	N/A
	DX	34.4	4.2	9.7	28.0	9.3	0.9	12.4	40.8	4.4	1.4	145.7	32.5%
	AC	34.4	3.0	9.7	28.0	9.3	1.0	12.3	41.2	4.4	1.4	144.9	32.9%
	WC	34.4	3.1	9.7	28.0	9.3	2.0	12.3	41.2	4.4	1.4	145.9	32.4%

Appendix G Energy Savings End Use Tables: ASHRAE 90.1-2004 Baseline

Table 10-1 Community Hospital End Uses: Climate Zones 1A–4A

Climate	Model	Electricity (kBtu/ft^2)							Gas (kBtu/ft^2)			Total End Uses	Percent Savings
		Heating	Cooling	Lights	Equip	Fans	Pumps	Humid	Heating	Equip	Water Systems		
1A	Baseline	0.0	71.3	20.4	35.8	28.3	1.5	0.2	55.6	9.0	8.4	230.5	N/A
	DX	0.0	48.3	14.3	35.8	16.3	1.3	0.1	21.7	9.0	7.4	154.3	33.1%
	AC	0.0	50.0	14.3	35.8	16.3	3.2	0.1	24.6	9.0	7.4	160.7	30.3%
	WC	0.0	46.0	14.3	35.8	16.3	8.0	0.1	24.6	9.0	7.4	161.5	29.9%
2A	Baseline	0.0	61.9	20.4	35.8	28.9	1.5	2.6	78.2	9.0	10.0	248.4	N/A
	DX	0.0	40.9	14.3	35.8	16.2	1.3	1.6	33.0	9.0	8.9	161.1	35.1%
	AC	0.0	40.6	14.3	35.8	16.2	2.9	1.5	34.8	9.0	8.9	164.0	34.0%
	WC	0.0	38.2	14.3	35.8	16.2	7.6	1.5	34.8	9.0	8.9	166.3	33.0%
2B	Baseline	0.0	49.9	20.4	35.8	30.8	1.5	21.6	85.5	9.0	9.1	263.6	N/A
	DX	0.0	30.8	14.3	35.8	16.3	1.3	13.3	33.1	9.0	8.1	162.0	38.5%
	AC	0.0	30.8	14.3	35.8	16.3	2.4	12.9	32.7	9.0	8.1	162.3	38.4%
	WC	0.0	23.4	14.3	35.8	16.3	6.1	12.9	32.8	9.0	8.1	158.7	39.8%
3A	Baseline	0.0	50.8	20.4	35.8	28.1	1.5	6.6	87.2	9.0	11.3	250.7	N/A
	DX	0.0	33.7	14.3	35.8	16.1	1.3	4.1	41.7	9.0	10.1	166.1	33.7%
	AC	0.0	31.8	14.3	35.8	16.1	2.7	3.9	42.8	9.0	10.1	166.5	33.6%
	WC	0.0	30.9	14.3	35.8	16.1	7.4	3.9	42.8	9.0	10.1	170.4	32.0%
3B	Baseline	0.0	34.9	20.4	35.8	30.5	1.4	38.3	78.4	9.0	10.9	259.7	N/A
	DX	0.0	21.9	14.3	35.8	16.5	1.2	25.3	32.2	9.0	9.7	166.0	36.1%
	AC	0.0	20.1	14.3	35.8	16.5	2.1	23.4	31.2	9.0	9.7	162.0	37.6%
	WC	0.0	16.5	14.3	35.8	16.5	4.8	23.4	31.2	9.0	9.7	161.2	37.9%
3C	Baseline	0.0	21.0	20.4	35.8	26.7	1.5	5.4	97.8	9.0	12.7	230.2	N/A
	DX	0.0	11.7	14.3	35.8	13.9	1.3	3.4	38.6	9.0	11.3	139.3	39.5%
	AC	0.0	8.9	14.3	35.8	13.9	2.5	3.0	40.3	9.0	11.3	138.5	39.9%
	WC	0.0	9.8	14.3	35.8	13.9	6.9	3.0	40.3	9.0	11.3	142.2	38.2%
4A	Baseline	0.0	41.2	20.4	35.8	27.6	1.4	11.1	99.5	9.0	12.9	259.0	N/A
	DX	0.0	27.2	14.3	35.8	16.0	1.2	7.0	46.0	9.0	11.5	168.2	35.1%
	AC	0.0	24.1	14.3	35.8	16.0	1.8	6.4	46.5	9.0	11.5	166.2	35.8%
	WC	0.0	24.6	14.3	35.8	16.0	3.8	6.4	46.5	9.0	11.5	171.1	33.9%

Table G-2 Community Hospital End Uses: Climate Zones 4B–8A

Climate	Model	Electricity (kBtu/ft^2)							Gas (kBtu/ft^2)			Total End Uses	Percent Savings
		Heating	Cooling	Lights	Equip	Fans	Pumps	Humid	Heating	Equip	Water Systems		
4B	Baseline	0.0	25.4	20.4	35.8	31.0	1.4	44.2	83.4	9.0	12.7	263.2	N/A
	DX	0.0	15.9	14.3	35.8	16.9	1.2	29.9	31.7	9.0	11.3	166.1	36.9%
	AC	0.0	13.4	14.3	35.8	16.9	1.8	28.2	30.3	9.0	11.3	161.2	38.8%
	WC	0.0	11.3	14.3	35.8	16.9	3.8	28.2	30.3	9.0	11.3	161.1	38.8%
4C	Baseline	0.0	15.1	20.4	35.8	25.3	1.3	12.0	94.7	9.0	13.6	227.3	N/A
	DX	0.0	9.4	14.3	35.8	14.4	1.2	7.9	40.4	9.0	12.1	144.6	36.4%
	AC	0.0	7.5	14.3	35.8	14.4	1.7	7.5	41.5	9.0	12.1	144.0	36.7%
	WC	0.0	7.9	14.3	35.8	14.4	4.3	7.5	41.5	9.0	12.1	146.9	35.4%
5A	Baseline	0.0	23.8	20.4	35.8	27.1	1.5	22.1	103.3	9.0	14.0	257.1	N/A
	DX	0.0	15.6	14.3	35.8	15.3	1.3	14.0	46.7	9.0	12.5	164.5	36.0%
	AC	0.0	14.9	14.3	35.8	15.3	2.0	13.9	47.3	9.0	12.5	165.1	35.8%
	WC	0.0	13.6	14.3	35.8	15.3	5.3	13.9	47.3	9.0	12.5	167.1	35.0%
5B	Baseline	0.0	16.8	20.4	35.8	28.1	1.4	34.7	95.4	9.0	13.8	255.4	N/A
	DX	0.0	10.6	14.3	35.8	15.6	1.2	22.4	40.3	9.0	12.3	161.7	36.7%
	AC	0.0	9.4	14.3	35.8	15.6	1.7	20.6	40.1	9.0	12.3	159.1	37.7%
	WC	0.0	7.9	14.3	35.8	15.6	3.7	20.6	40.1	9.0	12.3	159.5	37.5%
6A	Baseline	0.0	18.9	20.4	35.8	26.5	1.5	23.5	109.8	9.0	15.1	260.5	N/A
	DX	0.0	14.0	14.3	35.8	15.0	1.4	14.9	51.9	9.0	13.4	169.6	34.9%
	AC	0.0	11.4	14.3	35.8	15.0	1.9	14.8	52.4	9.0	13.4	167.9	35.5%
	WC	0.0	10.6	14.3	35.8	15.0	4.5	14.8	52.4	9.0	13.4	169.8	34.8%
6B	Baseline	0.0	13.2	20.4	35.8	28.1	1.4	39.2	101.3	9.0	15.2	263.6	N/A
	DX	0.0	9.5	14.3	35.8	15.7	1.3	25.3	44.8	9.0	13.5	169.2	35.8%
	AC	0.0	6.9	14.3	35.8	15.7	1.6	23.9	44.4	9.0	13.5	165.2	37.3%
	WC	0.0	6.0	14.3	35.8	15.7	3.1	23.9	44.4	9.0	13.5	165.8	37.1%
7A	Baseline	0.0	11.8	20.4	35.8	26.1	1.4	27.5	115.3	9.0	46.6	264.0	N/A
	DX	0.0	8.6	14.3	35.8	14.7	1.3	17.2	57.5	9.0	14.8	173.4	34.3%
	AC	0.0	6.6	14.3	35.8	14.7	1.7	17.1	57.9	9.0	14.8	172.0	34.9%
	WC	0.0	6.4	14.3	35.8	14.7	3.7	17.1	57.9	9.0	14.8	173.8	34.2%
8A	Baseline	0.0	7.1	20.4	35.8	24.3	1.5	30.9	141.9	9.0	18.5	289.5	N/A
	DX	0.0	5.4	14.3	35.8	14.7	1.5	21.3	86.3	9.0	16.5	205.1	29.2%
	AC	0.0	3.9	14.3	35.8	14.7	1.7	21.0	86.5	9.0	16.5	203.7	29.6%
	WC	0.0	3.8	14.3	35.8	14.7	2.8	21.0	86.5	9.0	16.5	204.8	29.3%

Table G-3 Surgery Center End Uses: Climate Zones 1A–4A

Climate	Model	Electricity (kBtu/ft^2)							Gas (kBtu/ft^2)			Total End Uses	Percent Savings
		Heating	Cooling	Lights	Equip	Fans	Pumps	Humid	Heating	Equip	Water Systems		
1A	Baseline	1.4	55.0	14.2	28.0	19.7	0.7	0.1	29.4	4.4	0.8	153.7	N/A
	DX	1.1	38.4	9.7	28.0	10.5	0.6	0.0	11.9	4.4	0.7	105.5	31.4%
	AC	1.1	38.7	9.7	28.0	10.5	2.1	0.0	14.7	4.4	0.7	109.9	28.5%
	WC	1.1	37.8	9.7	28.0	10.5	6.9	0.0	14.7	4.4	0.7	113.9	25.9%
2A	Baseline	7.0	47.8	14.2	28.0	20.0	0.7	1.5	38.9	4.4	0.9	163.3	N/A
	DX	5.2	331	9.7	28.0	10.5	0.7	0.9	17.0	4.4	0.8	110.4	32.4%
	AC	5.3	31.8	9.7	28.0	10.5	1.9	0.7	18.9	4.4	0.8	112.0	31.4%
	WC	5.3	31.7	9.7	28.0	10.5	6.7	0.7	18.9	4.4	0.8	116.7	28.5%
2B	Baseline	7.6	39.4	14.2	28.0	22.1	0.7	11.9	42.5	4.4	0.9	171.5	N/A
	DX	5.5	25.4	9.7	28.0	10.8	0.6	6.0	15.2	4.4	0.8	106.4	37.9%
	AC	5.5	24.9	9.7	28.0	10.8	1.5	5.7	15.3	4.4	0.8	106.6	37.9%
	WC	5.5	19.8	9.7	28.0	10.7	5.2	5.7	15.3	4.4	0.8	105.1	38.7%
3A	Baseline	10.1	39.9	14.2	28.0	19.8	0.7	4.0	44.0	4.4	1.0	166.1	N/A
	DX	8.9	27.8	9.7	28.0	10.5	0.7	2.4	20.8	4.4	0.9	114.2	31.2%
	AC	8.9	25.4	9.7	28.0	10.5	1.7	2.4	21.7	4.4	0.9	113.4	31.7%
	WC	8.9	26.1	9.7	28.0	10.5	6.6	2.4	21.7	4.4	0.9	119.0	28.3%
3B	Baseline	8.0	27.0	14.2	28.0	21.3	0.7	22.9	37.1	4.4	1.0	164.5	N/A
	DX	6.5	17.8	9.7	28.0	10.6	0.5	12.1	14.1	4.4	0.9	104.6	36.4%
	AC	6.5	16.1	9.7	28.0	10.6	1.2	11.2	13.7	4.4	0.9	102.4	37.7%
	WC	6.5	13.8	9.7	28.0	10.6	3.9	11.2	13.7	4.4	0.9	102.7	37.5%
3C	Baseline	11.4	15.4	14.2	28.0	18.2	0.7	2.4	45.6	4.4	1.1	141.3	N/A
	DX	7.2	8.7	9.7	28.0	8.5	0.6	1.1	16.6	4.4	1.0	85.7	39.3%
	AC	7.2	6.9	9.7	28.0	8.5	1.2	1.0	18.9	4.4	1.0	86.8	38.5%
	WC	7.2	7.8	9.7	28.0	8.5	3.9	1.0	18.9	4.4	1.0	90.4	36.0%
4A	Baseline	15.1	32.6	14.2	28.0	19.6	0.7	6.8	49.3	4.4	1.2	171.8	N/A
	DX	12.2	22.8	9.7	28.0	10.4	0.7	4.0	23.8	4.4	1.0	117.0	31.9%
	AC	12.2	19.5	9.7	28.0	10.4	1.5	3.6	24.1	4.4	1.0	114.6	33.3%
	WC	12.2	21.0	9.7	28.0	10.4	6.1	3.6	24.1	4.4	1.0	120.6	29.8%

Table G-4 Surgery Center End Uses: Climate Zones 4B–8A

Climate	Model	Electricity (kBtu/ft^2)							Gas (kBtu/ft^2)			Total End Uses	Percent Savings
		Heating	Cooling	Lights	Equip	Fans	Pumps	Humid	Heating	Equip	Water Systems		
4B	Baseline	11.0	19.6	14.2	28.0	21.6	0.6	26.8	38.9	4.4	1.1	166.2	N/A
	DX	8.3	12.8	9.7	28.0	10.8	0.6	14.6	14.8	4.4	1.0	105.0	36.8%
	AC	8.3	10.8	9.7	28.0	10.9	1.0	13.9	14.0	4.4	1.0	102.1	38.6%
	WC	8.3	9.4	9.7	28.0	10.8	3.0	13.9	14.0	4.4	1.0	102.6	38.3%
4C	Baseline	14.6	11.7	14.2	28.0	18.0	0.7	6.1	47.2	4.4	1.2	146.0	N/A
	DX	11.2	7.1	9.7	28.0	8.9	0.6	2.7	19.0	4.4	1.1	92.9	36.4%
	AC	11.2	5.8	9.7	28.0	8.9	1.0	2.6	20.4	4.4	1.1	93.2	36.2%
	WC	11.2	6.2	9.7	28.0	8.9	3.0	2.6	20.4	4.4	1.1	95.9	34.3%
5A	Baseline	18.7	18.8	14.2	28.0	19.2	0.8	12.9	50.1	4.4	1.2	168.4	N/A
	DX	15.4	12.4	9.7	28.0	9.7	0.7	6.6	22.2	4.4	1.1	110.3	34.5%
	AC	15.4	11.9	9.7	28.0	9.7	1.3	6.6	23.4	4.4	1.1	111.5	33.8%
	WC	15.4	11.4	9.7	28.0	9.7	4.0	6.6	23.4	4.4	1.1	113.6	32.5%
5B	Baseline	16.2	13.4	14.2	28.0	20.2	0.7	20.0	46.4	4.4	1.2	164.6	N/A
	DX	12.9	8.6	9.7	28.0	10.1	0.6	9.9	19.4	4.4	1.1	104.8	36.3%
	AC	12.9	7.6	9.7	28.0	10.1	1.0	9.2	19.2	4.4	1.1	103.2	37.3%
	WC	12.9	6.5	9.7	28.0	10.1	2.6	9.2	19.2	4.4	1.1	103.8	37.0%
6A	Baseline	22.2	14.8	14.2	28.0	18.6	0.8	14.0	52.0	4.4	1.3	170.2	N/A
	DX	18.1	11.0	9.7	28.0	9.4	0.7	7.5	24.7	4.4	1.2	114.7	32.6%
	AC	18.1	9.0	9.7	28.0	9.4	1.2	7.5	25.7	4.4	1.2	114.2	32.9%
	WC	18.1	8.7	9.7	28.0	94.	3.4	7.5	25.7	4.4	1.2	116.1	31.8%
6B	Baseline	20.6	10.3	14.2	28.0	19.9	0.7	23.4	47.1	4.4	1.3	170.0	N/A
	DX	16.4	7.6	9.7	28.0	10.1	0.7	12.4	21.0	4.4	1.2	111.5	34.4%
	AC	16.4	5.6	9.7	28.0	10.1	1.0	11.9	20.9	4.4	1.2	109.1	35.9%
	WC	16.4	5.0	9.7	28.0	10.1	2.2	11.9	20.9	4.4	1.2	109.7	35.5%
7A	Baseline	26.1	9.3	14.2	28.0	18.4	0.8	16.8	53.3	4.4	1.4	172.5	N/A
	DX	22.2	6.8	9.7	28.0	9.3	0.7	9.0	27.3	4.4	1.3	118.8	31.2%
	AC	22.2	5.3	9.7	28.0	9.3	1.0	8.9	28.0	4.4	1.3	118.3	31.4%
	WC	22.2	5.3	9.7	28.0	9.3	2.6	8.9	28.0	4.4	1.3	119.9	30.5%
8A	Baseline	39.0	5.7	14.2	28.0	17.5	0.9	20.7	68.6	4.4	1.6	200.5	N/A
	DX	34.4	4.2	9.7	28.0	9.3	0.9	12.4	40.8	4.4	1.4	145.7	27.3%
	AC	34.4	3.0	9.7	28.0	9.3	1.0	12.3	41.2	4.4	1.4	144.9	27.7%
	WC	34.4	3.1	9.7	28.0	9.3	2.0	12.3	41.2	4.4	1.4	145.9	27.2%

Appendix H Fan Performance Characteristics

H.1 Baseline and Low-Energy Equivalent Fan Summary

The following appendix summarizes the calculation methodology for determining the motor-belt-fan combined efficiency for modeling the supply, return, and exhaust fan. See Section 6.3 for a detailed explaination and example of the calculation procedure.

Baseline CAV Fan Calculation

Based on Constant Volume AHU-1 serving Issaquah Floor 1 Critical Care Unit

Flow Rate	25,000 cfm
Total Static	6.00 in WG
Fan Heat Gain	3.6℉
Total_η	71% 1.0 W/cfm 1.3 bhp/1000 cfm
Power	24,758 W
Fan Motor	30 hp

Internal Pressure Drop	
0.50 in WG	Heating Coil
1.00 in WG	Cooling Coil
0.50 in WG	25% Filter*
1.50 in WG	95% Filter*
3.50 in WG	Total

* Avg clean and dirty filters

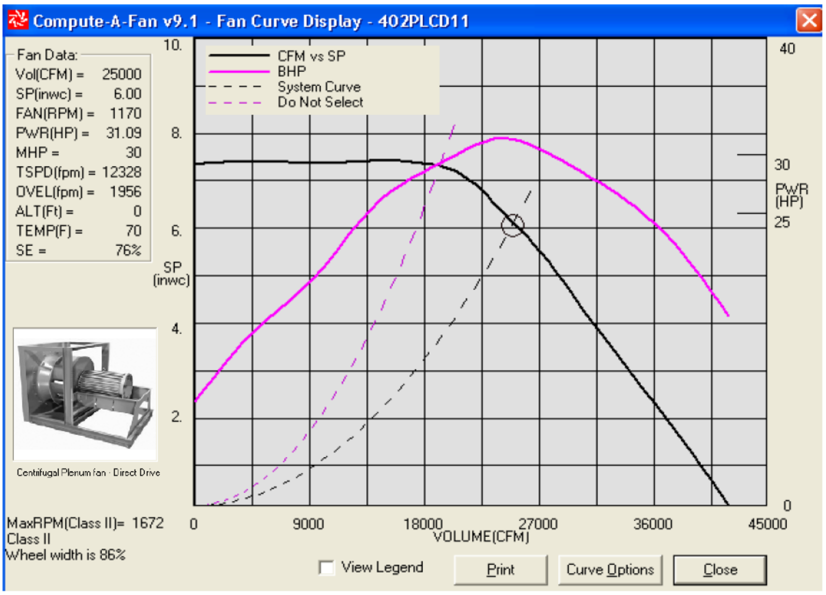
External Pressure Drop	
0.1 in WG	Inlet Transition
0.4 in WG	Outlet Transition
1.0 in WG	Duct Mains
0.5 in WG	Duct Branches
0.5 in WG	Terminal Box*
2.50 in WG	Total

* Including Sound Attenuation & Electric or HHW Coil

Efficiency	
Fan_η*	76%
Motor_η**	93.6%
Belt_η***	100%

* Loren Cook Static Efficiency (SE)
** NEMA Premium Eff
*** Direct Drive so no loss

Supply Fan : Constant Volume Centrifugal Airfoil Plenum Fan - Belt Driven



Fan Data:
Vol(CFM) = 25000
SP(inwc) = 6.00
FAN(RPM) = 1170
PWR(HP) = 31.09
MHP = 30
TSPD(fpm) = 12328
OVEL(fpm) = 1956
ALT(Ft) = 0
TEMP(F) = 70
SE = 76%

MaxRPM(Class II)= 1672
Class II
Wheel width is 86%

Flow Rate	20,000 cfm
Total Static	1.75 in WG
Total_η	64% 0.3 W/cfm 0.4 bhp/1000 cfm
Power	6,402 W
Fan Motor	10 hp

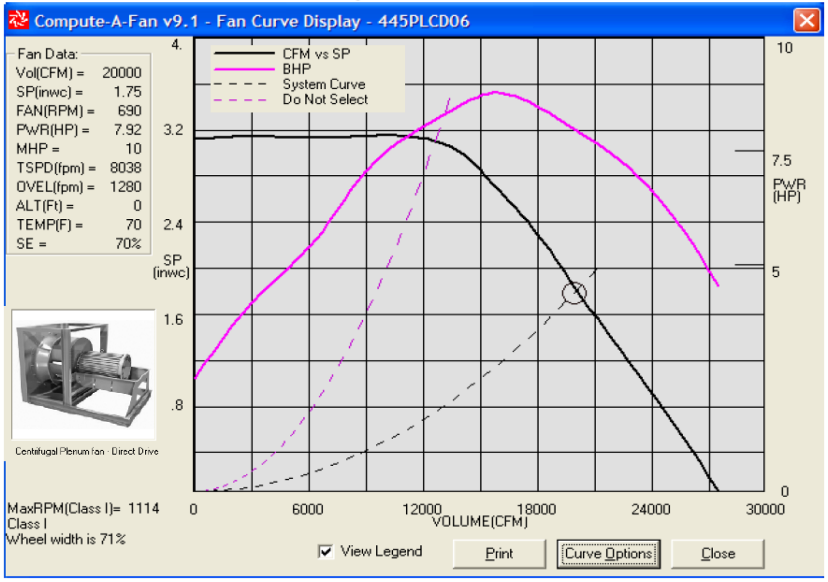
Internal Pressure Drop	
0.25 in WG	Motorized Damper
0.25 in WG	Total

External Pressure Drop	
1.50 in WG	Plenum/Duct Mains
1.50 in WG	Total

Efficiency	
Fan_η*	70%
Motor_η**	91.7%
Belt_η***	100%

* Loren Cook Static Efficiency (SE)
** NEMA Premium Eff
*** Direct Drive so no loss

Return Fan : Constant Volume Airfoil Blade Single Width Plenum Fan - Belt Drive



Fan Data:
Vol(CFM) = 20000
SP(inwc) = 1.75
FAN(RPM) = 690
PWR(HP) = 7.92
MHP = 10
TSPD(fpm) = 8038
OVEL(fpm) = 1280
ALT(Ft) = 0
TEMP(F) = 70
SE = 70%

MaxRPM(Class I)= 1114
Class I
Wheel width is 71%

Equivalent Supply Fan : Constant Volume Centrifugal Airfoil

Flow Rate	25,000 cfm	
Total Static	7.75 in WG	[Supply + Return Pressure Drop]
Total_η	73% 1.2 W/cfm	[f(Supply cfm, Δp Supply + Return, Supply + Return Power)] 1.7 bhp/1000 cfm
Power	31,160 W	[Supply + Return Power]

Proposed CAV Fan Calculation

Based on Constant Volume AHU-1 serving Issaquah Floor 1 Critical Care Unit

Supply Fan : Constant Volume Centrifugal Airfoil Plenum Fan - Belt Driven

Flow Rate	25,000 cfm
Total Static	5.00 in WG
Fan Heat Gain	3.0°F
Total_η	71% 0.8 W/cfm 1.1 bhp/1000 cfm
Power	20,632 W
Fan Motor	30 hp

Internal Pressure Drop	
0.25 in WG	Heating Coil
0.75 in WG	Cooling Coil
0.50 in WG	25% Filter*
1.50 in WG	95% Filter*
3.00 in WG	Total

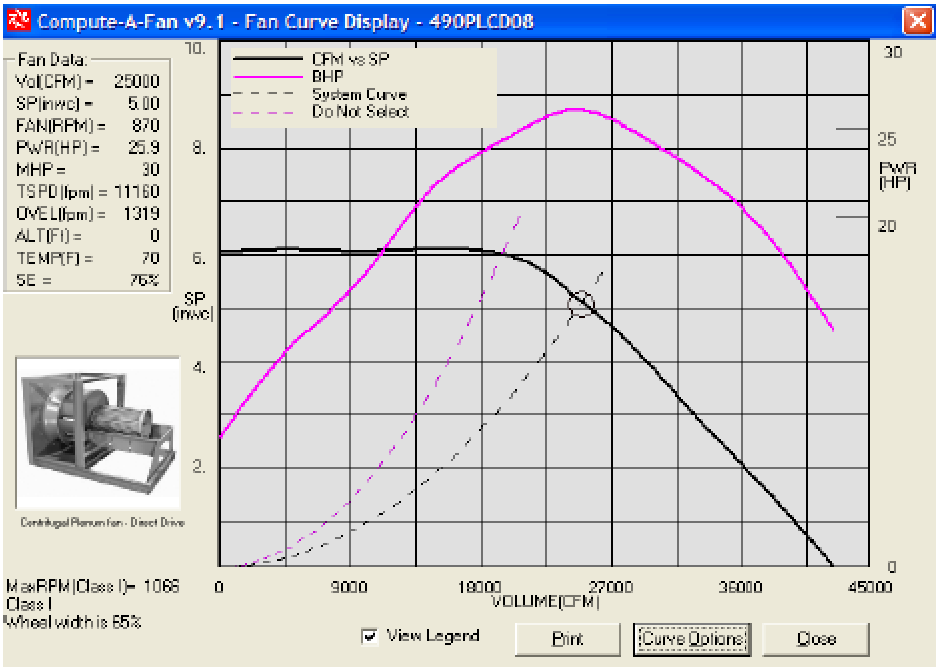
* Avg clean and dirty filters

External Pressure Drop	
0.1 in WG	Inlet Transition
0.2 in WG	Outlet Transition
0.8 in WG	Duct Mains
0.4 in WG	Duct Branches
0.5 in WG	Terminal Box*
2.00 in WG	Total

* Including Sound Attenuation & Electric or HHW Coil

Efficiency	
Fan_η*	76%
Motor_η**	93.6%
Belt_η***	100%

* Loren Cook Static Efficiency (SE)
** NEMA Premium Eff
*** Direct Drive so no loss



Compute-A-Fan v9.1 - Fan Curve Display - 490PLCD08

Fan Data:
Vol(CFM) = 25000
SP(inwc) = 5.00
FAN(RPM) = 870
PWR(HP) = 25.9
MHP = 30
TSPD(fpm) = 11160
OVEL(fpm) = 1319
ALT(Ft) = 0
TEMP(F) = 70
SE = 76%

MaxRPM(Class I)= 1066
Class I
Wheel width is 65%

Return Fan : Constant Volume Airfoil Blade Single Width Plenum Fan - Belt Drive

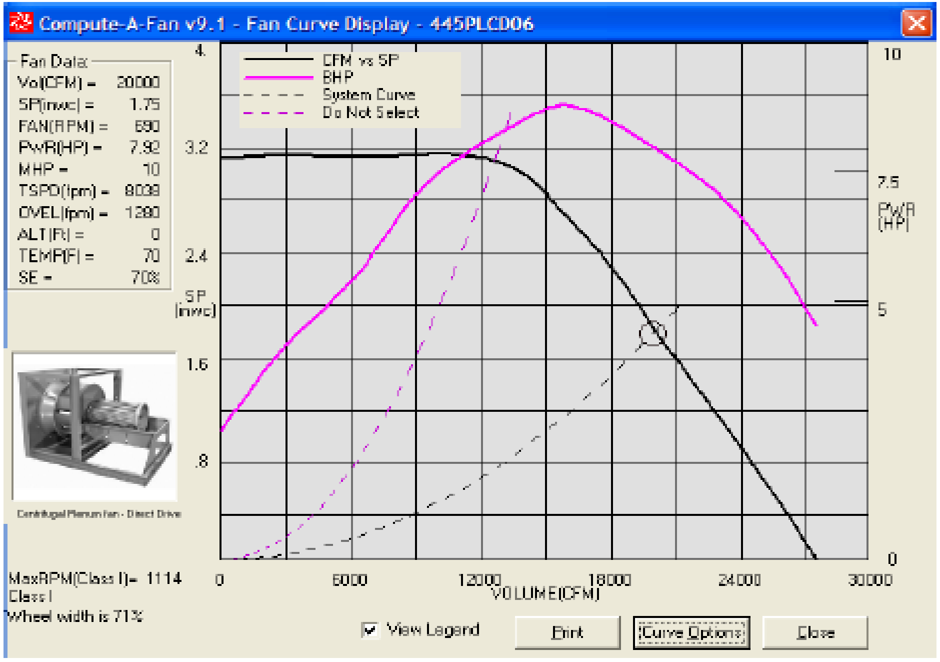
Flow Rate	20,000 cfm
Total Static	1.75 in WG
Total_η	64% 0.3 W/cfm 0.4 bhp/1000 cfm
Power	6,402 W
Fan Motor	10 hp

Internal Pressure Drop	
0.25 in WG	Motorized Damper
0.25 in WG	Total

External Pressure Drop	
1.50 in WG	Plenum/Duct Mains
1.50 in WG	Total

Efficiency	
Fan_η*	70%
Motor_η**	91.7%
Belt_η***	100%

* Loren Cook Static Efficiency (SE)
** NEMA Premium Eff
*** Direct Drive so no loss



Compute-A-Fan v9.1 - Fan Curve Display - 445PLCD06

Fan Data:
Vol(CFM) = 20000
SP(inwc) = 1.75
FAN(RPM) = 690
PWR(HP) = 7.92
MHP = 10
TSPD(fpm) = 8039
OVEL(fpm) = 1280
ALT(Ft) = 0
TEMP(F) = 70
SE = 70%

MaxRPM(Class I)= 1114
Class I
Wheel width is 71%

Equivalent Supply Fan : Constant Volume Centrifugal Airfoil

Flow Rate	25,000 cfm	
Total Static	6.75 in WG	[Supply + Return Pressure Drop]
Total_η	73% 1.1 W/cfm	[f(Supply cfm, Δp Supply + Return, Supply + Return Power)] 1.4 bhp/1000 cfm
Power	27,034 W	[Supply + Return Power]

Baseline VAV Fan Calculation

Based on Variable Volume AHU-2 serving Issaquah Floor 2 + 3 MOB

Supply Fan : Variable Volume Centrifugal Airfoil - Direct Drive

Flow Rate	20,000 cfm
Total Static	4.50 in WG
Fan Heat Gain	2.7°F
	70%
Total_η	0.8 W/cfm
	1.0 bhp/1000 cfm
Power	15,048 W
Fan Motor	20 hp

Internal Pressure Drop	
0.50 in WG	Heating Coil
1.00 in WG	Cooling Coil
0.50 in WG	25% Filter*
-	95% Filter*
2.00 in WG	Total

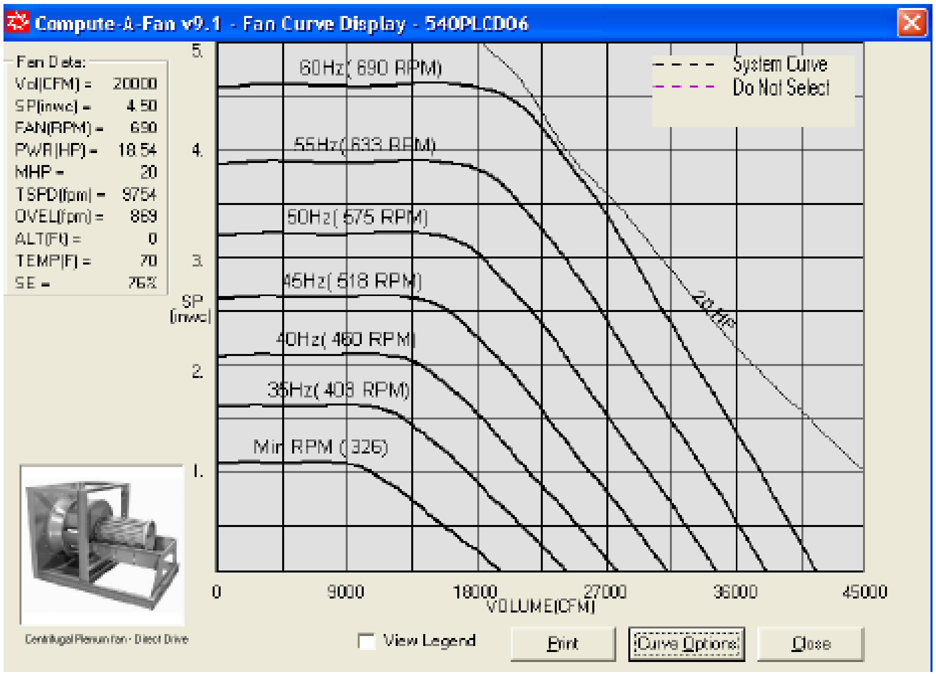
* Avg clean and dirty filters

External Pressure Drop	
0.1 in WG	Inlet Transition
0.4 in WG	Outlet Transition
1.0 in WG	Duct Mains
0.5 in WG	Duct Branches
0.5 in WG	Terminal Box*
2.5 in WG	Total

* Including Sound Attenuation & Electric or HHW Coil

Efficiency	
Fan_η*	76%
Motor_η**	92.4%
Belt_η***	100%

* Loren Cook Static Efficiency (SE)
** NEMA Premium Eff
*** Direct Drive so no loss


Compute-A-Fan v9.1 - Fan Curve Display - 540PLCD06

Fan Data:
Vol(CFM) = 20000
SP(inwc) = 4.50
FAN(RPM) = 690
PWR(HP) = 18.54
MHP = 20
TSPD(fpm) = 9754
OVEL(fpm) = 869
ALT(Ft) = 0
TEMP(F) = 70
SE = 76%

Return Fan : Variable Volume Airfoil Blade Single Width Plenum Fan - Direct Drive

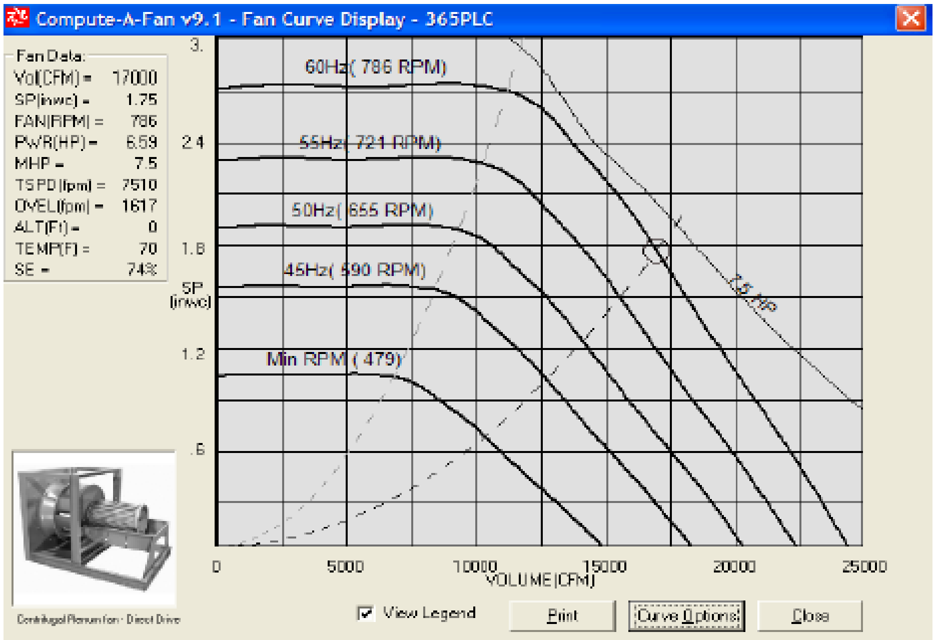
Flow Rate	17,000 cfm
Total Static	1.75 in WG
	68%
Total_η	0.3 W/cfm
	0.4 bhp/1000 cfm
Power	5,148 W
Fan Motor	7.5 hp

Internal Pressure Drop	
0.25 in WG	Motorized Damper
0.25 in WG	Total

External Pressure Drop	
1.50 in WG	Plenum/Duct Mains
1.50 in WG	Total

Efficiency	
Fan_η*	74%
Motor_η**	91.7%
Belt_η***	100%

* Loren Cook Static Efficiency (SE)
** NEMA Premium Eff
*** Direct Drive so no loss


Compute-A-Fan v9.1 - Fan Curve Display - 365PLC

Fan Data:
Vol(CFM) = 17000
SP(inwc) = 1.75
FAN(RPM) = 786
PWR(HP) = 6.59
MHP = 7.5
TSPD(fpm) = 7510
OVEL(fpm) = 1617
ALT(Ft) = 0
TEMP(F) = 70
SE = 74%

Equivalent Supply Fan : Variable Volume Centrifugal Airfoil

Flow Rate	20,000 cfm	
Total Static	6.25 in WG	[Supply + Return Pressure Drop]
Total_η	73%	[f(Supply cfm, Δp Supply + Return, Supply + Return Power)]
	1.0 W/cfm	1.4 bhp/1000 cfm
Power	20,195 W	[Supply + Return Power]

Proposed VAV Fan Calculation

Based on Variable Volume AHU-2 serving Issaquah Floor 2 + 3 MOB

Supply Fan : Variable Volume Centrifugal Airfoil - Direct Drive

Flow Rate	20,000 cfm
Total Static	3.75 in WG
Fan Heat Gain	2.3°F
Total_η	70% 0.6 W/cfm 0.8 bhp/1000 cfm
Power	12,540 W
Fan Motor	15 hp

Internal Pressure Drop	
0.25 in WG	Heating Coil
1.00 in WG	Cooling Coil
0.50 in WG	25% Filter*
-	95% Filter*
1.75 in WG	Total

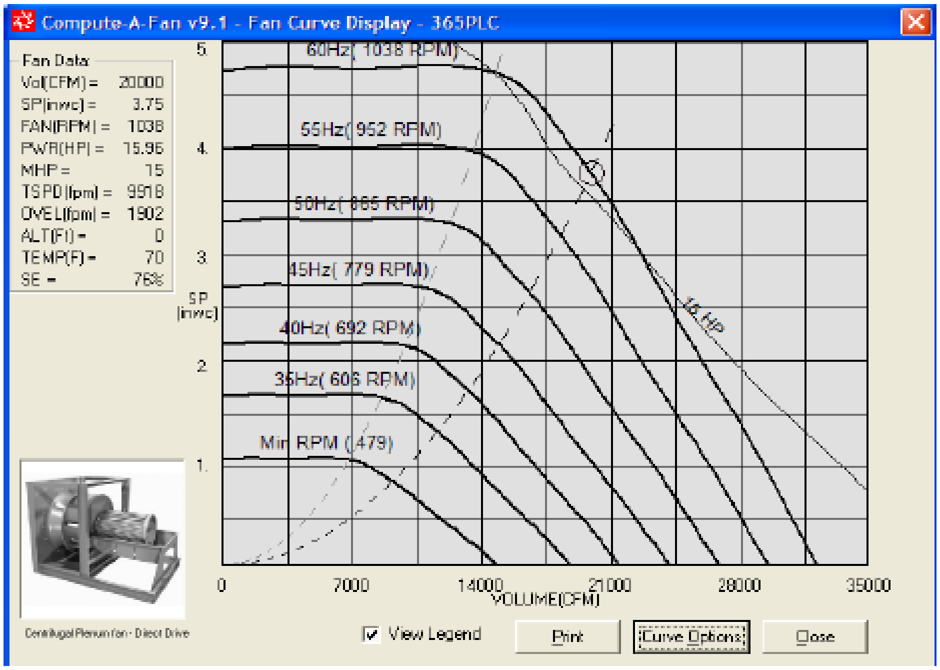
* Avg clean and dirty filters

External Pressure Drop	
0.1 in WG	Inlet Transition
0.2 in WG	Outlet Transition
0.8 in WG	Duct Mains
0.4 in WG	Duct Branches
0.5 in WG	Terminal Box*
2.0 in WG	Total

* Including Sound Attenuation & Electric or HHW Coil

Efficiency	
Fan_η*	76%
Motor_η**	92.4%
Belt_η***	100%

* Loren Cook Static Efficiency (SE)
** NEMA Premium Eff
*** Direct Drive so no loss



Fan Data
Vol(CFM) = 20000
SP(inwc) = 3.75
FAN(RPM) = 1038
PWR(HP) = 15.96
MHP = 15
TSPD(fpm) = 9918
OVEL(fpm) = 1902
ALT(Ft) = 0
TEMP(F) = 70
SE = 76%

Return Fan : Variable Volume Airfoil Blade Single Width Plenum Fan - Direct Drive

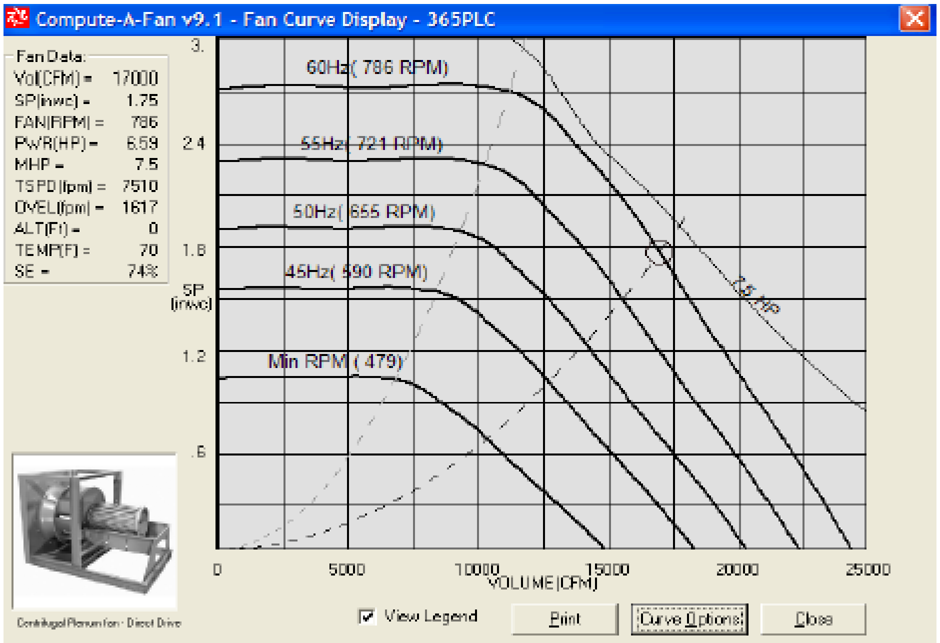
Flow Rate	17,000 cfm
Total Static	1.75 in WG
Total_η	68% 0.3 W/cfm 0.4 bhp/1000 cfm
Power	5,148 W
Fan Motor	7.5 hp

Internal Pressure Drop	
0.25 in WG	Motorized Damper
0.25 in WG	Total

External Pressure Drop	
1.50 in WG	Plenum/Duct Mains
1.50 in WG	Total

Efficiency	
Fan_η*	74%
Motor_η**	91.7%
Belt_η***	100%

* Loren Cook Static Efficiency (SE)
** NEMA Premium Eff
*** Direct Drive so no loss



Fan Data:
Vol(CFM) = 17000
SP(inwc) = 1.75
FAN(RPM) = 786
PWR(HP) = 6.59
MHP = 7.5
TSPD(fpm) = 7510
OVEL(fpm) = 1617
ALT(Ft) = 0
TEMP(F) = 70
SE = 74%

Equivalent Supply Fan : Variable Volume Centrifugal Airfoil

Flow Rate	20,000 cfm	
Total Static	5.50 in WG	[Supply + Return Pressure Drop]
Total_η	73% 0.9 W/cfm	[f(Supply cfm, Δp Supply + Return, Supply + Return Power)] 1.2 bhp/1000 cfm
Power	17,687 W	[Supply + Return Power]

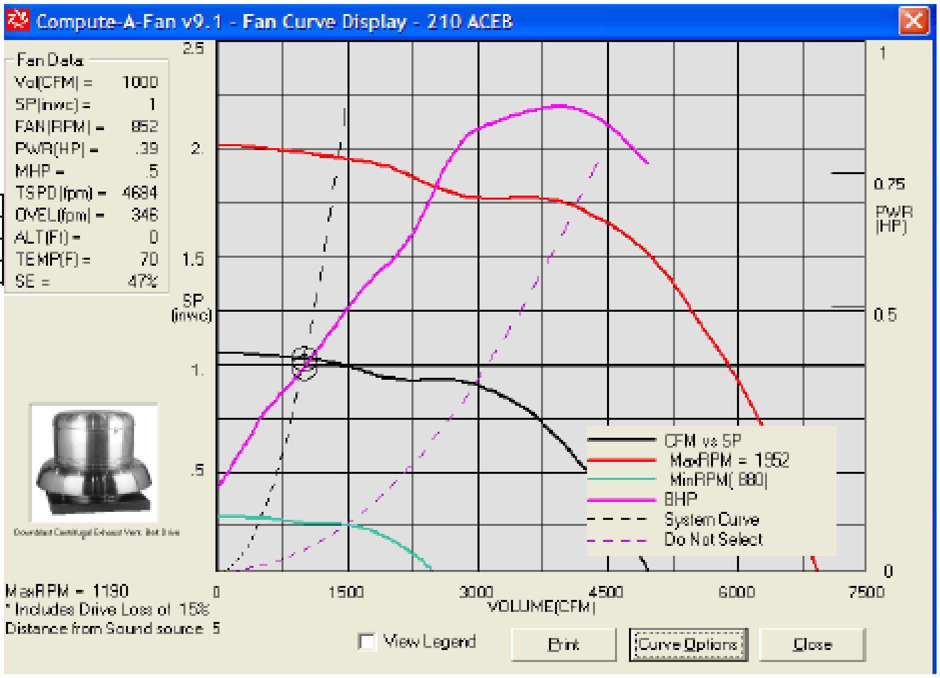
Baseline Dedicated Exhaust Fan Calculation

Flow Rate	1,000 cfm
Total Static	1.00 in WG
	31%
Total_η	0.4 W/cfm
	0.5 bhp/1000 cfm
Power	383 W
Fan Motor	3/4 hp

Efficiency	
Fan_η*	47%
Motor_η**	76.7%
Belt_η***	85%

* Loren Cook Static Efficiency (SE)
** No EPACT Rating < 1 hp
*** High drive loss belt drive

Downblast Centrifugal Exhaust - Belt Drive



Fan Data
Vol(CFM) = 1000
SP(inwc) = 1
FAN(RPM) = 952
PWR(HP) = .39
MHP = .5
TSPD(fpm) = 4684
OVEL(fpm) = 346
ALT(Ft) = 0
TEMP(F) = 70
SE = 47%

MaxRPM = 1190
* Includes Drive Loss of 15%
Distance from Sound source 5

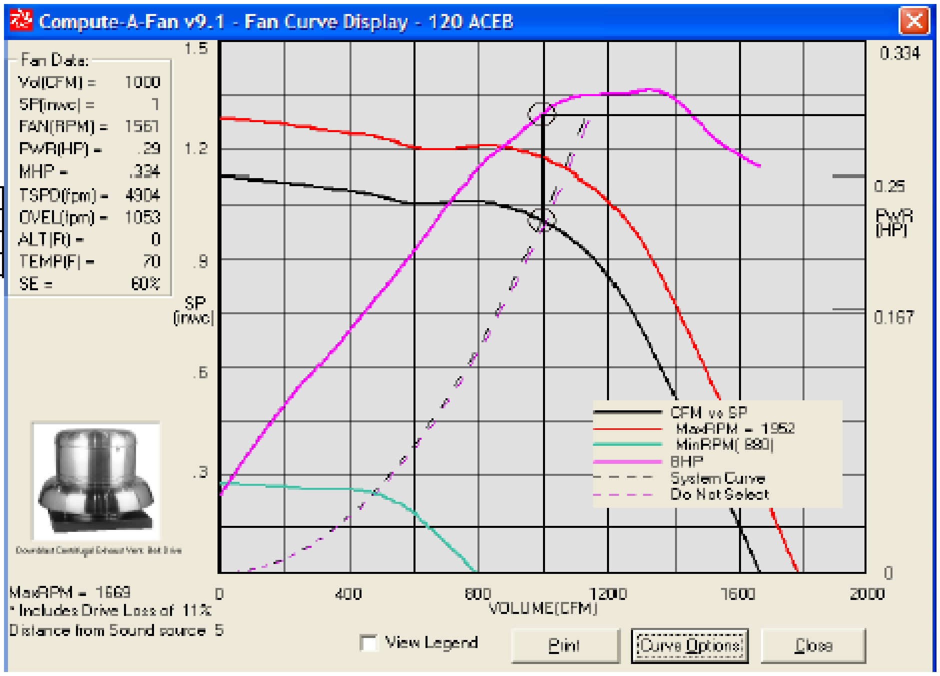
Proposed Dedicated Exhaust Fan Calculation

Flow Rate	1,000 cfm
Total Static	1.00 in WG
	46%
Total_η	0.3 W/cfm
	0.3 bhp/1000 cfm
Power	257 W
Fan Motor	1/3 hp

Efficiency	
Fan_η*	60%
Motor_η**	85.5%
Belt_η***	89%

* Loren Cook Static Efficiency (SE)
** No NEMA Rating < 1 hp
*** Low drive loss belt drive

Downblast Centrifugal Exhaust - Belt Drive



Fan Data:
Vol(CFM) = 1000
SP(inwc) = 1
FAN(RPM) = 1561
PWR(HP) = .29
MHP = .334
TSPD(fpm) = 4904
OVEL(fpm) = 1053
ALT(Ft) = 0
TEMP(F) = 70
SE = 60%

MaxRPM = 1569
* Includes Drive Loss of 11%
Distance from Sound source 5

H.2 NEMA Motor Premium Efficiencies

Table H-1 Motor Premium Efficiencies

Motor Size (hp)	Motor Efficiency (%)
1	85.5
1.5	86.5
2	86.5
3	89.5
5	89.5
7.5	91.7
10	91.7
15	92.4
20	93.0
25	93.6
30	93.6
40	94.1
50	94.5
60	95.0
75	95.4
100	95.4
125	95.4
150	95.8
200	96.2

H.3 Fan Efficiency Charts

Total Efficiency (W/cfm) = f(Motor, Drive, Fan, ΔP)

Motor/Drive Eff = 0.80

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in WG]	2.0	0.7	0.7	0.6	0.5	0.5	0.5	0.4	0.4
	2.5	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5
	3.0	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.6
	3.5	1.3	1.1	1.0	0.9	0.9	0.8	0.7	0.7
	4.0	1.5	1.3	1.2	1.1	1.0	0.9	0.8	0.8
	4.5	1.7	1.5	1.3	1.2	1.1	1.0	0.9	0.9
	5.0	1.8	1.6	1.5	1.3	1.2	1.1	1.0	1.0
	5.5	2.0	1.8	1.6	1.5	1.3	1.2	1.2	1.1
	6.0	2.2	2.0	1.8	1.6	1.5	1.4	1.3	1.2
	6.5	2.4	2.1	1.9	1.7	1.6	1.5	1.4	1.3

Motor/Drive Eff = 0.85

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in W G]	2.0	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4
	2.5	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5
	3.0	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.6
	3.5	1.2	1.1	1.0	0.9	0.8	0.7	0.7	0.6
	4.0	1.4	1.2	1.1	1.0	0.9	0.9	0.8	0.7
	4.5	1.6	1.4	1.2	1.1	1.0	1.0	0.9	0.8
	5.0	1.7	1.5	1.4	1.3	1.2	1.1	1.0	0.9
	5.5	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.0
	6.0	2.1	1.8	1.7	1.5	1.4	1.3	1.2	1.1
	6.5	2.2	2.0	1.8	1.6	1.5	1.4	1.3	1.2

Motor/Drive Eff = 0.90

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in WG]	2.0	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.3
	2.5	0.8	0.7	0.7	0.6	0.5	0.5	0.5	0.4
	3.0	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5
	3.5	1.1	1.0	0.9	0.8	0.8	0.7	0.7	0.6
	4.0	1.3	1.2	1.0	0.9	0.9	0.8	0.7	0.7
	4.5	1.5	1.3	1.2	1.1	1.0	0.9	0.8	0.8
	5.0	1.6	1.4	1.3	1.2	1.1	1.0	0.9	0.9
	5.5	1.8	1.6	1.4	1.3	1.2	1.1	1.0	1.0
	6.0	2.0	1.7	1.6	1.4	1.3	1.2	1.1	1.0
	6.5	2.1	1.9	1.7	1.5	1.4	1.3	1.2	1.1

Motor/Drive Eff = 0.95

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in WG]	2.0	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3
	2.5	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4
	3.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5
	3.5	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.6
	4.0	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7
	4.5	1.4	1.2	1.1	1.0	0.9	0.9	0.8	0.7
	5.0	1.5	1.4	1.2	1.1	1.0	1.0	0.9	0.8
	5.5	1.7	1.5	1.4	1.2	1.1	1.0	1.0	0.9
	6.0	1.9	1.6	1.5	1.3	1.2	1.1	1.1	1.0
	6.5	2.0	1.8	1.6	1.5	1.3	1.2	1.1	1.1

Motor/Drive Eff = 1.00

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in W G]	2.0	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3
	2.5	0.7	0.7	0.6	0.5	0.5	0.5	0.4	0.4
	3.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5
	3.5	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5
	4.0	1.2	1.0	0.9	0.9	0.8	0.7	0.7	0.6
	4.5	1.3	1.2	1.1	1.0	0.9	0.8	0.8	0.7
	5.0	1.5	1.3	1.2	1.1	1.0	0.9	0.8	0.8
	5.5	1.6	1.4	1.3	1.2	1.1	1.0	0.9	0.9
	6.0	1.8	1.6	1.4	1.3	1.2	1.1	1.0	0.9
	6.5	1.9	1.7	1.5	1.4	1.3	1.2	1.1	1.0

Total Efficiency (bhp/1000 cfm) = f(Motor, Drive, Fan, ΔP)

Motor/Drive Eff = 0.80

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in WG]	2.0	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5
	2.5	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7
	3.0	1.5	1.3	1.2	1.1	1.0	0.9	0.8	0.8
	3.5	1.7	1.5	1.4	1.3	1.1	1.1	1.0	0.9
	4.0	2.0	1.7	1.6	1.4	1.3	1.2	1.1	1.0
	4.5	2.2	2.0	1.8	1.6	1.5	1.4	1.3	1.2
	5.0	2.5	2.2	2.0	1.8	1.6	1.5	1.4	1.3
	5.5	2.7	2.4	2.2	2.0	1.8	1.7	1.5	1.4
	6.0	2.9	2.6	2.4	2.1	2.0	1.8	1.7	1.6
	6.5	3.2	2.8	2.6	2.3	2.1	2.0	1.8	1.7

Motor/Drive Eff = 0.85

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in W G]	2.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5
	2.5	1.2	1.0	0.9	0.8	0.8	0.7	0.7	0.6
	3.0	1.4	1.2	1.1	1.0	0.9	0.9	0.8	0.7
	3.5	1.6	1.4	1.3	1.2	1.1	1.0	0.9	0.9
	4.0	1.9	1.6	1.5	1.3	1.2	1.1	1.1	1.0
	4.5	2.1	1.9	1.7	1.5	1.4	1.3	1.2	1.1
	5.0	2.3	2.1	1.9	1.7	1.5	1.4	1.3	1.2
	5.5	2.5	2.3	2.0	1.9	1.7	1.6	1.5	1.4
	6.0	2.8	2.5	2.2	2.0	1.9	1.7	1.6	1.5
	6.5	3.0	2.7	2.4	2.2	2.0	1.9	1.7	1.6

Motor/Drive Eff = 0.90

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in WG]	2.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5
	2.5	1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.6
	3.0	1.3	1.2	1.0	1.0	0.9	0.8	0.7	0.7
	3.5	1.5	1.4	1.2	1.1	1.0	0.9	0.9	0.8
	4.0	1.7	1.6	1.4	1.3	1.2	1.1	1.0	0.9
	4.5	2.0	1.7	1.6	1.4	1.3	1.2	1.1	1.0
	5.0	2.2	1.9	1.7	1.6	1.5	1.3	1.2	1.2
	5.5	2.4	2.1	1.9	1.7	1.6	1.5	1.4	1.3
	6.0	2.6	2.3	2.1	1.9	1.7	1.6	1.5	1.4
	6.5	2.8	2.5	2.3	2.1	1.9	1.7	1.6	1.5

Motor/Drive Eff = 0.95

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in WG]	2.0	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4
	2.5	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.6
	3.0	1.2	1.1	1.0	0.9	0.8	0.8	0.7	0.7
	3.5	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.8
	4.0	1.7	1.5	1.3	1.2	1.1	1.0	0.9	0.9
	4.5	1.9	1.7	1.5	1.4	1.2	1.1	1.1	1.0
	5.0	2.1	1.8	1.7	1.5	1.4	1.3	1.2	1.1
	5.5	2.3	2.0	1.8	1.7	1.5	1.4	1.3	1.2
	6.0	2.5	2.2	2.0	1.8	1.7	1.5	1.4	1.3
	6.5	2.7	2.4	2.2	2.0	1.8	1.7	1.5	1.4

Motor/Drive Eff = 1.00

		Fan Efficiency							
		40%	45%	50%	55%	60%	65%	70%	75%
Tot Press Drop [in W G]	2.0	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4
	2.5	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5
	3.0	1.2	1.0	0.9	0.9	0.8	0.7	0.7	0.6
	3.5	1.4	1.2	1.1	1.0	0.9	0.8	0.8	0.7
	4.0	1.6	1.4	1.3	1.1	1.0	1.0	0.9	0.8
	4.5	1.8	1.6	1.4	1.3	1.2	1.1	1.0	0.9
	5.0	2.0	1.7	1.6	1.4	1.3	1.2	1.1	1.0
	5.5	2.2	1.9	1.7	1.6	1.4	1.3	1.2	1.2
	6.0	2.4	2.1	1.9	1.7	1.6	1.5	1.3	1.3
	6.5	2.6	2.3	2.0	1.9	1.7	1.6	1.5	1.4

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This Technical Support Document describes the process and methodology for the development of the Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities, which is intended to provide recommendations for achieving 30% whole-building energy savings in small hospitals and healthcare facilities over levels achieved by following the ANSI/ASHRAE/IESNA Standard 90.1-1999.

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