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Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities

by

Eric Bonnema, Shanti Pless, Ian Doebber

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Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities[a]

Eric Bonnema[1,*], Shanti Pless[1], Ian Doebber[1]
[1]*National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado, 80401, USA*

ABSTRACT
The *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities* (AEDG-SHC) was recently completed. It is the sixth document in a series of guides designed to achieve 30% savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999. The guide [1] is available for print purchase or as a free download from *http://www.ashrae.org/aedg* and provides user-friendly assistance and recommendations for the building design, construction, and owner communities to achieve energy savings. Included in the guide are prescriptive recommendations for quality assurance and commissioning; design of the building envelope; fenestration; lighting systems (including electric lighting and daylighting); heating, ventilation, and air-conditioning (HVAC) systems; building automation and controls; outside air (OA) treatment; and service water heating (SWH). The guide educates, provides practical recommendations for exceeding code minimums, and provides leadership to help design teams and owners produce higher efficiency commercial buildings.

Keywords: 30% energy savings, high performance buildings, energy efficiency, Advanced Energy Design Guide, small healthcare facilities

1. INTRODUCTION
The *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities* (AEDG-SHC) is targeted to help small- to medium-sized acute care, outpatient, and inpatient buildings achieve site energy savings of at least 30% compared to the minimum requirements of ANSI/ASHRAE/IES Standard 90.1-1999 [2]. The 30% energy savings target is the first step toward achieving a net-zero energy building—a building that draws from outside sources less or equal energy than it generates on site from renewable energy sources annually [3]. The guide was developed in collaboration with these partnering organizations: the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the American Institute of Architects (AIA), the U.S. Green Building Council (USGBC), the Illuminating Engineering Society

*Corresponding author. Email: eric.bonnema@nrel.gov; Tel: +1 303 384-6185
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(IES), the U.S. Department of Energy (DOE), and the American Society for Healthcare Engineering (ASHE). The healthcare facilities covered in the scope of the guide are smaller than 90,000 ft^2 (8,360 m^2), 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 [1,858 m^2])

Three major objectives drove the development of the guide: (1) to achieve a 30% energy savings over Standard 90.1-1999 [4]; (2) to produce a reference document for contractors, owners, and designers of small hospitals and healthcare facilities; and (3) to provide how-to assistance to contractors and designers [5]. The guide is intended to show that achieving the 30% target is not only possible, but easily achievable. Case studies show 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 successfully implement the recommendations.

By specifying a target and identifying paths for different climate zones, the guide provides one example of how to meet the 30% savings target and how to build facilities that use substantially less energy than those built to meet the minimum Standard 90.1-1999 energy code requirements. There may be other means of achieving the target, and it is hoped that the guide generates ideas for innovation.

2. LAYOUT AND CONTENT

The introduction of the guide contains information about its goal and scope, as well as instructions for its use. Next the guide 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. It 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; heating, ventilating, and air-conditioning (HVAC); and service water heating (SWH). The recommendations are simply one path to reach the 30% energy savings target over 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 with 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.

Next the guide presents seven detailed case studies that illustrate techniques and methods discussed. 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 *http://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 subsection 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 subsection contains climate zone-specific information about explicit types of walls, roofs, floors, doors, insulation, infiltration, and vertical fenestration. The lighting subsection details best practices for interior finishes, specific lamp and ballast types, lighting layouts, and control strategies for specific space types. The daylighting subsection 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 subsection includes best practices for multiple-zone variable-air volume (VAV) air-handling systems, water-source (including ground-source) heat pumps, dedicated outdoor air (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 subsection 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) [1].

3. DEVELOPMENT PROCESS

The SHC-AEDG was developed by a project committee (PC) that represents a diverse group of professionals. ASHRAE, AIA, IES, USGBC, ASHE, and DOE collaborated to provide guidance and support. Members of the PC came from these partner organizations, the ASHRAE Standing Standards Project Committee 90.1, and the ASHRAE Technical Committee 9.6, Healthcare Facilities. A steering committee (SC) made up of representatives of ASHRAE, AIA, IES, USGBC, ASHE, and DOE oversaw the PC as the guide was developed. The SC assigned a timeline for the task, an energy savings goal, a target audience, space types to include, and possible topics to incorporate.

Following SC guidance, the PC developed a one-year plan for completing the document. The PC used a schedule 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. Many meetings and conference calls were also held with the full PC during the development of the guide.

4. EVALUATION APPROACH

The guide contains a set of energy efficiency recommendations for each of the eight DOE climate zones across the United States. The following steps describe how the energy savings potential of the guide's recommendations was determined.

4.1. Develop "Typical" Small Hospital and Healthcare Facility Prototypes

For building characteristics that are not specified by Standard 90.1 but that are needed to develop code-compliant baseline models, the PC chose two recently constructed healthcare facilities (a surgery center and a community hospital) as the foundation for the prototypes. Information from the construction drawings for these facilities, along with publications data, was used to determine "typical" small hospital and healthcare facility characteristics. The publications surveyed include:

- The *2003 Commercial Buildings Energy Consumption Survey* (CBECS) [6]
- Additional data sets from the PC, including actual floor plates and space programming requirements for the community hospital and the surgery center
- The DOE Buildings Database (*http://eere.buildinggreen.com*)
- McGraw Hill Dodge construction data
- The *Green Guide for Healthcare* [7]
- DOE Commercial Buildings Benchmark Models [8]
- ASHRAE Standard 62.1-2004 [9]
- 2006 AIA *Guidelines for Design and Construction of Health Care Facilities* [10]

These documents were used to develop the prototype model characteristics, including form and floor plate, plug/process loads, ventilation rates, and operating schedules. These characteristics are the same for the baseline and low-energy models, and are documented in Table 1.

Table 1. Prototype Characteristics [11]

Building Characteristic	Prototype Models	
	Community Hospital	Surgery Center
Size	65,000 ft^2	41,000 ft^2
Number of floors	1	3
Peak number of occupants	675	414
Constructions	Steel-framed wall Roof with insulation entirely above deck	Steel-framed wall Roof with insulation entirely above deck
WWR	26%	20%
Occupancy	Fully occupied during the day Partially occupied at night	Fully occupied during the day Vacant at night
Whole-building weighted average 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: Packaged variable air volume system (PVAV) with direct expansion (DX) cooling, water boiler heating Low-energy: PVAV with DX cooling or air-cooled chiller or water-cooled chiller, water boiler heating	Baseline: PVAV with DX cooling, water boiler heating Low-energy: PVAV with DX cooling or air-cooled chiller or water-cooled chiller, water boiler heating

4.2. Create Baseline Models from the Prototypes that are Minimally Code Compliant for Standard 90.1-1999

The baseline models for the small hospital and healthcare facility were developed by applying the applicable criteria in Standard 90.1-1999 to the prototype models. The baseline small hospital and healthcare facility energy modeling assumptions obtained from Standard 90.1-1999 include the envelope characteristics, building lighting loads, HVAC equipment efficiency, operation, control, sizing, fan power assumptions, and SWH efficiency.

4.3. Create the Low-Energy Models Based on the Recommended Energy Efficiency Technologies in the Guide

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 energy efficiency measures, the low-energy building models were simulated by implementing the following energy efficiency technologies. The energy efficiency measures that were applied to all climate zones and included in the energy saving calculation are:

- Enhanced building opaque envelope insulation
- Enhanced window glazing with overhangs
- Reduced lighting power density (LPD) 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

4.4. Verify 30% Energy Savings Across the Various HVAC System Types Over the Eight U.S. Climate Zones

EnergyPlus[12] was used to perform building energy simulation analysis to assess and quantify the energy savings potential of the guide's recommendations. Two sets of simulations were run for each prototype: the first meets the minimum requirements of Standard 90.1-1999; the second uses the recommendations in the guide to achieve 30% energy savings. For each low-energy design, three cooling equipment types were modeled: a package rooftop system with direct expansion (DX) cooling, a packaged rooftop system with a central air-cooled chiller, and a packaged rooftop system with a central water-cooled chiller. The recommendations result in greater than 30% energy savings in all climate zones for each prototype within the range of cooling system types.

The flowchart in Figure 1 shows the evaluation approach.

5. MODELING METHODS

5.1. Climate Zones

The guide contains a unique set of energy efficiency recommendations for a range of climate zones. The common set of climate zones includes eight zones covering the entire United States (see Figure 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. The combination of climate zones 1 through 8, along with their respective subzones "A," "B," and "C," create 15 unique climate zones.

Fifteen specific climate locations (cities) were selected as being most representative of each subzone, as shown in the list. To determine energy savings, Typical Meteorological Year 2 weather files for each location were used to simulate the baseline and low-energy models.

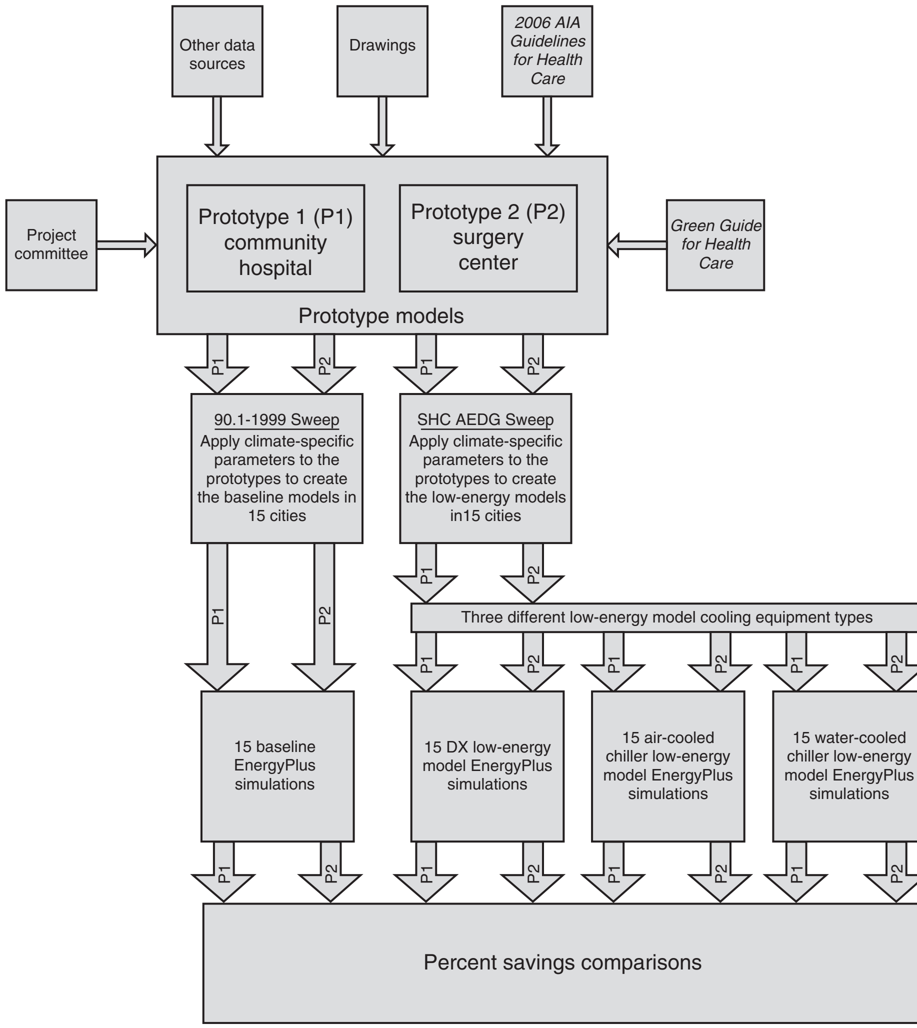

Figure 1. Evaluation Approach Flowchart [11].

- 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)

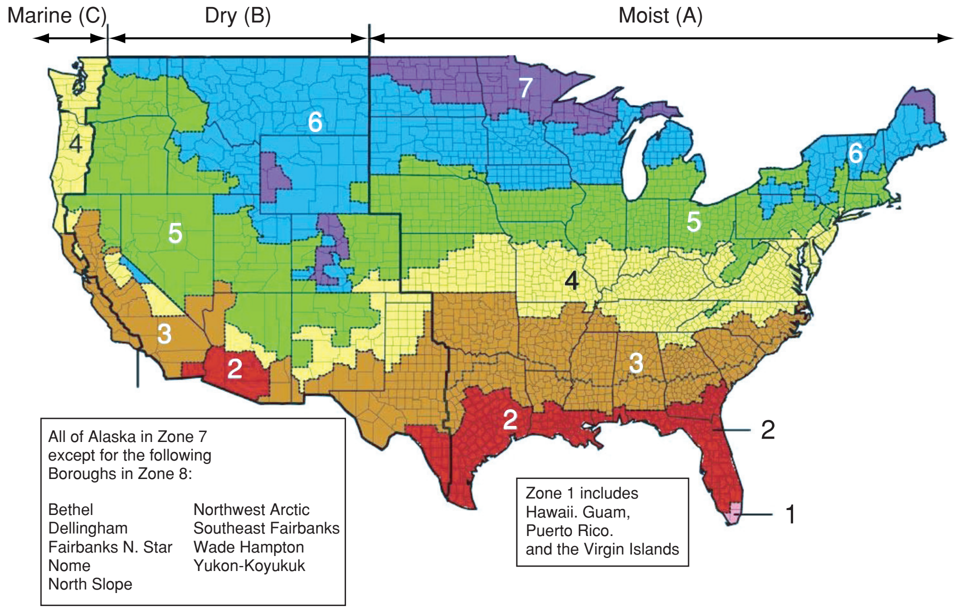

Figure 2. Climate Zones and Representative Cities [11].

- 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)

5.2. Analysis Platform

EnergyPlus version 3.1 was used to complete the energy simulations [12]. EnergyPlus 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. Alongside EnergyPlus, Opt-E-Plus [13], a software research tool that integrates with EnergyPlus, was used to aid in this analysis. Opt-E-Plus was developed by the commercial buildings research group at NREL and was used to create and manage the EnergyPlus input files.

The main analysis started with 8 "seed" EnergyPlus input files (1 baseline and 3 low-energy models for the 2 prototypes). Opt-E-Plus was then used to sweep these input files across the 15 climate zones, generating 120 input files. Interim analysis included sweeping 16 other "seed" EnergyPlus input files across the 15 climate zones to create 240 separate input files, for a total of 360 individual EnergyPlus input files. During this sweep, Opt-E-Plus applied climate zone-specific AEDG-SHC recommendations (such as roof insulation values) to each input file. When interfaced with a Linux supercomputer, Opt-E-Plus was able to complete approximately 1,440 linear simulation hours in only 12 clock hours.

The results were then analyzed to determine the energy savings over the code-compliant baseline. If the 30% savings target was not met for each simulation, changes were made to the recommendations and the analysis restarted from the beginning. These "seed" input files were continuously updated based on the results of the previous simulation iteration as the project progressed and were reswept numerous times. The automation of certain portions of this iterative process with Opt-E-Plus made this project possible in the allotted time frame. Ultimately, the 30% savings goal was achieved for each climate zone.

6. RECOMMENDATIONS

The guide makes recommendations for enhanced efficiency in several building systems to meet the 30% savings target. To further illustrate the impacts of these recommendations, Table 2 shows the comparison between Standard 90.1-1999 and the climate-specific recommendations for climate zone 5A (Chicago). The recommendations presented are either minimum or maximum values. Minimum values include:

- R-values (continuous insulation [c.i] where noted)
- Mean lumens/watt (MLPW)
- Solar Reflectance Index (SRI)
- Energy efficiency ratio (EER)
- Integrated energy efficiency ratio (IEER)
- Integrated part-load value (IPLV)
- Coefficient of performance (COP)
- Effectiveness
- Combustion efficiency (E_c)
- Thermal efficiency (E_t)
- Energy factor (EF)
- Duct or pipe insulation thickness

Maximum values include:

- Fenestration insulation (U-factors)
- Fenestration solar heat gain coefficient (SHGC)
- Total fenestration to gross wall area ratio (WWR)
- Lighting power density (LPD)
- Fan brake horsepower (bhp)
- Fan input power per cfm of supply airflow (W/cfm)

Table 2 highlights some recommendations; although examples from only one climate zone are shown here, the guide contains recommendations for all eight climate zones.

Table 2. Standard 90.1-1999 v. AEDG for Climate Zone 5 [11]

	Item	Component	Standard 90.1-1999 (Bin 17)	SHC AEDG (Climate Zone 5)
Envelope	Roofs	Insulation entirely above deck	R-15 c.i.	R-30 c.i.
		SRI	None	Comply with Standard 90.1
	Walls	Mass (HC > 7 Btu/ft^2)	R-7.6 c.i.	R-13.3 c.i.
		Steel framed	R-13 + R-3.8 c.i.	R-13 + R-15.6 c.i.
		Below grade walls	None	R-7.5 c.i.
	Floors	Mass	R-8.3 c.i.	R-16.7 c.i.
		Steel framed	R-19	R-38
	Slabs	Unheated	None	R-15 for 24 in.
	Doors	Swinging	U-0.70	U-0.50
		Nonswinging	U-1.45	U-0.50
	Vertical fenestration	Total fenestration to WWR	30.1-40%	40% max
		Thermal transmittance	0.57	0.29
		SHGC	0.39	0.34
		Visible transmittance	None	0.69
		Exterior sun control	None	Projection factor > 0.5
	Skylights	Area (percent of roof)	2.1-5%	3%
		Thermal transmittance	1.10	0.60
		SHGC	0.62	0.40
Lighting/Daylighting	Daylighting	Design the building to maximize access to natural light through sidelighting: - Staff areas (exam rooms, nurse stations, offices, corridors) - Public spaces (waiting, reception)	None	Diagnostic and treatment block: shape the building footprint such that the area within 15 ft of the perimeter exceeds 40% of the floorplate
				Inpatient units: ensure that 75% of the occupied space (not including patient rooms) lies within 20 ft of the perimeter
	Interior finishes	Daylit room interior surface average reflectance	None	88% on ceilings and walls above 7 ft 50% on walls below 7 ft

continued over

	Item		Component	Standard 90.1-1999 (Bin 17)	SHC AEDG (Climate Zone 5)
Lighting/Daylighting	Interior lighting		LPD	1.6 W/ft^2	1.0 W/ft^2
			Light source system efficacy (linear fluorescent and high-intensity discharge)	None	90 MLPW minimum
			Light source system efficacy (all other sources)	None	50 MLPW minimum
			Lighting controls - general	None	Manual on, auto-off in all zones except 24-hour patient care areas
			Dimming controls daylight harvesting	None	Dim fixtures within 15 ft of sidelighting edge and within 10 ft of toplighting edge
HVAC	Critical care access	Single-duct VAV air handling system (indoor or outdoor) with DX cooling and water boilers	DX air conditioner (packaged or split system)	8.5 EER 7.5 IPLV	10.0 EER 9.7 IPLV
			Air-cooled chiller efficiency	9.2 EER 9.6 IPLV	9.6 EER 11.5 IPLV
			Water-cooled chiller efficiency	3.8 COP 3.9 IPLV	Comply with Standard 90.1
			Chilled water pumps	None	Variable-frequency drive (VFD) and National Electrical Manufacturers Association (NEMA) premium efficiency
			Cooling tower	None	VFD and tower fans
			Gas boiler	80% E_c	90% E_c at peak design heating water temperature
			Economizer	None	Yes
			Fans	1.1 hp/1000 cfm	bhp ≤ supply cfm × 0.0013+A, NEMA premium efficiency motors
			Zone airflow setback	None	Yes

continued over

	Item		Component	Standard 90.1-1999 (Bin 17)	SHC AEDG (Climate Zone 5)
HVAC	Noncritical Care Access	Single-duct VAV air handling system	DX air conditioner (packaged or split system)	8.5 EER 7.5 IPLV	10.0 EER 9.7 IPLV
			Air-cooled chiller efficiency	9.2 EER 9.6 IPLV	9.6 EER 11.5 IPLV
			Water-cooled chiller efficiency	3.8 COP 3.9 IPLV	Comply with Standard 90.1
			Chilled water pumps	None	VFD and NEMA premium efficiency
			Cooling tower	None	VFD and tower fans
			Gas boiler	80% E_c	90% E_c at peak design heating water temperature
			Economizer	None	Yes
			Fans	1.1 hp per 1,000 cfm	bhp ≤ supply cfm × 0.0013+A, NEMA premium efficiency motors
			Space temperature setback	None	Yes
		WSHP system	Water-source heat pump < 65 kBtu/h	Cooling: 9.3 EER at 85°F Heating: 3.8 COP at 70°F	Cooling: 12 EER at 86°F Heating: 4.5 COP at 68°F
			Water-source heat pump ≥ 65 kBtu/h	Cooling: 10.5 EER at 85°F Heating: 3.8 COP at 70°F	Cooling: 12 EER at 86°F Heating: 4.2 COP at 68°F
			Water pumps	None	VFD and NEMA premium efficiency
			Cooling towers/fluid cooler	None	VFD on fans
			Gas boiler	80% E_c	90% E_c at peak design heating water temperature
			Economizer	None	Comply with Standard 90.1
			Exhaust air energy recovery in dedicated OA system	None	Zone A: 50% total effectiveness Zone B: 50% sensible effectiveness Zone C: 50% total effectiveness
			WSHP fans	None	0.4 W/cfm
			Other fans (dedicated OA system, exhaust)	None	bhp ≤ supply cfm × 0.0013+A, NEMA premium efficiency motors
			Space temperature setback	None	Yes

continued over

	Item		Component	Standard 90.1-1999 (Bin 17)	SHC AEDG (Climate Zone 5)
HVAC	Noncritical Care Access	Fan coil and chiller system	DX air conditioner (packaged or split system)	8.5 EER 7.5 IPLV	10.0 EER 9.7 IPLV
			Air-cooled chiller efficiency	9.2 EER 9.6 IPLV	9.6 EER 11.5 IPLV
			Water-cooled chiller efficiency	3.8 COP 3.9 IPLV	Comply with Standard 90.1
			Chilled water pumps	None	VFD and NEMA premium efficiency
			Cooling tower	None	VFD and tower fans
			Gas boiler	80% E_c	90% E_c at peak design heating water temperature
			Economizer	None	Yes
			Exhaust air energy recovery in dedicated OA system	None	Zone A: 50% total effectiveness Zone B: 50% sensible effectiveness Zone C: 50% total effectiveness
			Fan coil units	None	0.4 W/cfm
			Other fans (dedicated OA system, exhaust)	None	bhp supply cfm 0.0013+A, NEMA premium efficiency motors
			Space temperature setback	None	Yes
	Ducts and dampers		OA damper	None	Motorized
			Duct seal class	Supply: seal class B Exhaust: seal class B Return: seal class C	Supply: seal class A Exhaust: seal class B Return: seal class B
			Insulation level	R-6	R-6
	SWH		Gas storage (>75 kBtu/h)	80% E_t	90% E_t
			Gas instantaneous	0.81 E_F or 81% E_t	0.81 E_F or 81% E_t
			Electric (storage or instantaneous)	EF = 0.93-0.00132 Volume	EF > 0.99-0.0012 Volume
			Pipe insulation (d < 1.5 in./d 1.5 in.)	0.5 in./1 in.	1 in./1.5 in.

A review of the recommendations for all climate zones indicates how climate affects specific differences between low-energy and baseline models. For example, the recommended increase in roof insulation is greater in cold climates than in hot climates, reflecting the greater potential for extra insulation to save energy in colder regions. Mass wall insulation nearly doubles in hot and cold climates compared to Standard 90.1-1999; steel-framed walls add continuous insulation in hot climates and significantly increase in R-value in cold climates. Slab insulation increases over Standard 90.1-1999 in cold climates only, again reflecting the greater impact of insulation in cold climates. Vertical glazing thermal transmittance changes fairly substantially in hot climates because it switches from single to double glazing, but the value changes less dramatically in cold climates. SHGCs change slightly in hot and cold climates. Adding window overhangs with a projection factor greater than 0.5 was recommended for all climate zones.

The concept for improving the building envelope was based around the fact that most small healthcare facilities use constant-volume reheat systems to handle the space conditioning needs. These systems have traditionally been common in such facilities because they can independently control temperature and humidity and maintain space pressurization requirements. The roof, wall insulation, and window performance was increased, which reduced the constant-volume airflow needs and associated reheat. The envelope thermal performance was increased to the point that the reduced airflow needs meet the code-required minimum values. This saves on fan power and reheat energy, and smaller constant-volume systems can save capital costs with smaller air systems and reduced cooling capacity.

The daylighting recommendations include designing the building to maximize access to natural light through sidelighting in staff areas (exam rooms, nurse stations, offices, corridors) and public spaces (waiting, reception), along with daylighting controls. General LPDs were reduced 37.5% in this guide compared to Standard 90.1-1999, representing a large proportion of the total energy savings.

HVAC cooling efficiencies improved 15% in this guide compared to Standard 90.1-1999 in all climates zones except 6, 7, and 8, where they remained unchanged from Standard 90.1-1999 because the cooling energy represented a small portion of the whole-building energy use. Because high air change rates and humidity control are required in many space types, the constant-volume reheat HVAC systems that have traditionally been used in these facilities use a lot of energy for reheat. The baseline energy modeling shows that reheat represents more than 20% of the total energy use in all climate zones. Thus, high-efficiency condensing boilers are recommended for all climate zones because of the significant reheat energy required to maintain airflow requirements and humidity control in all locations. The SWH recommendations indicate the value of using either high-efficiency or point-of-use water heaters to reduce water heating energy use.

7. ENERGY SAVINGS RESULTS

Annual hourly simulations of two prototype buildings established the energy savings results from the application of the guide. One prototype building was the 65,000 ft^2

(6,040 m^2) community hospital; the other was a 41,000 ft^2 (3,810 m^2) surgery center. Both prototypes were simulated in all 15 climate locations, representing humidity subzones for the eight climate zones depicted in the guide and the standard.

The results of the simulations are indicated in Figure 3, showing the energy savings compared to the baseline for the community hospital and the surgery center.

All locations achieved the 30% savings for the community hospital and the surgery center. In general, the community hospital outperformed the surgery center in most climate locations because of its continuous (24-hour) operation. With lower lighting levels, additional heating energy was necessary to compensate for the heating typically gained from lighting power sources. However, this was more than offset by the cooling load reduction associated with lower lighting levels.

Complete results of the prototype facility simulations are presented in the *Technical Support Document: Development of the Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities*, available at *http://www.nrel.gov/docs/fy10osti/46314.pdf* [11].

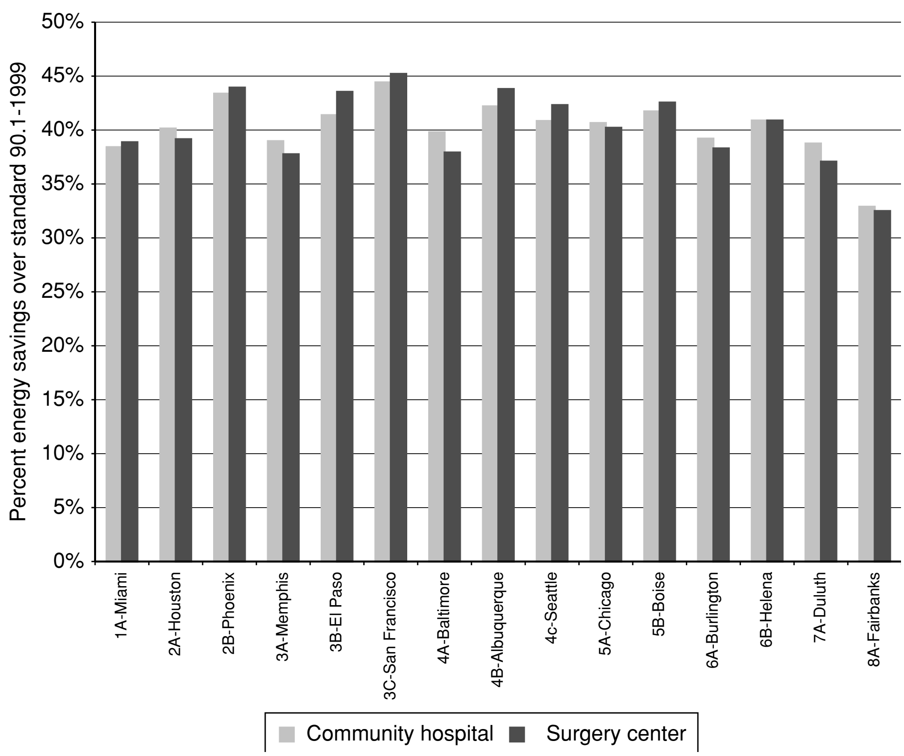

Figure 3. Percent Savings for the PVAV with DX Cooling Models.

8. BUNDLED ENERGY EFFICIENCY MEASURE ANALYSIS

During the modeling process, a baseline model and a low-energy model were created and compared to provide the percent savings numbers. The low-energy model was created by starting with the prototype model and applying as many guide recommendations as possible. However, it is difficult to determine which recommendations provide the most energy savings because they are all applied to the prototype model in a single operation. To better understand how each recommendation affects energy performance, a study was performed in which each guide recommendation was incrementally and aggregately applied until the low-energy model was achieved. This study was termed *a bundled energy efficiency measure analysis* and consisted of seven steps: (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 boiler and SWH efficiencies; (6) improve DX cooling efficiencies; and (7) implement a zone airflow setback strategy in which the HVAC terminal boxes mimicked constant air volume boxes during occupied times and VAV

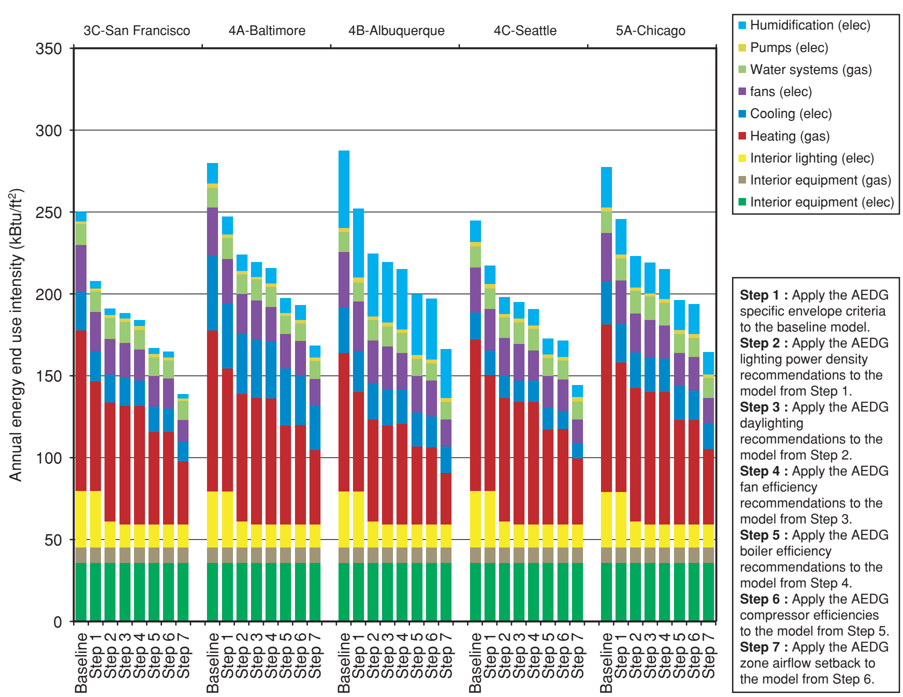

Figure 4. Community Hospital Bundled Energy Efficiency Measure Analysis Results for Climate Zones 1A through 3B.

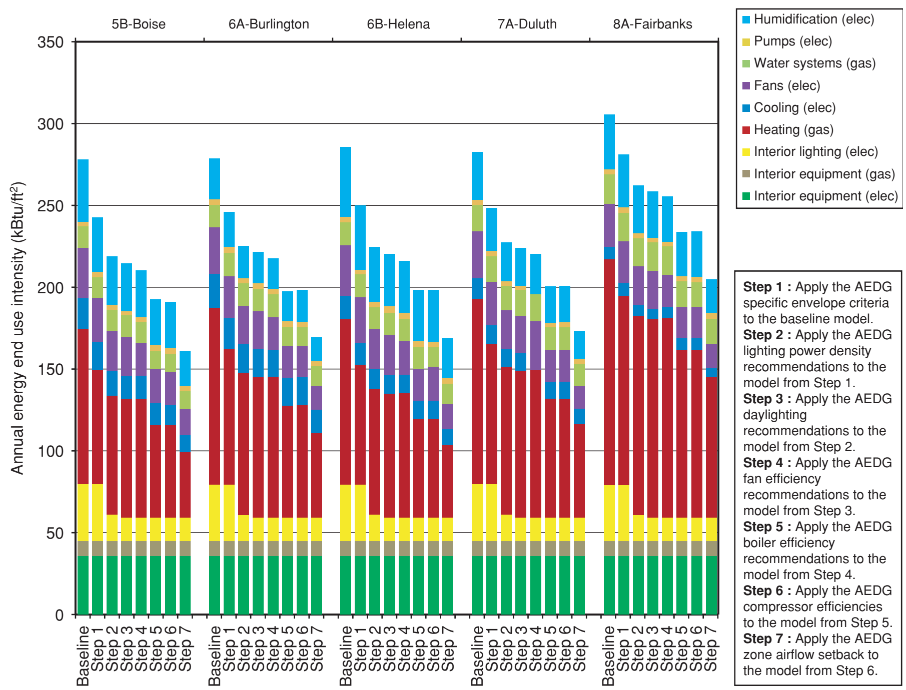

Figure 5. Community Hospital Bundled Energy Efficiency Measure Analysis Results for Climate Zones 3C through 5A.

boxes during unoccupied times. The bundled energy efficiency analysis energy results by end use for the community hospital are shown in Figure 4 (climate zones 1A through 3B), Figure 5 (climate zones 3C through 5A), and Figure 6 (climate zones 5B through 8A).

The results of this analysis show the biggest energy savers are the LPD reductions and the implementation of a zone airflow setback. Colder climates benefited more from the improved boiler efficiencies; hotter climates benefited more from improved cooling efficiencies.

9. SUMMARY

As with the previous guides in the series, the SHC-AEDG provides a simple, easy-to-use guide to help the building designer, contractor, and owner identify a clear prescriptive path to 30% energy savings over Standard 90.1-1999. In many ways, the SHC-AEDG is a simple interface to a complex analysis performed using EnergyPlus. 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

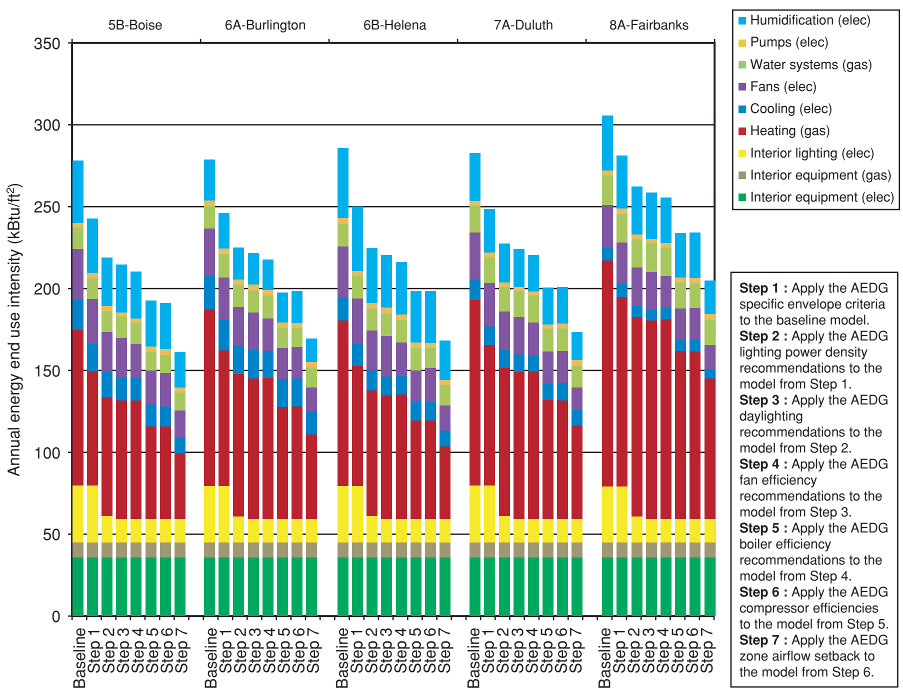

Figure 6. Community Hospital Bundled Energy Efficiency Measure Analysis Results for Climate Zones 5B through 8A.

opportunities. The SHC-AEDG is available for print purchase or as a free download from *http://www.ashrae.org/aedg*.

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 developing a large hospital best practices guide and is used in planning the next series of 50% savings Advanced Energy Design Guides. Also, U.S. government healthcare facilities are starting to use the guide to meet EPAct 2005 energy efficiency requirements.

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