Photo: NREL/DOE

Installing a "cool roof" is an excellent means of reducing building temperatures—decreasing the need for cooling energy. A bright white roof is ideal because its surface is minimally heated by the sun. Installation is most economically accomplished either during new construction or once an old roof already has been scheduled for retrofit.

Building Envelope Critical to High-Performance Hospitals

One of the most effective methods of reducing a new hospital facility's energy consumption is to properly plan its building envelope. A high-performance building envelope also can increase patient and staff comfort and well-being.

This fact sheet has been developed by the U.S. Department of Energy's Hospital Energy Alliance to provide healthcare systems with guidance in the design and construction or retrofit of energy-efficient building envelopes.

The building envelope, made up of all areas that interface between a building's interior and exterior, is a major factor in determining how much energy will be needed to heat, cool, and light the building.

More than 70 percent of the total energy consumed in healthcare facilities is attributable to lighting and HVAC (heating, ventilation, and air conditioning) needs.[1] The amount of energy consumed by lighting and HVAC is directly influenced by a building's design, construction, and material specifications. For instance, a hospital designed to take advantage of passive solar heating or cooling can limit both the capital and operating costs of its HVAC system.

Further, evidence-based design guidelines[2] identify building envelope features—such as daylighting, views, and materials—as important factors in creating safe and therapeutic patient environments.

Major Considerations

There are six major factors to consider when designing a high-performance building envelope. They are highlighted below.

Building Shape, Volume, and Orientation—A building's shape, volume, and orientation have an impact on daylighting, solar heat gain or loss, air movement, indoor environmental quality, and energy consumption.

Eighteen percent of energy consumption in healthcare facilities is attributable to lighting.[3] This can be reduced significantly by designing buildings that maximize how far daylight penetrates into a building's interior. Savings from reducing the need for electric lighting in controlled spaces during daylight hours can be as high as 87 percent.[4] Decreased use of electric lighting, in turn, can result in a 10 to 15 percent reduction of energy consumed by a building's HVAC system in cooling-dominated climates.[5]

Climate—The building envelope should be designed according to climate variations and thermal comfort requirements for the building site. The eight climate zones in the United States are identified on the map on Page 2 and referenced on the accompanying table. These zones are delineated by county borders and vary considerably in temperature, humidity, and other climatic factors.[6] The local climate is a key factor in determining which design features will reduce energy needs the most. For instance, in a cool climate, windows that face southward provide a building with more passive solar heat.

1. 2003 Commercial Buildings Energy Consumption Survey, U.S. Department of Energy.
2. Malloch, Kathy (Ed.). *Introduction to Evidence Based Practice in Nursing and Healthcare*. Second Edition. Jones and Bartlett Publishers. Sudbury, MA. 2010. For additional information, visit http://www.healthdesign.org/.
3. 2003 Commercial Buildings Energy Consumption Survey, U.S. Department of Energy.
4. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities*, citing "Daylighting Patient Rooms in Northwest Hospitals," by Brown, et al. (2005).
5. ASHRAE. *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities* (Foreword XVI). Atlanta, GA. 2009. Available from http://www.ashrae.org/publications/page/1604.
6. A detailed description of the classification of the climate zones is available at http://www.energycodes.gov/rc/climate_paper_review_draft_rev.pdf.

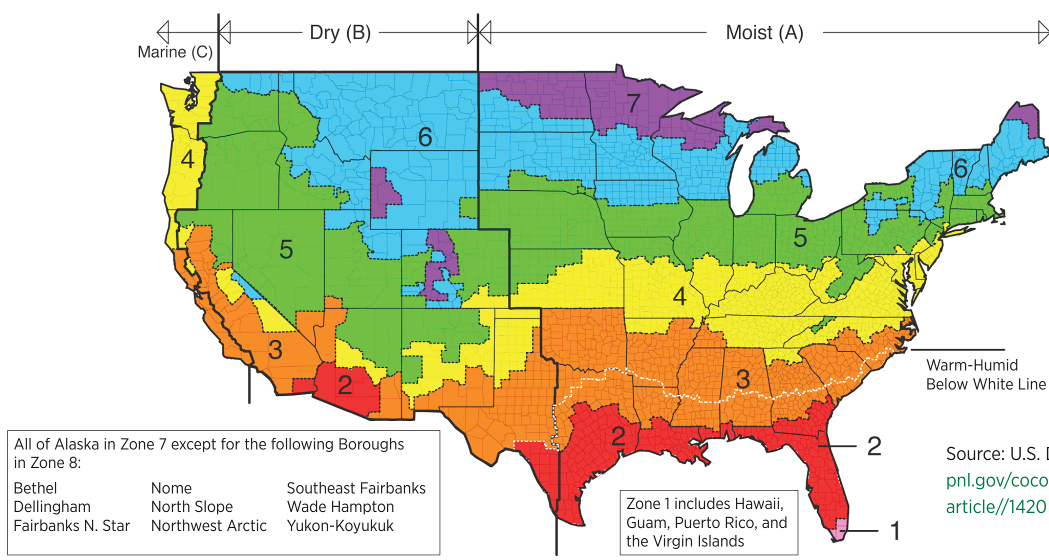
Table 1: Building Envelope Design Recommendations for Achieving 30% Energy Savings in Small Hospitals and Healthcare Facilities

Item	Component	Recommendations from the ASHRAE Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities (<90,000 sq ft)							
		Climate Zone							
		1	2	3	4	5	6	7	8
Roof	Insulation above deck	R-25*			R-30*			R-35*	
	Solar reflectance index (SRI)	78			Comply with Standard 90.1**				
Walls	Mass (HC >7 Btu/ft^2)	R-5.7*	R-7.6*	R-11.4*	R-13.3*		R-19.5*		R-25*
	Steel-framed	R-13 + R-7.5*				R-13 + R-15.6*	R-13 + R-18.8*		R-13 + R-21.6*
	Below grade walls	Comply with Standard 90.1**		R-7.5*			R-12.5	R-15*	R-17.5*
Floors	Mass	R-4.2*	R-10.4*	R-12.5*	R-14.6*	R-16.7*	R-19.5*	R-20.9*	R-23*
	Steel-framed	R-19	R-30		R-38		R-49	R-60	
Slabs	Unheated	Comply with Standard 90.1**			R-15 for 24”		R-20 for 24”		R-20 for 48”
Doors	Swinging	U-0.70			U-0.50				
	Non-swinging	U-1.450	U-0.50						
Vertical Fenestration	Total fenestration to gross wall area ratio	40% maximum							
	Thermal transmittance (all types and orientations)	U-0.43			U-0.29				U-0.20
	SHGC (all types and orientations)	SHGC-0.26			SHGC-0.34				SHGC-0.40
	Visible transmittance	VT-0.63			VT-0.69				VT-0.65
	Exterior sun control (SE & W only)	Projection factor >0.5							
Skylights	Area (percent of roof area)	3% maximum							
	Thermal transmittance (all types and orientations)	U-0.75		U-0.65	U-0.6				
	SHGC (all types and orientations)	SHGC-0.35			SHGC-0.4			Comply with Standard 90.1**	
Daylighting	Design the building to maximize access to natural light through sidelighting and toplighting: • Staff areas (exam rooms, nurse stations, offices, and corridors) • Public spaces (waiting and reception)	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							

*c.i. or Continuous Insulation

**Comply with the more stringent of either the applicable edition of ASHRAE 90.1 or the local code requirement

U.S. Climate Zones for Use in Implementing Building Energy Codes and Standards



Source: U.S. DOE. http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article//1420

Thermal Efficiency—The materials selected for hospital design or reconstruction should be specified according to the recommendations for energy-efficient building design for each climate zone. These recommendations typically include specifications for:

- Thermal resistance (R-value) and thermal conductance (U-value) for the opaque envelope components, such as roofs, walls, and floors.
- Solar heat-gain coefficient and thermal conductance (U-value) of fenestration products.
- Reflectance and emissivity of roofing products.

Enhancing the thermal efficiency of the building envelope can result in considerable energy and cost savings. For example, roofs that qualify for ENERGY STAR® ratings can reduce the peak cooling demand by 10 to 15 percent.[7]

Fenestration (Doors, Windows, Skylights, and Openings)—The design, orientation, size, and material specifications for all fenestration should be based on careful consideration of the interaction among daylighting, visual performance, and HVAC needs. Shading devices can be used to control solar penetration into the building; local climate should be considered in their design. An estimated 10 to 40 percent reduction in lighting and HVAC costs is attainable through improved fenestration in commercial buildings.[8]

Air and Moisture Control—Proper sealing of the building envelope prevents air and moisture infiltration. This could result in the growth of mold, bacteria, toxins, and microbiological volatile organic compounds, reduce indoor air quality, and increase HVAC-related loads.

Improvements to the indoor environment can reduce healthcare costs and work losses from communicable respiratory diseases by 9 to 20 percent.[9]

Building Material Properties—Building envelope materials should be specified carefully, as they contribute significantly toward creating healthy, comfortable, and non-hazardous hospitals. Consider recycled or refurbished materials or bio-based products. Be mindful of the embodied energy (energy required to extract, manufacture, transport, install, and dispose of building materials) of the materials specified.

Design Integration Is Key

A high-performance building envelope integrates the design of its individual components with interior lighting and HVAC strategies. Energy-simulation tools should be used to examine the complex interaction between energy consumption and building envelope design and specifications. Listed below are strategies related to energy-efficient building envelope design and construction or retrofits and operations and maintenance.

Opaque Surfaces (Walls, Roofs, and Floor Slabs)

- Build walls, roofs, and floors of adequate insulation for the climate zone to provide comfort and energy efficiency. Pay special attention to roofs that are especially vulnerable to solar gain in summer and heat loss in winter.

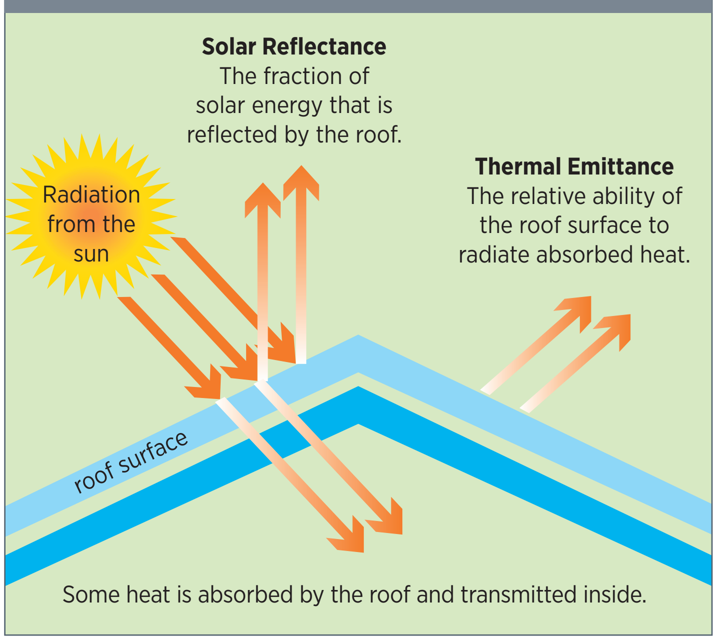
Efficiency Recommendation for Roofs

Roof Slope	Recommended Solar Reflectance		Best Available Solar Reflectance*	
	Initial	Three years after installation	Initial	Three years after installation
Low-slope (<2:12)	65% or greater	50% or greater	87%	85%
High-slope (≥2:12)	25% or greater	15% or greater	77%	60%

* To receive these solar reflectance ratings, roof products must be tested when new and after three years of exposure. Initial reflectance may decrease over time, due to aging, dirt, and microbial accumulation. For products that can be installed on both low- and high-slope roofs, follow "low-slope" guidelines.

Source: DOE, modified. http://www1.eere.energy.gov/femp/technologies/eep_roof_products.html.

Thermal Performance of a Cool Roof



Source: Cool Roof Rating Council. http://www.coolroofs.org/.

7. http://www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products.
8. Ander, G.D. "Windows and Glazing." *Whole Building Design Guide*, updated 26 May 2008. http://www.wbdg.org/resources/windows.php?r=minimize_consumption.
9. Lawrence Berkeley National Laboratory (LBNL). 2009. *Hospital Energy Benchmarking Guidance.* Berkeley, CA.

- Consider increasing the thermal mass of the envelope. This allows the building to absorb energy slowly, hold it longer, reduce indoor temperature fluctuations, and reduce the overall heating and cooling requirements. Thermal mass materials include traditional materials (such as stone and adobe) and cutting-edge products (such as those that incorporate phase-change materials).
- Think about installing green or cool roofs, where appropriate, to reduce energy consumption and the urban heat island effect. See the table and diagram on Page 3 for more information about cool roofs.

Fenestration

- Select glazing type after careful consideration of all fenestration performance specifications, such as U-factor, solar heat-gain coefficient, visible transmittance, air leakage, and condensation resistance.
- Consider specifying high-performance windows, which can be six times more energy efficient than lower-quality windows.[10] The former could include insulated windows with multiple glazings; those with low-emissivity coatings; those with low-conductance, gas-filled windows; and smart windows, such as electrochromic windows (see photograph below) and those using suspended-particle-device technology.
- Consider the use of external shading devices, such as overhangs, designed according to the building-site climate.
- Situate and size fenestration openings to best accommodate energy efficiency, comfort, and visual considerations.

Air and Moisture Control

- Ensure that vapor retarders and air-retarding systems have been properly specified and installed. Pay careful attention to potential thermal bridges in the building envelope, where moisture and air control problems also can be aggravated.
- Adopt careful detailing, weather stripping, and sealing of the envelope assemblies to minimize air infiltration.

Operations and Maintenance

- Include building envelope components with the building's commissioning plan to ensure that all material specifications, performance requirements, and construction guidelines are being met.
- Ensure that inspection of building envelope components is part of the overall operations and maintenance protocol. Building envelope maintenance should include a visual survey and repair of any deterioration and openings or cracks in roofs and walls; infrared surveys to detect insulation deterioration; and inspection of window-gasket systems and sealants and repair of any problems.

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) publication *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities* has helpful recommendations related to building envelope design. To download this publication, visit http://www.ashrae.org/publications/page/1604.[11]

Electrochromatic windows are designed to change tint to either allow in more daylight or to eliminate solar heat and glare as needed. Both states contribute to energy efficiency, with the clear state reducing the need for electric lighting and the darkened state decreasing the need for air conditioning. Unlike blinds or permanently tinted windows, electrochromatic windows do not interfere with views.

Photo: Soladigm

10. The National Fenestration Rating Council has developed a standardized rating system. See http://www.nfrc.org/label.aspx.
11. Specific building envelope recommendations for achieving 30 percent savings are referenced on pages 15–39.

Case Study

Ringgold County Hospital

Mount Ayr, Iowa • 2009

Ringgold County Hospital recently replaced old structures with a new 62,000-square-foot, 16-bed facility. Situated on a 22-acre site, the new facility offers inpatient and outpatient care that includes clinical services, emergency, surgery, a lab, diagnostic imaging, and physical therapy. The hospital features a high-mass, energy-efficient building envelope that was carefully designed through collaboration among the hospital owners, architects, engineers, sustainability experts, and the local utility company. The team studied the building's envelope, use of daylighting, and the artificial lighting and HVAC methods most appropriate for southern Iowa.

Details

- The total construction cost was $14.8 million.
- Walls are made of a precast concrete panel system with an integral core of R-21 insulation.
- The floor slab is insulated with R-21 insulation, which is extended 7 to 10 feet across the building's perimeter and down into its foundation.
- It has an ENERGY STAR-qualified cool roof with R-30 insulation and a coating of white flexible thermoplastic polyolefin membrane that has a solar reflectance of 0.79 and a thermal emittance of 0.85.
- Daylight is harvested with a total window-to-wall area ratio of 7.4 percent.
- Windows have double-pane glazing with a U-value of 0.29 and solar heat-gain coefficient of 0.42.
- Stepped-level dimming lighting controls and occupancy sensors optimize the use of electrical lighting.
- The building incorporates premium-efficiency HVAC and water-heating equipment.
- The facility uses variable frequency drives on the heating pump and fans.

Benefits

- Annual energy savings of 188,399 kWh of electricity consumption and 23,060 therms of natural gas consumption.[12]
- Simple payback period of 2.6 years (1.4 years after financial incentives from local utility company).
- Improved indoor environmental quality, visual quality, and thermal comfort.

The image on the left shows the west wall of the Ringgold County Hospital building. An infrared image of the building envelope shows the thermal integrity of the walls. The only evidence of thermal bridging is around windows.

12. Results from a post-occupancy verification study. Energy performance compared to an ASHRAE 90.1-2004 code-compliant baseline building.

Hospital Energy Alliance

HEA is a forum in which healthcare leaders work together with DOE, its national laboratories, and national building organizations to accelerate market adoption of advanced energy strategies and technologies.

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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