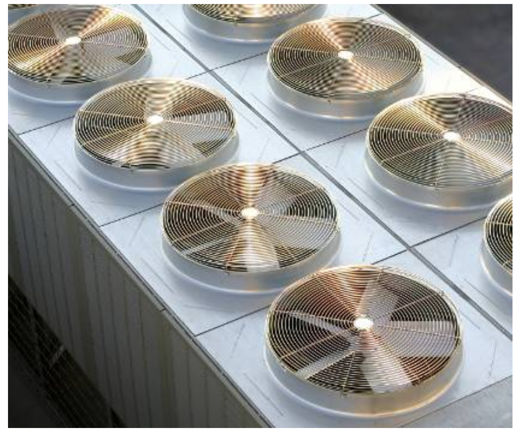
Energy Efficiency: Integrated Design and HVAC Systems

HEALTHCARE - TOP 5 GREEN BUILDING STRATEGIES

EPA Publication 909-F-07-001

What? Energy use in healthcare facilities is higher than nearly all other building types. With rising energy costs and climate change concerns energy efficiency is financially prudent and increasingly expected. Efficiency can be gained from integrated design practices, including systems to control heat gain, and increase the efficiency of heating, ventilation, and air conditioning (HVAC) systems.



Why?

Enhanced Community Reputation:

- Increases energy efficiency and reduced climate impact
- Demonstrates environmental stewardship

Environmental/Staff/Patient Benefit:

- Improves patient and staff comfort with less intrusive indoor environment

Cost Competitive:

- Lowers HVAC size and rating through integrated design
- Improves facility's overall operational efficiency
- Reduces operational costs

How?

- Use integrated design (viewing building systems as interrelated instead of separate)
- Focus on building envelope
- Perform energy audit of existing facilities (consider using ENERGY STAR for Healthcare; www.energystar.gov)
- Model and plan energy use for new buildings
- Use benchmarking data
- Use high-efficiency HVAC, chiller, and variable speed pumps
- Install high performance windows

Case Studies

- Emory University
- University of Florida

Green Guide for Health Care (GGHC) Criteria: *Construction: Energy & Atmosphere and Operations: Energy Efficiency* *www.gghc.org*

This is one of 5 ***Building Healthy Hospitals*** case studies developed by EPA's Pacific Southwest Regional Office, with Resource Conservation Challenge and Pollution Prevention funds.

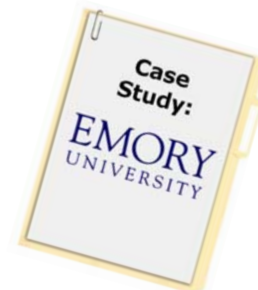
www.epa.gov/region09/waste/p2/projects/hospart.html

Indoor Air • Sustainable Flooring • Process Water Efficiency • Lighting Efficiency • Energy Efficiency

CASE STUDY 1: HIGH EFFICIENCY CHILLERS

Applicability:	New construction or major renovation projects.
Environmental Impact:	▪ 40 to 50 percent reduction in energy use required for space cooling ▪ 48 percent savings in cooling tower energy use.
Other Benefits:	Long term operating efficiency.

Background



Electrical centrifugal water chillers (chillers) represent the single largest electrical load in most institutional and commercial facilities, accounting for 35-50 percent of a building's annual electricity use[1]. Though chillers generally operate below full-load, chillers are rated at full load efficiency, application part load value (APLV), and integrated part load value (IPLV). To reduce long-term operating costs, Emory installed two 350-ton high efficiency chillers with a coefficient of performance (COP) of 5.2 at the Winship Cancer Institute. The high efficiency units run in parallel and are connected to one of Emory's four chiller plants, using 0.676 kilowatt-hours (kwh) per ton of cooling produced.

Performance

Emory recently began metering the chillers separately to determine actual kilowatt tons per hour per square foot (kwh ton/hour/square foot). To adjust for differences in climate, this data was divided by the degree cooling days for the month, providing a normalized metric that can be compared to facilities elsewhere in the country (see Exhibit 3). Exhibit 4 compares Emory's chillers to commonly used efficiency standards.

The chillers are included in the preventive maintenance and leak detection program for other equipment on campus and data is recorded and analyzed using a computer program. The chillers at Winship Cancer Institute use refrigerant R134A, a non-ozone-depleting chemical used in high-pressure systems. Purge systems are primarily used in low-pressure chillers; therefore, this maintenance activity is eliminated for Winship Cancer Institute. No additional unique maintenance activities are required to operate the high efficiency chillers; therefore, the operation and maintenance (O&M) costs are comparable to standard chillers.

Emory has established detailed design and construction specifications—applicable to all construction and major remodel projects on campus—that include requirements for

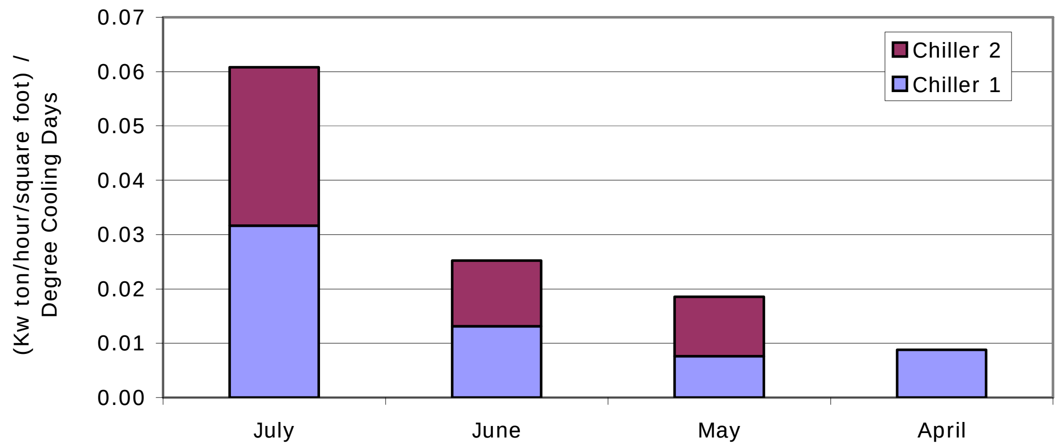
---

[1] "Supply Side Focus: Chiller Equipment; The Elements of Energy Efficiency." Maintenance Solutions, August 2004. Online: www.facilitiesnet.com/ms/article.asp?id=1833

purchasing chillers[2]. In addition to design and operating features, Emory requires all new building on campus to use construction design specifications reflecting various green and energy efficiency requirements; for chillers, Emory's specifications are as follows:

- Have minimum full load and part load efficiencies meeting or exceeding ASHRAE Standard 90.1-2004[3] (specifications allow the project manager to require a more stringent efficiency, as needed).
- Are manufactured by Carrier, Trane, or York (York chillers were selected for installation at the Winship Cancer Institute).

EXHIBIT 3 | WINSHIP CANCER INSTITUTE NORMALIZED CHILLER ENERGY USE



[2] Emory 2006 Design and Construction Standards, online: www.fm.emory.edu/emory-std/2006%20Emory%20Design%20&%20Construction%20Standards.pdf

[3] ASHRAE Standard 90.1 (2004) available online at: www.realread.com/prst/pageview/browse.cgi?book=1931862664

EXHIBIT 4 | EMORY CHILLERS VERSUS FEMP CHILLER EFFICIENCY RECOMMENDATIONS

	Part Load Optimized Chillers			Full Load Optimized Chillers			
Centrifugal Chiller Size	ASHRAE Standard	FEMP IPLV	Best Available IPLV	ASHRAE Standard	FEMP Full-Load	Best Available Full-Load	**Winship (350 tons)**
150-299 tons	0.78	0.52 or less	0.47	0.84	0.59 or less	0.50	**--**
300-2,000 tons	0.66	0.45 or less	0.35	0.68	0.56 or less	0.47	**0.676**

Note: IPLV = Integrated Part Load Value

FEMP = Federal Energy Management Program

Adapted from "How to Buy an Energy Efficient Water-Cooled Electric Chiller," Department of Energy, January 2004. Online: http://www1.eere.energy.gov/femp/pdfs/wc_chillers.pdf.

American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) Standards available online: http://www.ashrae.org/.

Cost

High efficiency chillers are designed with enhanced controls, improved condenser sections, and high-efficiency compressors; these features raised the initial cost to Emory by about 20 percent more than a comparable standard unit. However, the use of these chillers—combined with the lower demand for chiller water through other energy conservation measures—resulted in a 42 percent reduction in the energy required for space cooling and a 48 percent savings in cooling tower energy use. Emory estimates the simple payback from using the new chillers instead of units with standard energy efficiency at less than 4 years (see Exhibit 5).

The simple payback for recovering the cost premium of the chillers is directly related to the cost of energy. At $0.05 per kilowatt-hour (kwh), Emory's energy costs are low compared to elsewhere in the United States. In addition, Emory's energy costs are low despite recent annual increases; costs have increased from $33.30 per megawatt-hour ($0.033/kwh) between 2001 and 2006 (natural gas prices have more than doubled during this time as well). As energy prices increase, Emory has been able to cost-justify more efficient equipment with a higher cost premium. At many other institutions and in many other parts of the U.S. higher costs could easily yield payback periods for the cost premium of 1.0 year or less.

EXHIBIT 5 | COST/BENEFIT ANALYSIS – WINSHIP CANCER ENERGY-EFFICIENT CHILLER

Annual Hours of Operation	Standard ASHRAE Efficiency		Winship Cancer Institute High-Efficiency		Cost Premium	Annual Savings	Payback (years)
	Annual kwh	Annual Cost	Annual kwh	Annual Cost			
7,000	2,183,751	$109,187	1,263,387	$63,169	$100,000	$46,018	2.17

Note: Emory University energy costs approximately $0.05 per kwh in 2006.
The chillers at the Winship Cancer Institute operate at 70% average load.

Case Study *Vitals*

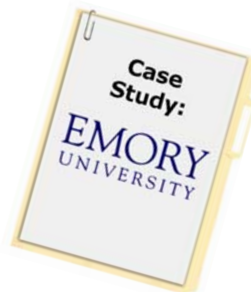
The following summarize success criteria for implementing this project at other healthcare facilities:

- **Develop or Adopt Green Design Standards -** Emory's detailed design and construction specifications provide the University with a clear path to implementing energy efficiency strategies on every project. Further, Emory requires the standards as the "default" specifications for all buildings on campus. Though Emory's standards generally follow LEED standards, other organizations can adopt standards wholesale or modify them to suite their needs.
- **Establish Multi-Disciplinary Team -** Healthcare facilities should ensure that its design team encompasses several disciplines so that collectively the design team understands expectations for energy efficiency projects and purchasing requirements for energy-intensive systems.
- **Know Your Organizations Investment Parameters –** Chillers are available in a variety of efficiency ratings with more efficient units coming with progressively higher initial costs. The cost premium acceptable to a healthcare facility for purchasing an energy-efficient chiller typically depends on cost/benefit analyses (e.g., simple payback, internal rate of return) of the investment appropriate for the institution. Designers of healthcare facilities typically have the benefit of using very long "useful life" design horizons. In addition, areas with higher energy costs or increasing energy costs will realize shorter payback.
- **No Additional Installation or Operation Issues -** Emory has used high efficiency chillers for several years with no additional installation or maintenance issues or concerns.

CASE STUDY 2: HIGH EFFICIENCY AND VARIABLE-SPEED PUMPS

Applicability:	New construction or major renovation projects
Environmental Impact:	40 percent reduction in energy use required for pump systems
Other Benefits:	Long-term operating efficiency

Background



Pumps serve a variety of purposes in HVAC systems, but primarily function to move air or water within the system to control temperature. Pumps have conventionally been designed to operate at a single-speed, using the same amount of energy at all times of operation regardless of load demand. Manufacturers have begun offering improved efficiency pumps in two ways:

- Designing pumps with efficiency ratings 20 to 40 percent higher than standard new models.
- Including variable-speed motors that operate with variable energy loads depending on the amount of air or liquid that must be circulated at any given time, using only what energy is needed.

Performance

Emory's Winship Cancer Institute uses high-efficiency, variable-speed pumps to pump: (a) chilled water to the air handling units, and (b) condenser water from the chillers to the cooling towers. A computer system installed in the building controls the pumps, monitoring differential pressure to monitor load increases and decreases and set pumping requirements accordingly; in this way the pump output (and therefore the energy input) changes to match the HVAC requirements at the particular time of day.

Energy use associated with the pumps is estimated at 40 percent less than a typical facility of comparable size (see Emory's calculations using USGBC's LEED Calculator 2.0 results in Attachment A). The savings in pump energy is due not only to the use of variable speed, high-efficiency pumps, but also to HVAC equipment efficiency differences and energy recovery methods. These HVAC system improvements resulted in a smaller amount of chiller water being handled by the pumps. As a result, the pumps operate less frequently *and* more efficiently, significantly reducing overall energy use.

Cost

Emory installed the pumps as part of the new building construction at Winship Cancer Center.

EXHIBIT 6 | HIGH-EFFICIENCY, VARIABLE SPEED PUMP FEATURES
▪ Energy savings from pumps alone in the HVAC system is unavailable, but based on vendor data and operational history, Emory estimates payback of pumps at approximately 3 years. ▪ Variable-speed high-efficiency pumps have operating efficiency 40 percent better than standard new pumps ▪ Energy savings of approximately 205 kwh per year (LEED Calculator 2.0 estimate)
Note: Emory University energy costs approximately $0.05 per kwh in 2006. Pumps operate approximately 7,000 hours per year.

Case Study *Vitals*

The following summarize success criteria for implementing this project at other healthcare facilities:

- **Look for Additional Benefits Accruing to Other Systems -** Improving efficiency in building systems can have a waterfall effect, reducing the energy demands in other related systems. For example, in Emory's case HVAC equipment efficiency differences and energy recovery methods decreased the demand for chilled water, also reducing the frequency pumps must operate. It is important to understand the effects energy- and water-efficiency strategies will have on other systems and make design decision using more efficient operating assumptions.

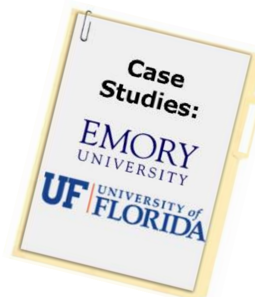
- **Smaller Pumps are Good Candidates** – Emory found payback on larger pumps (more than 10 HP) not as attractive because of the run duration and cycling.

- **No Additional Installation or Operation -** Emory has found no additional installation or maintenance issues or concerns with the variable speed pumps and has been using them successfully in numerous buildings across campus for many years.

CASE STUDY 3: LOW-E WINDOWS

Applicability:	New construction or major renovation projects; windows selection is based on location and climate of facility, as well as the building design and window position
Environmental Impact:	30 to 50 percent reduction in energy use
Other Benefits:	Long term operating efficiency; improved access to daylight and natural views for occupants without increasing energy costs for heating and cooling

Background



Windows are a critical part of the building envelope and provide considerable aesthetic value to building occupants by introducing natural light and providing a visual connection to the outside environment. However, windows can also represent a large source of heat gain or loss. Unmanaged solar energy can increase the heating load of the building, demanding more of the air conditioning systems. Similarly, windows with a poor ability to keep heat in allow warm air to escape the building in the winter, increasing the demands on heating systems.

Window manufacturers have developed many new insulating and glazing techniques to improve the performance of windows. The National Fenestration Rating Council defines five performance areas to consider when choosing windows most suited for your local climate[4]:

- U-Factor measures how well a product prevents heat from escaping a home or building. U-Factor ratings generally fall between 0.20 and 1.20 with lower numbers indicating a product better at keeping heat in.
- Solar Heat Gain Coefficient (SHGC) measures how well a product blocks heat from the sun from entering the building. SHGC is expressed as a number between 0 and 1, with a lower SHGC indicating a product that is better at blocking unwanted heat gain.
- Visible Transmittance (VT) measures how much light comes through a product. VT is expressed as a number between 0 and 1 with a higher VT indicating higher potential for daylighting.

4 "The Facts About Solar Heat Gain and Windows." National Fenestration Rating Council; online at: www.nfrc.org/documents/SolarHeatGain.pdf

- Air Leakage (AL) measures how much outside air comes into a home or building through a product. AL rates typically fall in a range between 0.1 and 0.3 with a lower AL indicating a product that is better at keeping air out.

Condensation Resistance (CR) measures how well a product resists the formation of condensation. CR is expressed as a number between 1 and 100 with a higher CR indicating a product better able to resist condensation.

More so than other green building strategies, window selection must be tailored to the local climate of a facility and building orientation. For example, facilities in warmer climates should install windows with a lower SHGC and those in a cooler climate should install windows with a lower U-factor. Low-e windows can be applied in different ways specific to local climates and heating and cooling needs. Low-e coatings applied to exterior windowpanes prevent heat gains from exterior radiation; whereas low-e coatings applied to interior windows prevent heat loss. Manufactures often offer several low-e coatings with varying degrees of solar gain.

Performance

Both Emory's Winship Cancer Institute and the University of Florida's Sports and Orthopedic Surgery and Sports Medicine Institute installed low-e windows throughout their facilities. Exhibit 7 compares the products installed at each facility against the ASHRAE 90.1 standard.

EXHIBIT 7 | CASE STUDY LOW-E WINDOWS VERSUS ASHRAE 90.1 STANDARD

	U-COG	SHGC	VT	SC
ASHRAE 90.1	0.571	0.404	0.732	0.43
Emory - Winship Cancer Inst.	0.370	0.372	0.328	0.47
U of F - Orthopedic Surgery and Sports Medicine Institute	0.38	0.380	Not Available	0.42

Note: U-COG: U-Factor at center of glass
SHGC: Solar heat gain coefficient
VT: Visible transmittance
SC: Shading coefficient

Emory installed low-e windows throughout the Winship Cancer Institute to reflect the sun's radiant energy and reduce heat entering the building. Low-e interior glass was purchased from Viracon, Inc. and low-e windows and curtainwall systems were purchased from EFCO. These windows drastically reduced the cooling requirements of the building, but also resulted in a slight increase in heating needs during the winter months. Because both the buildings at Emory and the University of Florida are located in a humid, subtropical climate, the slight increase in heating needs was easily compensated for in the reduced cooling needs due to the installation of low-e windows.

Cost

Windows manufactured with low-e coatings typically cost about 10 to 15 percent more than regular windows, but they reduce energy loss by as much as 30 to 50 percent[5]. Furthermore, this improvement in the building envelope—particularly when coupled with other strategies that improve the efficiency of the building envelope—ultimately impacts the demands of building HVAC systems. These benefits should be included in evaluating the lifecycle costs of installing efficient windows.

EXHIBIT 8 | 2005/2006 ENERGY USE DENSITY – HEALTHCARE FACILITIES: UNIV. OF FLORIDA ORTHOPEDICS CENTER EMORY WINSHIP CANCER CENTER

- Windows with low-e coatings vary widely in cost depending on performance, glazing, and other factors; generally the price premium is 10 to 15 percent, approximately the cost premium for the buildings at both Emory and the University of Florida.
- Low-e coatings reduce energy loss from 30 to 50 percent.
- Neither Emory nor the University of Florida have data on energy reduction specifically from the windows.

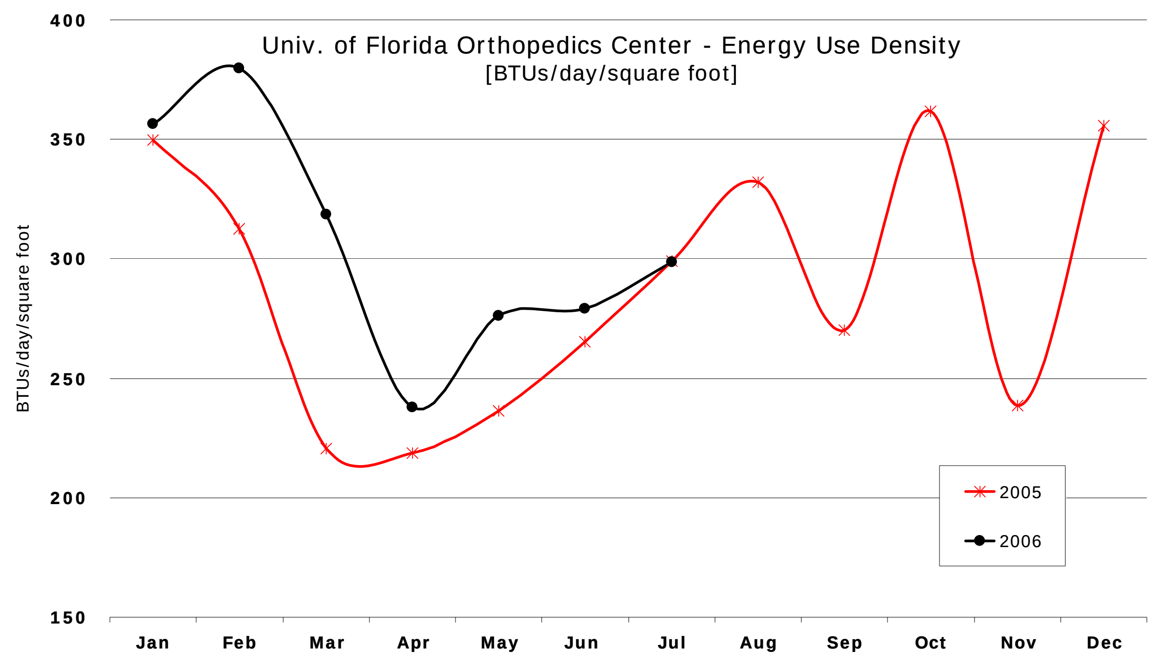
<u>Univ. of Florida Orthopedic Center:</u>

- Energy use density for the Orthopedic Center varies between 210 to 380 BTUs/day/square foot; the building contains 46 exam rooms with support services of Radiology, Rehabilitation, and Biomechanics representing a relatively equal mix of patient rooms, offices, and therapy rooms. The building's energy use density is approximately 50 percent lower than other medical building on campus (though the comparable buildings contain more energy-intensive diagnostic equipment).
- Univ. of Florida Energy management staff estimate that approximately 20 percent of that energy efficiency at the Orthopedic Center is the result of the windows used in the building based on their experience managing energy across campus and data provided by the window vendor and architect.

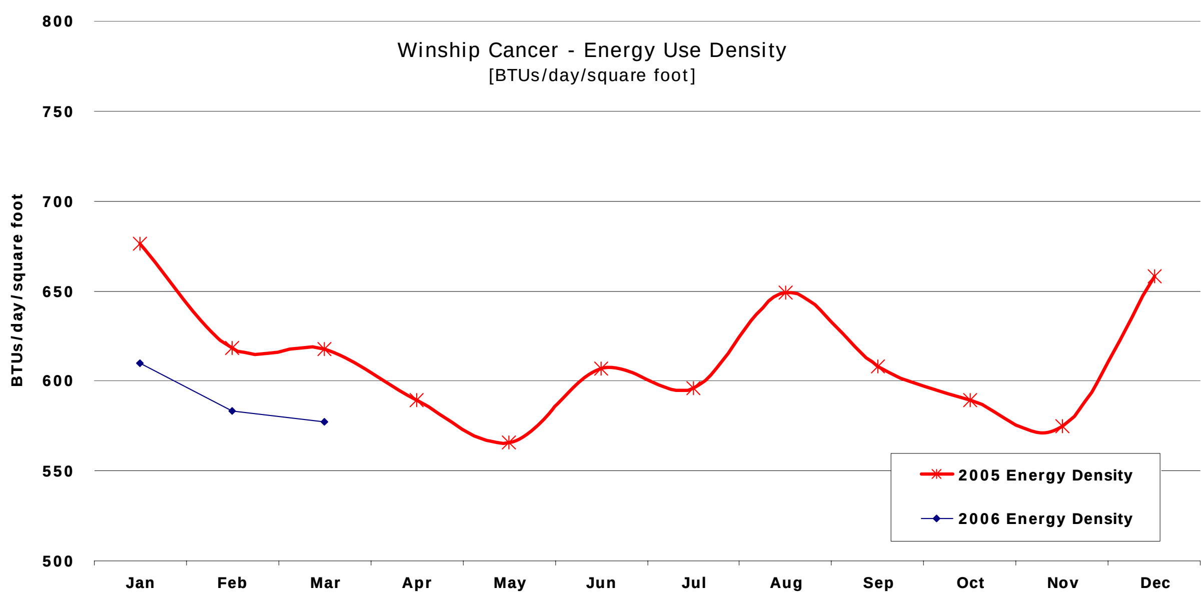
<u>Emory Winship Cancer Center:</u>

- Energy use density for Winship Cancer varies between 560 to 680 BTUs/day/square foot; the building contains a large amount of energy-intensive treatment and patient care equipment along with patient rooms and offices. Comparisons to other buildings at Emory are difficult because of the lack of similar activities occurring elsewhere.
- Emory Building Management staff estimate the simple payback of the windows used in the building at approximately 7 years.

[5] "Low Emissivity Window Glazing or Glass." U.S. Department of Energy Efficiency and Renewable Energy. Online: www.eere.energy.gov.



Note: University of Florida energy costs are $0.954 per kwh in 2006.



Note: Emory energy costs are $0.05 per kwh in 2006.

Case Study *Vitals*

The following summarize success criteria for implementing similar projects at other healthcare facilities:

- Efficient windows are defined by the climate of the building in which they will be installed. Engineers and vendors are able to make recommendations based on local climate and building orientation.
- Efficiency improvements to the building envelope directly impact the heating and cooling needs of the building; therefore, HVAC systems should be adjusted accordingly to account for decreased demands on the systems.

Return to:

GreenLink newsletter
Green Corner home page for more success stories