Morrison Residence Hall

National Champions!

Energy Star National Building Competition

Photo by Shannon Wolfe

The Carolina Watt Busters Team

UNC ENERGY MANAGEMENT

Introduction

Energy Conservation has become a core value for the University of North Carolina at Chapel Hill (UNC). With environmental and fiscal pressures rising, more focus must be placed on conserving our energy resources. The University, having recently developed an in house building optimization program, saw an opportunity to learn and compare strategies with others around the country. The first ever EPA National Building Competition promised to be fun, inspiring and informational. The goal was to see just how much energy could be saved by focusing all the resources available from across the campus on one task; to save energy at Morrison Residence Hall.

Morrison is a 218,000 square foot, 10 story building constructed in 1965 and renovated in 2007. It has over 800 beds and uses cooling water, heating steam, and electricity from campus wide distribution systems. The building also uses solar hot water to offset the steam consumption. During the 2007 renovation the heating, ventilating and cooling (HVAC) system was replaced. More efficient windows were installed and the lighting was upgraded.

Morrison is also home to the sustainability themed housing community on campus. Students in this community participate in programs on energy conservation and sustainability.

Four Steps to Success

At the beginning of the competition the stakeholders discussed and agreed on four primary areas of opportunity for energy conservation. These areas included; optimization of the HVAC systems, optimization of the existing solar thermal system, lighting upgrades to portions of the building, and an education and awareness program for building occupants. Small teams were formed for each focus area and progress was reviewed in biweekly meetings. The stakeholders selected a name to rally behind, the Carolina Watt Busters!

Heating, Ventilating, and Air Conditioning Optimization

In July 2008 UNC began a rapid implementation energy conservation project. The goal was to reduce the campus energy consumption by 15 percent in three months using primarily in-house resources. The effort focused on simple measures of optimizing the HVAC systems. The lessons learned through the first six months of this project seeded the work for the Energy Star Building Energy Loss Competition.

Work began with a thorough review of the building, the mechanical plans, and the operational needs and schedules of the occupants. The HVAC systems were operating with no occupancy schedules. There was a constant discharge air temperature from the air handlers and full occupant control of space temperatures.

The initial step was to ensure proper operation of all dampers, valves and other major equipment. Any equipment in disrepair was serviced.

The system has 26 variable volume air handlers with preheat coils, cooling coils, and variable speed fans. The building is controlled with a full direct digital control (DDC) system. Each distinct space has a terminal box capable of varying cool air flow to the zone and also providing heating with a hot water coil.

The system was originally programmed for an airflow turndown of only 40 percent. This meant that over a large part of the year the system was distributing too much cold air to the spaces, since it was unable to reduce airflow to match the true cooling load. The system had to use additional heating water to reheat the air to keep the space temperatures at set point.

The minimum air flow set points were reprogrammed to allow for a 70 percent turndown. This resulted in a much wider range of opportunity to only provide enough cool air to condition the space without the need for reheat.

Care was taken that reductions in airflow did not eliminate code required minimum ventilation air. There was also a practical limit to the equipment's ability to control airflow at low flows that could not be exceeded. Lastly, the ventilation air and exhaust air had to be balanced to provide positive pressurization of the building. Without this, the building would "suck in" unwanted outside air through building cracks, doors, and other penetrations to the exterior walls.

The air handlers were originally programmed to supply 55 degree air, a common industry practice in this climate to prevent excess humidity in the summer. This supply air temperature is only needed in the peak of the cooling season or on very humid days. The control logic, therefore, was rewritten to allow the air handler supply temperature to vary from 58 degrees to 70 degrees depending upon the need for cooling from each of the zones. The objective is to supply air that is cooled only as much as is needed. This strategy will cause high humidity in the buildings at certain times of the year. Monitoring the building humidity disables this control strategy and drives the supply air temperature down to 55 degrees when the return humidity exceeds 55 percent.

This supply temperature reset strategy also meant that outside air could be used without mechanical cooling to condition the building. The strategy of using more outside air to condition a space is called economizing. By enabling the economizer to provide more outside air when the outside temperatures were up to 70 degrees proved to be another successful strategy. The building economizer control was previously set to operate when temperatures were 55 degrees or colder. In North Carolina there are more than 1600 hours per year where the outside air temperature is dry enough and between 55 degrees and 70 degrees to utilize for economizer operation.

In the next step of the process the room thermostats were programmed to control between 70 degrees and 75 degrees. The system "does nothing" when the space temperatures are between these set points. The airflow increases when the space temperature exceeds 75 degrees and the airflow decreases to the new minimum when temperatures drop below 70 degrees. If the temperature drops further then the heating hot water system provides reheat to keep the spaces at 70 degrees. The space cooling and heating loads do not vary dramatically day to day but will vary throughout the seasons.

Lastly, occupancy scheduling provided a greater range of allowable space temperatures during periods when zones were unoccupied for periods of a week or more. The air handlers and exhaust fans continued to run to maintain building pressurization. There were no periods when the entire building was unoccupied; instead certain floors were unoccupied throughout the contest period.

Typically, buildings at UNC have their HVAC system connected to a central monitoring system. Building operators use this system to continuously monitor building performance to identify problems with the building HVAC system. Additionally a 'front end' or user interface is normally provided that shows a graphical representation of each HVAC system. At Morrison this front-end system is not installed. For this reason reprogramming the system and resetting the occupancy schedules was not possible through a convenient user interface. This resulted in significant additional effort to manually reconfigure each zone to unoccupied.

Solar Thermal Optimization

The solar thermal system consists of 172 solar panels on the roof, a heat exchanger package, and a buried 6,000 gallon thermal energy storage tank. The panels are installed on the roof as four sets, one on each wing of the X shaped building Two sets face south southeast and the other two face west southwest. The original installation supplied hot water for domestic water use only. Several problems with this system had to be overcome before it could contribute any energy savings to the building.

Differences in panel orientation result in two peak collection times. The glycol working fluid runs through all the panels when the system is operating. Because of the panel orientation and the lack of valves to isolate flow to panels, there are times when half of the panels do not collect energy but in fact radiate it back to the atmosphere.

Additionally the generation capability of the system is not well matched to the heating demand of the building. Particularly during the summer when occupancy is approximately 50 percent, there is little demand for both domestic and reheat hot water.

The heat exchanger for the building to heat the domestic water is a constant rise design, which means there is no allowance for the solar thermal energy to preheat the water entering the heat exchanger. One of the first changes made was to allow the system to be switched over to augment the heating water in times of low domestic hot water demand. During times when the reheat is needed this is a good solution but when more energy is collected than necessary it can lead to simultaneous heating and cooling as the building systems are used to discharge collected heat. In some situations the solar collection system had to be shutdown to prevent overheating.

The solar thermal storage tank was designed for atmospheric pressure but a pressure relief valve was installed when the piping was connected to the tank thereby pressurizing the tank.

This led to a failure of the construction joints on both ends of the tank. The tank was repaired and the relief valve was removed to depressurize the tank.

Controls are not yet automated for changing from domestic water load to building heating load. Consequently through the competition period these changes were made manually. Future modifications to the system will consider more fully controlling the panels' collection to match the load and to better integrate with the HVAC and plumbing systems.

The energy avoidance for the system is approximately 327.8 million Btus per year. This displaces carbon-based steam energy that would otherwise be used.

Lighting Upgrades

As part of the EPA competition the lighting in Morrison Residence Hall was reviewed for opportunities to save energy. The building was recently renovated and all of the existing fluorescent fixtures in student rooms and common spaces were upgraded to T8 lamps and electronic ballasts. Two areas that offered some possibilities for energy savings were the main lobby/study area and the balcony lights.

One wing of the lobby is used for studying and small group meetings. This area has chairs and sofas and associated tables to allow using laptop computers. The whole area was lit by 50 watt halogen MR-16 miniature spotlights. Some of these were on a track, some in pendants, and some were installed in recessed ceiling fixtures. Substituting an LED lamp for a 50 watt halogen lamp is close to the limits of technology right now. This area was designed for low light levels, but an attempt to try LED lamps in this room several years ago was met with complaints that light levels were too low for computer use. Over the past two years the efficacy of LED lamps has improved markedly so another attempt was made. Forty-two 6 watt MR-16 lamps were retrofitted in the lobby.

This photograph shows the space after the installation of the LEDs. The lighting levels were similar to the levels with the halogen lamps, and there were no complaints about light levels. Since these lights remain on 24/7 there was significant opportunity for energy savings. As shown below the payback is less than one year.

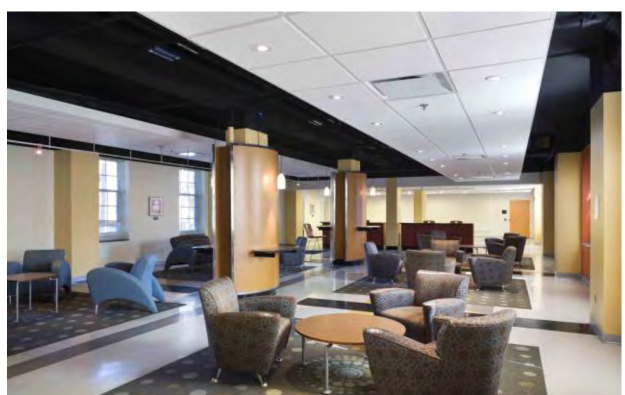


Photo by Warren Jochem

Lobby LED Lighting (1st yr analysis)								
QTY	**Watts**	**Watts/ Fixture**	**Total Watts**	**kWh/Yr**	**/year**	**Difference**	**Cost**	**Savings**
42	50	50	2,100	18,396	$1,104	$0	$0	$0
42	6	6	252	2,208	$132	$971	$840	($131)

The second area audited was the balcony outside the student rooms. As shown in the photo below there are ceiling mounted fixtures outside every suite entrance. When the building was renovated there were two 42 watt compact fluorescent lamps (CFL) installed in each fixture. Two lamps are required in each fixture because these lights are used for emergency egress. The 42 watt CFLs made the balconies extremely bright. The lights were so bright that students complained about the glare and it was even possible to use the outdoor basketball court behind the building at night without ever turning on the court lights.

Photo by Warren Jochem

The solution was to replace the two 42 watt CFLs with two 13 watt CFLs. This required new sockets and new ballasts, but because the fixtures were so new the manufacturer supplied a ballast and socket retrofit kit that was relatively easy to install. Light meter readings at night showed light levels were still adequate to meet the Illuminating Engineering Society of North America (IESNA) levels for emergency egress. All of these fixtures are controlled by a photocell that turns them on when it gets dark. Estimating their use at 50 percent of the time the following annual savings were calculated.

Balcony CFL Lighting (1st yr analysis)								
QTY	**Watts**	**Watts/ Fixture**	**Total Watts**	**kWh/Yr**	**$/year**	**Difference**	**Cost**	**Savings**
200	42	93	18,600	81,468	$4,888	$0	$0	$0
200	13	30	6,000	26,280	$1,577	$3,311	$8,130	($4,819)

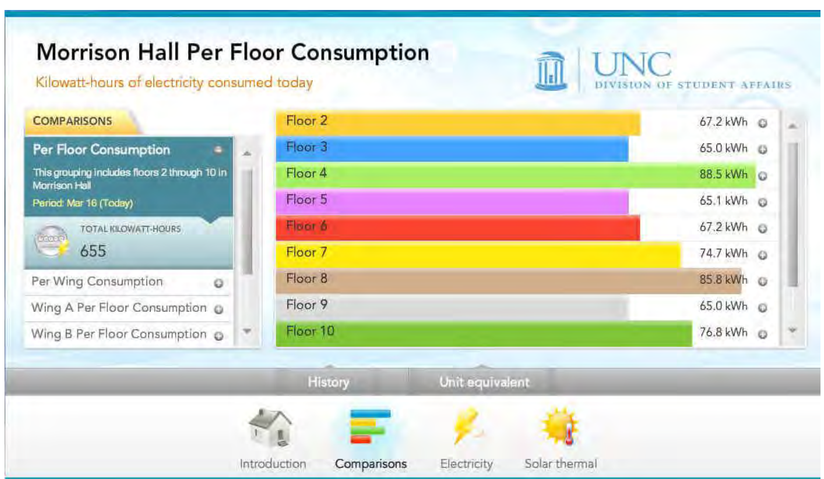
Because of the higher initial cost of the 13 watt lamps and ballasts the simple payback is closer to 2.5 years.

Occupant Education and Awareness

In addition to making changes to improve lighting and other building systems, the Carolina Watt Busters recognized the critical role people play in driving down energy use. From educating occupants to turn off lights and enable power management features on laptops to engaging and rewarding staff for finding new opportunities to save energy, small changes can make a big impact.

Photo by Jessica Knight O'Hara

Effective communication is the key to engaging occupants, and the Carolina team spread the word in a variety of ways. Since the competition took place during the summer and Morrison was to have camp students in and out of the building weekly, laminated flyers were designed and posted throughout targeted areas in Morrison encouraging students to turn off lights, use cold water to wash clothes, take short showers and other saving tips. Each flier was designed to focus on specific opportunities for the part of the building in which it was posted.



Morrison has a computer touch-screen monitor in the lobby which helped Morrison residents to keep track of energy consumption. The dashboard was installed during the 2007 renovation. The original scope provided information on HVAC and electrical energy use. The team commissioned the energy sub metering. Some of the HVAC meters were not able to read accurately as the energy use dropped, due to conservation efforts, below their design operating range. In response to HVAC metering problems, the dashboard was reconfigured to only display electrical energy to each zone. Building occupants have the greatest impact on electrical consumption.

Competitions were also held between the floors in the dorm to see who could save the most energy.

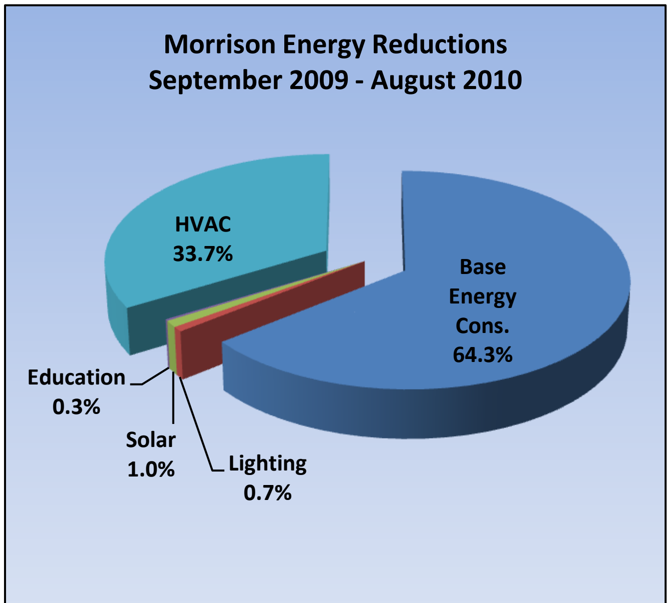
Project Cost and Funding

The total cost for the efforts outlined above was less than $35,000. This included educational materials, lighting upgrades, and building control system contractor assistance.

The funding was provided by the [Renewable Energy Special Projects Committee (RESPC).](#) RESPC is a student committee that manages the money created by the Student Renewable Energy Fee. The fee of $4 per student per semester provides more than $200,000 per year for renewable energy, energy efficiency, and energy education projects at UNC.

Conclusions

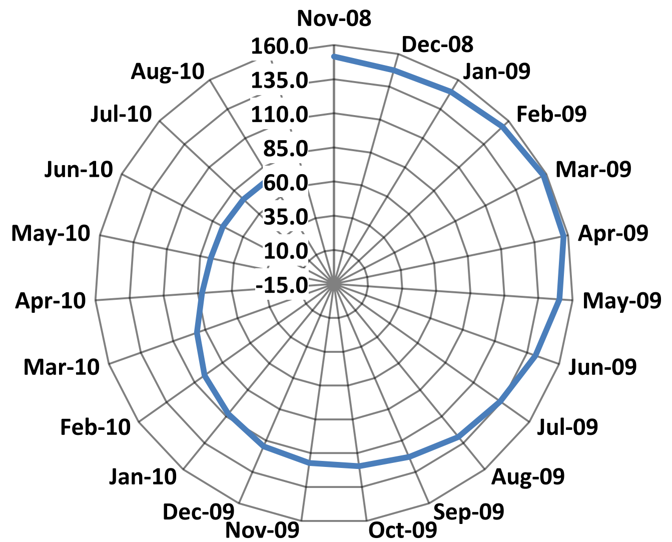
These efforts combined for over 35 percent in reduced energy consumption. All four initiatives saved energy with HVAC leading by contributing 33.7 percent of the savings, followed by solar thermal at 1.0 percent, then lighting upgrades at 0.7 percent, and then and finally Education and Awareness is estimated at 0.3 percent.



This chart shows the energy consumption for the contest year and the estimated contribution of each of the four focus areas. The total energy reduction was over 35%.

The success of Morrison required a paradigm shift from traditional approaches to energy conservation. Typically building audits are used to identify equipment enhancements or new technology. These opportunities require capital investment and time to plan, design, construct and commission a project. The excitement and short duration of the competition meant a new approach was needed for success. Time and funding resources were not in favor of an extended renovation of the energy systems. This competition demonstrates significant savings can be obtained using primarily internal resources. The subsequent success of the project led to buy-in by the HVAC staff. Without their buy-in sustainable isn't part of energy conservation.

Great success can be achieved with enthusiasm, dedication and teamwork. As managers we can help by allowing quality people to use their experience in a streamlined building tuning approach. Planning and analysis is necessary to a point, but action creates experience and experience creates expertise.



This chart shows the Energy Use Intensity (EUI) for Morrison Residence Hall since November 2008. The contest period started in September 2009. Note the rapid decline in energy intensity starting in April 2009 when work began, prior to the contest period.

<u>Team members</u>

Team Lead – Chris M Martin Jr, PE

HVAC – Todd Freeman and Jim McAdam, PE

Solar Thermal – Doug Mullen, PE and Jim Pike

Lighting Upgrades – Warren Jochem, PE

Education – Josh Alexander and Jessica O'Hara

Stakeholders - Housing and Residential Education: Steve Lofgren, PE, and Housing Support: Bob Humphreys, PE.

Funding – UNC Renewable Energy Special Projects Committee

Learn more about the competition at http://www.unc.edu/campus-updates/CCM3_022144.

Learn more about energy conservation at UNC at www.save-energy.unc.edu.