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UNIVERSITY OF NORTH CAROLINA'S HILLSBOROUGH HOSPITAL

STRATEGIES TO ACHIEVE 30% ENERGY SAVINGS OVER AND ABOVE ASHRAE 90.1

NELSON R. LONG PE, LEED® AP
AFFILIATED ENGINEERS, INC.

RICH HUBACKER, LEED® AP
ZGF ARCHITECTS

PART 1

EXECUTIVE SUMMARY

In 2009, North Carolina General Statute 143 (GS 143) was amended to create The Sustainable Energy-Efficient Buildings Program, which establishes new guidelines for major facility construction and renovation projects of public agencies in North Carolina. Included in these guidelines is the requirement for new construction projects over 20,000 square feet by public agencies to be 30% more energy-efficient than ASHRAE Standard 90.1 2004. As a public agency, UNC Health Care is required to meet these guidelines in their Hillsborough Hospital construction project, which is presently in the design phase.

Affiliated Engineers

This paper addresses the methodology, decision process and steps to achieve these aggressive energy savings requirements. The design process has been highly integrated, with all members of the team – including the Owner and all of the design disciplines – collaborating closely to achieve the new energy mandate.

This paper covers: the architectural, HVAC, plumbing, and lighting systems investigated; each option's estimated first cost; and, the anticipated energy savings associated with each option. The design team has met the following project and design challenges with innovative solutions to achieve the energy efficiency standards set forth by GS 143:

- Specific air change rates, filtration and room pressurizations required by NC Hospital Licensure Rules, ASHRAE Applications Handbook Chapter 7 and ASHRAE Standard 170;
- Increased comprehensive project deliverables and subsequent coordination and early planning efforts;
- Lack of active chilled beam installations in the United States in in-patient areas;
- A finite construction budget.

The project team has followed an integrated design approach with detailed analysis throughout the process. Every design decision has been critically assessed to determine what effect it may have on other building systems in the hospital. For example, the increased first cost for a more efficient lighting system is offset by reduced cost for the HVAC system. All design decisions have been made with the creative understanding of the synergies possible across building systems.

Concluding this white paper, we present a cost/energy savings matrix illustrating the potential energy saving percentage for each initiative relative to the total and the associated first cost impact of each item. This will be a complex set of options. Given the integrated nature of the design process, each option affects other options; resultant performance and energy savings relative to first cost are therefore difficult to project definitively.

PART 2
ALL ABOUT THE NEW NC SUSTAINABLE ENERGY-EFFICIENT BUILDINGS PROGRAM - GENERAL STATUTE 143

Opportunities for sustainable design innovation in the State of North Carolina have never been more promising, or more demanding. The Sustainable Energy-Efficient Buildings Program, established by GS 143, mandates requirements for energy-efficiency and water-conservation for major facility construction and renovation projects of public agencies in North Carolina. Included in these guidelines is the requirement for new construction projects over 20,000 square feet by public agencies to be 30% more energy-efficient than ASHRAE Standard 90.1 2004. This includes projects for the UNC System (16 campuses), Community College System (58 campuses), and the Department of Health and Human Services.

With more strenuous energy goals also comes a third-party commissioning agent requirement. Commissioning must start in schematic design or earlier, and run through initial building operation. Additionally, metering / sub metering is required for electricity, natural gas, fuel oil, and water to allow for post occupancy energy and water reporting. The 12-month reporting period assures that buildings are meeting the conservation measures. If discrepancies exist between actual usage and the targeted energy consumption, causes must be identified and plans for corrective action outlined by the owner.

Project deliverables are more expansive under the new law, which necessitates exhaustive coordination between disciplines and a more integrated approach during the advanced planning (programming) phase. Energy models need to be developed with approved software during SD, DD, and the CD phases. In addition to the base building model, which is a hypothetical code compliant building, GS 143 requires two options for architectural, lighting, HVAC and domestic hot water.

Both options must demonstrate the energy and water reduction goals, with the lowest life cycle cost being the determinant. And, unlike the LEED process, the energy-efficiency requirements of GS 143 is based on energy used (BTUs) not the cost of energy. The project team must drive major decision-making early in the process in order to meet the energy conservation strategies.

PART 3
PROJECT DESCRIPTION

The UNC Health Care System is a not-for-profit integrated health care system, owned by the State of North Carolina and based in Chapel Hill.

A distinguishing characteristic of UNC Health Care is its association with the UNC-Chapel Hill School of Medicine, a nationally recognized research institution. This relationship gives UNC Health Care a powerful pathway for moving the results of biomedical research from medical school laboratories to patient care settings. The UNC Hospitals (UNCH), located on the University's Chapel Hill campus is a 757-bed facility servicing more than 36,000 patients each year.

The establishment of the new Hillsborough Hospital and Clinic Building on a new 58-acre satellite campus in northern Orange County, North Carolina marks unchartered territory for UNC Health Care. The decision to develop a satellite hospital, separate from the UNCH main campus, is an acknowledgement that expansion space on the main campus has become extremely limited. The new campus is also intended to relieve pressure and congestion on the main campus and to better serve the growing population of the surrounding area.

The new greenfield site facilities will include a 241,000 square foot Hospital, a 60,000 square foot Clinic Building, and a 10,000 square foot Central Utility Plant (CUP). The hospital will include 68 inpatient beds relocated from the main Chapel Hill hospital and will

THE PLANNED UNC HILLSBOROUGH HOSPITAL SITE

contain new diagnostics and treatment, a surgical suite, outpatient pharmacy, laboratory services, physical and occupational therapy services, and emergency services, including a helicopter pad.

AEI is providing mechanical, electrical, plumbing, fire protection, lighting and information technology design for the hospital, as well as utility infrastructure design for the new CUP. ZGF Architects and their local architectural Partner, BJAC, are providing the full architectural design.

This project marks the first new hospital construction project that is subject to the new energy-efficiency and water-conservation requirements established by GS 143. In addition, UNC Hospitals has a goal of pursuing LEED-NC Gold certification under version 3.0 on this project, with possible participation in the Green Guide for Healthcare initiative.

PART 4

ARCHITECTURAL DESIGN CONSIDERATIONS ENVELOPE CONSTRUCTION

The building is being designed to integrate the surrounding conditions of topology, geology, local materials, and local climate/microclimate. The design considers resource and energy efficiency, healthy buildings, and materials to reduce adverse human impacts on the natural environment, while simultaneously improving quality of life and well being of occupants and the community.

Envelope Design

A well designed, tight envelope is one of the simplest ways to maintain energy efficiency and maintain the expected lifespan of the building. By effectively utilizing the building envelope itself, added heating, cooling, lighting, and other energy intensive systems can be minimized. Where active systems appear to be first-cost prohibitive, the team is looking closely at passive and manual systems and strategies to meet the design and performance goals of the project. The composition of construction elements in the envelope performs functions that can be individually or cumulatively adjusted to respond predictably to environmental variations and to maintain comfort using the least amount of energy.

The team first considered building siting and orientation to reduce reliance on electric lighting and regulating solar heat gain appropriate to diurnal and seasonal cycles. Orienting the building to maximize northern exposure and control southern is the most effective method to achieve good daylighting, though care must be taken to control glare from the east and west low angle sun. A lighting controls system working with the building management system (BMS) can allow for adjustments in electric lights where daylighting is sufficient to perform the tasks required in those spaces. Glazing coatings are becoming more effective and spectrally selective, allowing only visible light and reducing Solar Heat Gain (SHG). Selecting the type of glass and the correct placement on the façade is being carefully considered. Glazing percentages and thermal characteristics of different glazing types are currently being considered and modeled.

Zoning the building rationally can also help define the massing and orientation, and can play an important role in developing a concept for building services and distribution. Another consideration is the selection of heat recovery systems that can affect the distribution strategy.

A growing body of research shows that access to views of the outdoors and nature as an important part of a healing environment. The team is considering glazing, façade treatment, and program organization. Research showing the benefits of natural light has encouraged the design team to look closely at passive strategies that best drive natural light deep into the building.

The integrity of the air and vapor barrier is being carefully detailed and studied in the energy models. Performance testing of the curtain wall, roof penetrations, and flashing details – as well as the use of thermography – will be used to confirm performance assumptions. The thermal transfer properties of the opaque areas of the façades and roofs will be tested and adjusted where appropriate. Additional R -value here does not necessarily translate into improved energy performance.

PART 5
MECHANICAL SYSTEMS

Energy efficiency in the mechanical system is challenged by the required air change rates and space pressurization requirements as prescribed in ASHRAE Chapter 7 of the Application Handbook and ASHRAE Standard 170. This prohibits the use of variable air volume systems, which is the basis of design for the ASHRAE 90.1 model. ASHRAE 90.1 allows the Base Model to be modified to comply with codes or standards required for the building type. In this case, the design team modeled both the Base and the Proposed Buildings to comply with ASHRAE Standard 170 for space pressurization, room temperatures, supply and outside air change rates. By comparing both the Base and Proposed building models, we neither benefit from nor are penalized by the prescribed air change rates.

The HVAC energy-saving measures being considered for the new UNC Hillsborough Hospital include the following:

- Enthalpy wheels
- Terminal unit tracking for occupied/unoccupied areas
- Heat recovery chiller
- Condensing Boilers
- Domestic Hot Water Heating Boiler
- Variable Primary Pumping
- Chilled Water Fan Coil Units (FCU's) in Telecom and Electrical Rooms
- Active Chilled Beams

Enthalpy Wheels
Enthalpy wheels will be utilized to pre-cool/pre-heat the outside air of the air handling units. Enthalpy wheels are approximately 60 to 70 percent efficient. By also treating the latent component of the outside air stream, energy savings can be significantly increased compared to a sensible-only heat recovery device such as a glycol run-around loop or plate heat exchanger. Risk of cross-contamination is minimized by the wheel's purge to almost insignificant levels.

Terminal Unit Tracking
For areas that have a set operating schedule, such as Operating Rooms (OR's), the team is designing tracking air terminal units. Tracking air terminals units allow us to decrease the supply airflow in un-occupied spaces to a minimal ACH and still maintain space pressure relationships. An example is the operating rooms. The new facility will have 12 operating rooms and 2 procedure rooms. During unoccupied hours, the hospital will only keep four OR's operational. This allows us to decrease our space airflow from the required 20 ACH to a minimum; in our case we are using 4 ACH since the terminal units lose accuracy below a minimum percentage.

ASHRAE 90.1 requires that scheduled values must be identical between the Base model and the proposed model; therefore we cannot take any credit towards our energy savings.

Heat Recovery Chiller
The Main Distribution Frame (MDF) and Intermediate Distribution Frame (IDF) rooms through the hospital require year-round cooling. In order to accommodate this, we plan on providing a heat recovery chiller sized to satisfy the year-round cooling loads. Compared to the Central Utility Plant's (CUP) centrifugal chillers, the heat recovery chillers are inefficient at approximately 1.1 KW/Ton. However, due to the condenser heat rejection tied into the building heat/reheat system, we are getting free heat that more than offsets the cooling inefficiency. An added benefit is that the large main centrifugal chillers are also able to be shut-down in the winter months to save energy and allow for unit maintenance.

Condensing Boilers
ASHRAE 90.1 requires boiler efficiency of 80 percent.

We are designing our boiler plant around condensing boilers at 90 percent efficiency. A disadvantage of the smaller capacity is the need for more boilers; however this minimizes our required redundant boiler size making the overall connected Boiler Horsepower smaller.

Domestic Hot Water Heating Boilers
Compared to the 80 percent domestic hot water heating boilers, boilers are now available up to 97 percent efficiency. This is a direct energy savings and became the second most efficient strategy for this project.

Variable Primary Pumping
Because this option has a less first cost due to fewer pumps and less piping, any energy savings is essentially free and will payback immediately.

Chilled Water Fan Coil Units (FCU's) in Telecom and Electrical Rooms
ASHRAE 90.1 base model requires DX units to serve telecom and electrical rooms. Our proposed design is to replace the units with Computer Room Air Conditioners (CRAC's) supplied by the building chilled water system which is inherently more efficient then DX systems. Care must be taken to avoid running piping over telecom equipment or electrical panels.

Active Chilled Beams
Active Chilled beams allow the sensible and latent space loads to be de-coupled. Unlike a traditional constant volume reheat system in a hospital in which all of the air supplied to a space must be cooled/dehumidified then reheated to maintain space temperature, in an active chilled beam system the ventilation air is cooled/dehumidified and reheated to a neutral temperature. The space sensible load is handled with the cooling and heating coils that are part of the active chilled beam system.

Active chilled beams have been implemented extensively in Europe. However, to date we have not found any hospitals with active chilled beams installed in in-patient areas.

Active chilled beams were modeled in Patient Rooms, Exam/Treatment Rooms and administrative areas. Active Chilled beams were not modeled in Operating Rooms or Post Anesthesia Care Unit. Because of future possible renovation or modifications in the main part of the hospital, we modeled active chilled beams in the Bed Tower only, since the specific requirements of the patient rooms will most likely not change the use of this wing. This will allow approximately 30 percent of the hospital to be conditioned using active chilled beams.

By de-coupling the sensible and latent loads for a space, we can take full advantage of increased envelope construction and decreases in space heat gains, such as more efficient lighting. An "all air" system cannot take advantage of these efficiencies because the supply air must be cooled/dehumidified and reheated to satisfy comfort conditions and also supplied in a sufficient quantity to maintain the required air change rate as you would see in patient rooms at 6 Air Changes per Hour (ACH).

PART 6
ELECTRICAL SYSTEMS

Energy efficiency in the electrical system is best utilized through the use of carefully selected lighting controls and lighting power efficiency. Other areas where energy can be saved include the use of more efficient step-down, dry type transformers. Most large hospital energy loads come from the HVAC system and imaging equipment. The HVAC system is made more efficient through the use of variable frequency drives (VFD) on the motors and control systems. Imaging equipment uses short, high blasts of power that can be difficult to regulate and control.

The Electrical energy-saving measures being considered for the new UNC Hillsborough Hospital are the following:

- T-8, 28 watt lamps for the majority of fluorescent luminaries
- LED type lighting for the exterior areas

- Lighting controls including daylight harvesting
- Highly efficient step-down transformers

T-8, 28 watt lamps
This lamp type was selected over traditional T-8, 32 watt lamps based on a life cycle cost analysis that also compared T-5 and T-5 HO lamps. The T-8, 28 watt lamp and ballast combination offered a 22% energy savings over the baseline of ASHRAE 90.1. It also will provide a sufficient amount of light and the lowest life cycle cost. T-8, 25 watt lamps offer more energy savings but the lighting quality suffers and more light fixtures are required, adding more energy consumption and higher costs.

LED type lighting for exterior areas
Rather than use traditional metal-halide or high-pressure sodium light fixtures, the hospital will use LED lights. The expected energy savings is 50% for the same level of light output. The cost of these fixtures has decreased as a result of more widespread manufacturer production. The life cycle cost of LED fixtures is very low due to the long lamp life, which is projected at 70,000 hours.

Lighting controls
AEI is designing a wide variety of lighting controls for the hospital, all of which will significantly contribute to overall energy efficiency. Daylight harvesting will be incorporated in large areas with windows. Photo sensors will evaluate how much natural light is in each room and lights will dim or turn up as needed to meet the IES recommended levels. Occupancy sensors will control the lights in non critical areas, such as offices, storage rooms, and restrooms, which can be unoccupied for long periods of time. Areas such as electrical, mechanical and IT rooms will have timer switches that will turn off automatically after a certain length of time. These are deemed more reliable due to the amount of piping and cables that might block occupancy sensor coverage. Dimming ballasts will be added to the patient corridors so they can be turned down at night for increased energy efficiency, and the added benefit of maintaining patient diurnal cycles.

Highly efficient step-down transformers
Dry type transformers step down the 480 volt to 120/208 volt. These transformers use energy regardless of load. This energy becomes heat which then needs to be cooled thereby using even more energy. Using more efficient transformers reduces the "no-load" losses and has a positive impact on the building HVAC system as well. Although beneficial, we are too early in the design process to determine the potential savings of the high efficiency transformers.

PART 7
PROBLEMS AND COMPLICATIONS SCHEDULE COMPLICATED BY ENERGY MODELING REQUIREMENT.

The energy modeling required by General Statute 143 requires that a number of decisions be made early in order to accurately calculate the proposed energy savings. Items such as wall and roof construction, window and skylight selections had to be made early in Schematic Design. Exterior elevations needed to be completed prior to modeling the building. Building layouts and room arrangements, sizes, and so on, also needed to be finalized early as a room-by-room energy model was required to accurately calculate the cooling and heating affects of the required supply and outside air change rates, internal loads, and envelope contributions. The energy model was time and labor-intensive; sufficient time had to be allotted to the mechanical engineer to accurately model the building. Even minor changes to the architectural floor plan, wall or roof construction caused unfortunate set-backs to the mechanical engineer's energy model. To date, the energy model effort has taken more than 300 man-hours, each run requiring approximately three hours to complete requiring the use of a dedicated computer.

PART 8
CONCLUSIONS

In order to isolate each component's contribution to the overall building efficiency, we built the energy model with all of the items that showed an energy savings. We then ran alternates subtracting each component from the model individually. This important albeit time intensive process allowed us to isolate the total energy savings contribution made by each component. It is worth noting that the new statute excludes the receptacle and process load from the energy savings calculation as this is outside of the control of the design team.

paying an efficiency penalty in cooling of the telecommunications rooms but getting free heat which is helping to offset the required reheat due to the prescribed air change rates. The rest of the mechanical savings are modest and range from half a percent up to just under 6.0 percent for the high efficiency domestic hot water boilers.

ENERGY SAVINGS	BUILDING CONSUMPTION (10-6 BTU/YR)	TOTAL ENERGY SAVINGS (10-6 BTU/YR)	PERCENT SAVED (%)	ENERGY COST PER YEAR ($/YR)	SAVINGS PER YEAR ($/YR)
BASE LINE (90.1)	66,849.6			$1,079,767	
PROPOSED (ALL AIR SYSTEM)	43,827.6	23,022.00	34.44	$904,826	$174,941

The proposed building is an "all air" system, Variable Air Volume (VAV) tracking with reheat down to the prescribed minimum air change rate as listed in ASHRAE Standard 170; i.e. 6 ACH for a patient room. Currently we are at 34 percent energy savings, just above the state mandated amount.

Individual component contributions to the overall energy savings of the building are summarized as follows:

Architectural

Due to the required air change rates, the architectural enhancements have no net effect on the overall building efficiency and may actually make the building slightly less efficient. This is due to the reheat necessary to maintain a comfortable space temperature. The less efficient building envelope would in essence give us free reheat throughout the year, while the proposed building at present has to make-up reheat.

Mechanical

The largest savings in the mechanical system proved to be the heat recovery chiller. As stated earlier, we are

Lighting

The prescribed lighting levels listed in ASHRAE 90.1 are already very efficient and difficult to beat. Therefore, we are only showing a 3/4 percent energy savings above and beyond ASHRAE.

Active Chilled Beams

A final energy model was performed with active chilled beams in patient rooms, exam/treatment rooms, offices, etc. The model shows we are at approximately a 36 percent energy savings over the Base 90.1 model with the inclusion of active chilled beams. This is due to moving the required air change rate from the HVAC system to the room, thereby eliminating the need for reheat in the space. Pump energy was increased but will be more than offset by less fan energy.

Due to the possibility of future space changes and modifications in the main portion of the hospital, the Diagnostic and Treatment block, active chilled beams were only considered and modeled in the patient bed tower. Due to the configuration of this wing, occupancy use changes from patient rooms are very unlikely.

COMPONENT ENERGY SAVINGS	COMPONENT ENERGY SAVINGS (10-6 BTU/YR)	COMPONENT SAVINGS (%)	COMPONENT SAVINGS PER YEAR ($/YR)	COMPONENT FIRST COST INCREASE ($)	SIMPLE PAYBACK (YEARS)
ARCHITECTURAL					
ROOF	58.4	0.09	$467		
WALLS	66.5	0.10	$560		
GLASS	11.8	0.02	-$611		
WINDOW SHADING	-136.3	-0.20	-$379		
MECHANICAL					
HEAT RECOVERY CHILLER	13,471.9	20.15	$71,688	$104,000	1.45
CONDENSING BOILERS	216.3	0.32	$1,353	$11,000	8.13
AIR SIDE ECONOMIZER	1,336.1	2.00	$23,916	$9,000	0.38
VARIABLE PRIMARY PUMPING	1,312.4	1.96	$23,916	INCLUDED	IMMEDIATE
DOMESTIC H.W. BOILER	3,918.8	5.86	$24,508	$62,000	2.53
CHILLED WATER FCU'S INTELECOM & ELECTRICAL	252.2	0.38	$6,305	INCLUDED	IMMEDIATE
ELECTRICAL					
LIGHTING	501.2	0.75	$13,464	$90,000	6.68

ENERGY SAVINGS	BUILDING CONSUMPTION (10-6 BTU/YR)	TOTAL ENERGY SAVINGS (10-6 BTU/YR)	PERCENT SAVED (%)	ENERGY COST PER YEAR ($/YR)	SAVINGS PER YEAR ($/YR)
BASE LINE (90.1)	66,849.6			$1,079,767	
ACTIVE CHILLED BEAMS	42,549.3	24,300.30	36.35	$896,483	$183,284

"All air" systems: Are common in most hospitals, are inherently inefficient and, due to the prescribed air changes rates as listed in ASHRAE Standard 170, off-set any architectural envelope enhancements. This is due to the HVAC system being in reheat mode nearly year round. Systems that can decouple the room's sensible load from the main HVAC system such as active chilled beams or 4-pipe Fan Coil Units can take advantage of architectural enhancements to help create a very efficient building by avoiding the required reheat to maintain space comfort conditions typical of an "all air" system.

We found that the new energy-efficiency requirements of North Carolina General Statute 143 required some adjustments to the more typical project design delivery:

- **A truly integrated design approach**
  This methodology was driven by first principles that "pushed" the design process toward solutions that responded to the unique issues of the design program, the bioclimate and the client's strategic objectives. This is in contrast to LEED certification's tendency to "pull" the design process toward measures that achieve points. It required a large number of full team meetings and discussions about systems, strategies and components that could meet the program and the energy/water conservation requirements.

- **Team education**
  The new energy-efficiency requirements of GS 143 compelled the owner and design team to consider and evaluate technologies that are not typically installed in other UNC Hospitals buildings, including enthalpy wheels, active chilled beams, reduced wattage lighting fixtures and LED lights.

- **Early modeling**
  Block loads in Schematic Design and room by room models in Design Development were required to confirm the actual overall energy savings as well as savings by each individual design option. This effort was imperative to making early decisions and provided empirical data which helped drive the project development.

- **Empirical data support**
  The results obtained by running the energy models with accurate utility rate information, simplified decision making by the owner and the design team and helped maximize the capital project expenditure and optimize the energy efficiency on the project.

- **Front loaded design and decision making**
  Composition and details regarding orientation, massing, wall and roof construction, fenestration and shading were required to be made early enough to allow time to model the different energy performance aspects of each component. The modeling became a very time intensive activity, the magnitude of which in all honesty was not anticipated at the onset of the project.

- **Time will tell**
  Part of the new statute requires that the systems be carefully tracked and that confirmation of the energy savings are documented and reported after twelve months of occupancy. With a thorough, high quality commissioning effort, the inclusion of metering and sub-metering and on-going systems trending on the project, we are confident that UNC Hospitals' new Hillsborough facility and the state of North Carolina will reap the rewards of a successful, safe and highly efficient facility with reduced energy consumption and ultimately lower cost to operate.