UNC Building Performance
Analysis of Energy Efficiency and Occupant Comfort in UNC Campus Buildings

Full report for Environmental Capstone Spring 2014

Caleb Cates, Katelyn Costa, Lila Fleishman, Andrew Flinchum, Jamie Linden, Sarah Lowder, Shane Shields, Michael Titus, Rachel Tove-White
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ENST/ENVR 698—Environmental Capstone Spring 2014
Executive Summary

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Introduction and background
This study seeks to analyze the current performance of UNC campus buildings through an energy and comfort analysis of nine sample buildings, as well as assess possible areas for future improvement. Specifically, the project aims to determine whether various qualities such as age, renovations, use type, HVAC systems, or high performance standards have an effect on overall energy efficiency and occupant comfort. Furthermore, the study is intended to reveal areas in which the client, UNC Energy Management, can improve data collection methods to ensure more comprehensive and accurate future analyses.

Methods
The project began with background research on similar studies involving energy performance analysis across various building use types. Nine buildings were then selected across three categories of use: classroom/administrative, residence halls, and laboratories. Within each category an old, new/renovated, and “high-performer” was chosen. Energy data on each building was then collected through utility bills and their energy use intensities (EUIs) were found using Energy Star Portfolio Manager. Energy data was supplemented with temperature readings, occupant comfort surveys, and building head interviews.
Findings
This analysis found that the LEED buildings consumed less energy than the other buildings in their use categories, but had lower occupant comfort. Morrison was the only “high-performer” to be outpaced in its use category in terms of energy efficiency. While the labs consumed more energy overall, Genetic Medicine consumed as much energy as the other eight buildings combined. Occupant comfort was generally high, with an average rating of 3.09 out of 4. Genetic Medicine had the lowest comfort rating at an average of 2.48. Overall, we found a slight trend with more energy efficient buildings having higher occupant comfort.

Recommendations

Classrooms/Administrative
- Focus more attention on occupant comfort

Residential Halls
- Further investigate why Ehringhaus is so efficient

Laboratories
- Prioritize energy efficiency during the design and planning phase for future lab buildings, and pursue LEED standards
- Address poor occupant comfort in all lab buildings
- Address poor overall performance in Genetic Medicine Building
- Address awareness of energy with occupants and promote a culture of conservation

General
- Streamline future data collection
- Ensure that energy data is available for every building

Acknowledgements
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We would also like to thank Chris Martin and Jessica O’Hara of UNC Energy Management, as well as many other members of the campus community who provided direction, insight, and information throughout the completion of this project.

Additional Elements:
This paper also includes floor plans with temperature measurements labeled in the areas corresponding to where they were taken, the comfort survey designed and distributed by this team, and white papers summarizing information collected for each building studied. These can be found in Appendix A, B, and C respectively.
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# I. List of Abbreviations

The following table describes abbreviations and short-hands commonly used throughout this report. They are divided up by category.

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<thead>
<tr>
<th>Abbreviation/Short-Hand</th>
<th>Meaning</th>
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<tbody>
<tr>
<td><strong>Building Use</strong></td>
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<tr>
<td>C/A</td>
<td>Classroom/Administrative</td>
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<tr>
<td>Labs</td>
<td>Laboratories</td>
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<tr>
<td>Dorms</td>
<td>Residence Halls</td>
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<tr>
<td><strong>Building Name</strong></td>
<td></td>
</tr>
<tr>
<td>Botanical</td>
<td>NC Botanical Gardens Education Center</td>
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<td>Carmichael</td>
<td>Carmichael Residence Hall</td>
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<tr>
<td>Ehringhaus</td>
<td>Ehringhaus Residence Hall</td>
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<td>FedEx</td>
<td>FedEx Global Education Center</td>
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<td>Genetics</td>
<td>Genetic Medicine Building</td>
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<tr>
<td>Genome</td>
<td>Genome Sciences Building</td>
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<tr>
<td>Knapp-Sanders</td>
<td>Knapp-Sanders School of Government</td>
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<tr>
<td>Morrison</td>
<td>Morrison Residence Hall</td>
</tr>
<tr>
<td>Venable/Murray</td>
<td>Venable and Murray Halls</td>
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<tr>
<td><strong>Other</strong></td>
<td></td>
</tr>
<tr>
<td>BTU</td>
<td>British Thermal Units</td>
</tr>
<tr>
<td>EUI</td>
<td>Energy Use Intensity</td>
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<tr>
<td>HVAC</td>
<td>Heating, Ventilation, and Air Conditioning</td>
</tr>
<tr>
<td>kWh</td>
<td>Kilowatt Hours</td>
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<tr>
<td>LEED</td>
<td>Leadership in Energy and Environmental Design</td>
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<td>USGBC</td>
<td>United States Green Building Council</td>
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II. Introduction

UNC Chapel Hill consists of many buildings with varying ages, renovations, HVAC systems, and other properties that could affect energy use. In addition, some newer buildings are LEED certified and several others have been built to LEED standards. However, the university has not conducted a follow-up study to determine how the performance of LEED buildings on campus compares to other university buildings. The purpose of our study is to compare the energy use of nine campus buildings to understand whether energy performance improves with newer and high performance buildings. We will also compare their performance to buildings across the nation through the use of Energy Star Portfolio Manager. Our goal is to help UNC’s Energy Management Department understand the actual energy use of campus buildings and assess possible areas for improvement. In this way, we hope to help identify strengths and weaknesses in energy efficiency strategies for future construction or renovation projects.

Our information will serve four purposes:
1. Understand performance of buildings to reveal where UNC Energy Management can improve upon energy efficiency.
2. Discover whether “high performers” are outpacing other buildings to help UNC Energy Management assess which energy saving strategies work and which are less productive.
3. Find areas where UNC can better integrate energy efficiency and occupant comfort.
4. Determine where UNC Energy Management can improve in data collection to ensure more complete future analyses.

To assess energy use, we have selected a sample of three buildings from three categories: classroom/administrative, residence halls, and laboratories for a total of nine buildings. In each category, the three buildings consist of an older building, a newer or significantly renovated one, and one recognized for its energy-efficient performance. This range of sampling will help to control for differences in building use when comparing energy efficiencies. For instance, we anticipate that labs will consume a larger amount of energy than classroom/administrative or residence halls. Therefore, we will compare labs mainly to other labs. Additionally, within each category we aim to compare differences between buildings considered “high performers,” such as LEED buildings, and those not accredited for high performance to determine the practicality of the labels.

Our nine selected buildings are as follows (* indicates LEED-certified):

<table>
<thead>
<tr>
<th>Category</th>
<th>Classroom/Administrative</th>
<th>Residence Hall</th>
<th>Laboratory</th>
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<tbody>
<tr>
<td>Older</td>
<td>Knapp-Sanders School of Government</td>
<td>Ehringhaus Residence Hall</td>
<td>Genetic Medicine Building</td>
</tr>
<tr>
<td>Newer/Renovated</td>
<td>FedEx Global Education Center</td>
<td>Carmichael Residence Hall</td>
<td>Venable/Murray Halls</td>
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</table>
III. Background

1. Similarly Conducted Studies:
In 2013, Diana Y. Zheng of the University of California at Berkeley conducted an analysis of the actual energy performance of LEED campus buildings. Zheng compared post-occupancy energy use in Berkeley’s LEED buildings to conventional buildings of similar types. Additionally, she compared actual building energy consumption to the proposed LEED energy model. Zheng’s approach involved comparing buildings across types of use. Using energy use intensity (EUI) data compiled from monthly utility bills, she compared the power consumption across campus buildings, drawing comparisons across months and previous years. Zheng also factored in year of construction, renovations, and improvements made to the LEED sites. Zheng also carried out interviews with building occupants to access their behavior and level of comfort within these buildings. In her discussion, Zheng concluded that, overall, LEED buildings were performing at or better than projected in two out of three cases, demonstrating moderate support for the energy savings of LEED buildings.¹

Zheng’s findings demonstrate that while some LEED buildings reduce energy use, follow-up studies are needed to determine if buildings are meeting expectations. Drawing on some of the findings from these previous studies, we hope our analysis will further the research on LEED and building energy efficiency. Zheng’s study was also instrumental in our decision to select buildings across a range of uses, use utility bills for EUI comparisons, and collect surveys and interviews of occupants to supplement the energy data.¹

Another study was conducted at the University of Minnesota in 2008 and involved energy performance of 121 LEED New Construction buildings. One year of post-occupancy energy usage data was analyzed and resulted in findings that showed LEED buildings had saved energy. The study, however, also found that buildings with high process loads – like labs – used more than twice as much energy as anticipated in their energy models. This suggests that designers, in estimating projections, do not always accommodate the energy needs for lab buildings. This was interesting when comparing data from our own LEED certified lab buildings and further supported the need to separate building selection by use. Measurements used in the study include energy usage (obtained from utility bills among other unnamed sources), Energy Star ratings (obtained using the EPA’s Portfolio Manager), and design and baseline modeled results (gathered from USGBC files for the LEED project submittals). The study included equations for measured and proposed savings based on the EUIs ([baseline – design or measured]/baseline). The baseline numbers came from the average EUI of the commercial stock buildings. This study also surveyed building occupants to determine their comfort/productivity and looked at acoustics, lighting, temperature, air quality, productivity, and overall satisfaction. Overall, this study helped inform our decision to collect utility bills, use Energy Star Portfolio Manager, and obtain LEED submittals from USGBC. Additionally, it further confirmed the need to collect occupancy comfort data and separate building comparisons by use.²
2. LEED:
Description of LEED

LEED is a third party certification program and the nationally accepted benchmark for the design, construction and operation of high performance green buildings. Developed by the U.S. Green Building Council in 2000 through a consensus based process, LEED serves as a tool for buildings of all types and sizes. LEED certification offers third party validation of a project’s green features and verifies that the building is operating exactly the way it was designed to.

LEED is a certification used in our study to help us distinguish “high performance” buildings. It consists of five rating systems that cover several possible project types: Building Design and Construction, Interior Design and Construction, Building Operations and Maintenance, Neighborhood Development, and Homes. The Building Design and Construction (BD+C) rating system covers buildings that are under construction or are undergoing substantial renovation. The four LEED certified buildings on campus are newly constructed buildings that initiated the LEED certification process during the design phase. The only relevant category for this study, therefore, is the Building Design and Construction category. Additionally, LEED certification uses varying levels to distinguish performance. These levels are based on the total number of points accrued by the project. Beginning with the highest certification the order includes: Platinum, Gold, Silver, and Certified.

Points for LEED BD+C certification are accrued within multiple categories. By reviewing the LEED 2009 checklist and points allocation, we were able to determine which credit categories were most significant in earning LEED certification for buildings. The main LEED focus categories include: Sustainable Sites (26 possible points), Water Efficiency (10 possible points), Energy and Atmosphere (35 possible points), Materials and Resources (14 possible points), and Indoor Environmental Quality (15 possible points). The most significant portion of points for LEED certification occur within the Energy and Atmosphere category, with the "Optimize Energy Performance" subcategory allocating 19 possible points. This confirms that in analyzing the performance of LEED campus buildings, we should focus primarily on energy efficiency.

The LEED certification system is constantly evolving. In order to meet the changing needs of the environment and society, USGBC updates their standards with new versions to accommodate various advances in technology and design. The most recent version of LEED certification is LEED v4.0. None of UNC’s buildings, however, were built during LEED v4.0’s existence. As a result, they were all built to previous LEED standards and will be studied using LEED 2009 - the version immediately prior to LEED v4.0.

State LEED Policy
North Carolina Senate Bill 668 dictates energy standards for all state-owned buildings, including public university buildings. The bill was ratified on August 2, 2007 in response to the General Assembly of North Carolina’s finding that “public buildings can be built and renovated using sustainable, energy efficient methods that save money, reduce negative environmental impacts, improve employee and student performance, and make employees and students more productive”
The intent of the legislation is to promote the conservation of resources, primarily energy and water, in all state, university, and community college buildings. The bill set forth energy efficiency and water use standards for these buildings based on the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1-2010 standard. Part one of the bill requires: "New state, university and community college buildings and major renovations of these buildings to be constructed using high-performance standards and prohibit[s] the state from acquiring by purchasing buildings that did not meet standards." Section two deals with renovations of existing buildings and outlines the standards that must be upheld using evidence of these benefits found in the committee report. Section three requires energy audits every five years, annual updates, plans to manage energy water and other utility use, and life-cycle cost analyses for buildings. This bill became effective on July 1, 2007. Although this bill does not require LEED certification, the standards proposed were initially intended to require buildings to reach LEED Silver certification standards with an emphasis on energy efficiency. While building to these requirements necessitates certain LEED standards, Senate Bill 668 focuses a greater amount on energy, discounting LEED categories such as sustainable site selection. This is relevant to our study, as any campus building built after July 2007 should have greater energy savings.

**UNC LEED Policy**

UNC Chapel Hill’s policy for LEED follows that of the state. As a state-owned public university, the school is subject to Senate Bill 668. As a result, UNC currently has four buildings that have been LEED certified, with many others built to LEED standards. The four certified buildings are the Genome Sciences Building (LEED Gold), the Koury Oral Health Sciences building (LEED Gold), NC Botanical Gardens (LEED Platinum), and the School of Nursing Addition (LEED Certified). Other buildings in this project, deemed ‘LEED standard,’ were built to LEED standards, but never registered or attempted to gain LEED certification. Buildings in our study deemed “high-performers” are ones that were LEED certified or built to LEED standards.

### 3. Factors that affect Energy Consumption:

**HVAC systems**

Heating, ventilation and air-conditioning (HVAC) systems have a great effect on a building’s energy usage and efficiency. HVAC systems can account for 40% to 70% of a building’s total energy consumption, and updating outdated systems can largely increase efficiency. HVAC systems vary largely depending on the scale of the building. Small air handler systems are used for residential homes, while larger HVAC systems are used in commercial and industrial settings. The larger HVAC systems are more complex than their smaller counterparts as they address more variables.

The two main types of HVAC systems are central air handling units and ventilators/heat pumps. UNC primarily uses central air handling units which are significantly more efficient. However, ventilators and heat pumps are found in some older campus buildings. The central air handling units also enable greater control of the overall system and provide more options for air flow. Conversely, ventilators and heat pumps are used in individual rooms, allowing for greater control.
individual control. However, this feature sometimes makes the system less efficient as occupants can overuse the system in controlling for comfort. These systems are also very old and are commonly poorly maintained.\textsuperscript{8,9}

Most HVAC systems at UNC are commercial scale; the majority of which are variable air volume air handlers with terminal reheat. This system type is especially common in newer buildings including: Morrison, Knapp-Sanders, FedEx, Genetic, Genome, and Venable/Murray. Ehringhaus Residence Hall, an older building, uses radiators and window units located in each resident’s room. Carmichael Residence Hall uses high-quality fan coil units with dedicated outside treatment. These are expected to be more energy efficient, but are also installed within each resident’s room. Botanical is the only facility within our sample of buildings that uses ground source heat pumps, the most energy efficient of the systems among our selected buildings. The ground source heat pumps cycle a closed loop of water through the building to provide heating and cooling. The loop cycles through the ground where temperature remains moderate. While most of the UNC’s buildings rely on district steam and chilled water for heating and cooling, Botanical uses only electricity to power the heat pumps.\textsuperscript{10}

**Extra Use by Labs**

It is important to keep track of the energy use of all buildings, but it is especially critical for labs due to their large energy loads. There are several reasons for this high energy demand. Due to hazardous air quality issues, labs are required to have a minimum number of air changes per hour. A reasonable rate is 8 to 12 air changes, indicating that the air is being completely recirculated 8 to 12 times every hour. If a lab is open from 8am to 6pm, this means there could be 80 to 120 air changes. An additional number of air changes are required in lab buildings overnight, but the systems are typically set to a lower change rate during these hours. Looking at the three labs in our study, Genetics has a minimum of 8 to 10 air change per hour and Venable/Murray has a minimum of 8. Genome Sciences, a LEED certified building, has a minimum of 6 air changes, along with low lab space airflow cooling augmented with chilled beams; these features were expected to save energy.\textsuperscript{10}

In addition, each of these labs contains fume hoods, which typically use three to four times the amount of energy of an entire home. Closing the sashes of fume hoods when they are not in use saves a significant amount of energy. Yet a study conducted at California Institute of Technology found that, for their 800 campus fume hoods, sashes were shut only 9% of the time. This resulted in annual energy costs of $4,718 for each fume hood. UNC has a similar quantity of fume hoods, many of which are reportedly left open. Therefore, UNC lab buildings may be experiencing similar energy costs. Additional explanations for the high energy consumption of labs include high tech equipment such as ultra-low temperature freezers, super-computers, refrigerators, and other energy-intensive lab equipment. Furthermore, some of this equipment is left on overnight when it is not in use. However, in some cases it might be more efficient to leave equipment on overnight despite the loss of energy, as some machines require a large amount of energy when starting up.\textsuperscript{11}
Human Behavior

Human behavior can also have a significant impact on energy use. Although humans can impact energy use in a variety of ways, the behaviors that are the most relevant and consistent across our selected buildings are changing the thermostat settings and using personal fans and heaters.

First, recognizing proper thermostat settings is a critical step towards understanding energy use. On average, every degree the temperature is lowered in the winter corresponds to a one to three percent drop in monthly energy costs. Similarly, every degree the thermostat is raised in the summer, without surpassing the outside temperature, translates to a one to three percent savings. As a result, many energy utilities suggest customers keep their thermostats set at 68 degrees Fahrenheit in the winter and 78 in the summer. These numbers are determined based on the scientifically accepted values of "room temperature."\(^{12, 13, 14, 15}\) Room temperature refers to the small temperature range to which people are naturally accustomed and can feel comfortable. In scientific contexts, the range is considered to be between 20 and 25 degrees Celsius, or 68 to 77 degrees Fahrenheit. Taking into account other discrepancies such as humidity and clothing, the range can vary slightly. However, an estimate of 68 to 78 degrees Fahrenheit is considered a standard range to ensure comfort. As a result, setting the thermostat to 68 in the winter and to 78 in the summer can maximize energy savings while still maintaining a comfortable environment.\(^{16}\) Buildings can further minimize their energy use by raising the thermostat to upper 80s in the summer and lowering it to the mid-50s in the winter, when the buildings is unoccupied.\(^{17, 18}\) The majority of buildings on campus have temperatures directly controlled by UNC Energy Management. Of our nine buildings, Ehringhaus is the only building that has individual control.\(^{10}\)

Another factor to consider is that when occupants do not have control over the thermostat, they may use space heaters or fans, which drive up electricity consumption. Space heater capacities generally range between 10,000 Btu (2.93 kWh) and 40,000 Btu (11.72 kWh) per hour. They run on electricity, propane, natural gas, or kerosene and generally heat through convection. The U.S Consumer Product Safety Commission estimates that more than 25,000 residential fires occur each year because of a space heater, with more than 300 deaths and 6,000 injuries occurring. Electric space heaters are the only safe unvented space heaters for inside use. Safety guidelines recommend that electric heaters be plugged directly into the wall outlet, or the shortest possible heavy duty extension cord.\(^{19}\)

Energy use of fans varies by type. A ceiling fan uses 65-175 watts (W), while a window fan uses 55-250 W and a whole house fan uses 240-750 W. A window fan that operates under 200 W for 8 hours uses 1.6 kWh per day.\(^{20}\) Room air conditioners have capacities ranging from 5,500 Btu per hour (1.61 kWh) to 14,000 Btu per hour (4.10kWh). These units do a poor job of dehumidifying the air, particularly if the unit is oversized for the room.\(^{21}\) Putting this in perspective, a building with around 50 occupants using a fan or room air conditioner for 8 hours a day for a normal work week can result in an extra 20,800 to 53,040 kWh (70 to 180 MBtu) per year. Moreover, when comparing above kWhs, space heaters can use around 2 to 7 times as much energy as fans.
4. Steps UNC has already taken to Analyze Energy Data:

**UNC Energy Dashboard**
The UNC Energy Dashboard website was created to make valuable energy data more readily available to stakeholders in the UNC community. The website provides near real time data for steam, electricity, and chilled water consumption of campus buildings. It also provides monthly data for water, non-potable water, reclaimed water, harvested rainwater, solar thermal, and solar photovoltaic utilities. The dashboard formats this data both graphically and numerically. Spreadsheet data is available for download to those affiliated with the university.

The resounding strengths of this application are that it measures valuable data in an interpretable way and makes it available to the public. Anyone with an Internet connection can visit the dashboard website and track the data for certain buildings. Different time frame options allow for different measurements and trends to be shown. The various graphic options make the data both easier to decipher and more valuable to the general public. However, a drawback to the dashboard is the lack of direction when searching for specific information, making it less useful to the general public. The sheer volume of data can cause problems for those attempting to find numbers from a certain time period, especially those with elementary knowledge of energy sources. Another drawback is the lack of verification of the data. For example, the energy attributed to one building may actually be split between several buildings. Without knowledge of meters, one could misinterpret this data and make inaccurate assumptions. Finally, data is not taken continuously, but instead represents 15 minute time increments. Large variations of energy use can occur during those 15 minutes, making the data more of an estimate than an accurate portrayal.

**Energy Audits**
The North Carolina state Senate Bill 668 codified in 2007 requires energy audits to be performed on all state-owned public buildings every five years. In passing this bill, the General Assembly of North Carolina intended that “State agencies, the University of North Carolina, and the North Carolina Community College System shall perform after-construction measurement and verification of costs and savings to confirm that the performance goals of this section are met and ensure that economic and environmental goals are achieved” (SB 668). As part of the Facilities and Assessment Program put in place by the bill, the Department of Administration of the State Energy Office is required to conduct an energy audit for each State agency or State institution of higher learning.

In 2009, UNC conducted a comprehensive assessment of the energy reduction costs and savings for the campus, the Strategic Demand-Side Energy Plan. The analysis looked at a subset of university buildings and extrapolated the findings across the campus. This approach, however, did not end up being particularly accurate. While the analysis provided the university with a rough idea of opportunities for improvement, it concluded with a number of vague claims about making this campus ‘efficient’. In other words, UNC is still uncertain on its successes and areas for improvement in energy efficiency.  

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IV. Methods

1. Building Selection Process:
After discussions with UNC’s Energy Management Department and initial research, we acknowledged that building use would drastically affect energy consumption. As a result, we settled on three categories: classroom/administrative, residence halls, and laboratories. We decided to compare buildings within each category to avoid inconsistencies based on building use. For our initial list, we used UNC Energy Dashboard to find similar buildings with discrepancies in energy use. For instance, Aycock and Graham are two residence halls similar in size, occupancy and location. Yet, the dashboard showed Graham using a significantly larger amount of energy. Each category included two similar buildings with energy usage discrepancies and one LEED building. The goal was to narrow down causes for the discrepancies in energy use and compare ideas for improvements based on the highly regarded LEED building. However, we discovered the Energy Dashboard does not always reflect true energy consumption. As a result, our original list was not actually representative of buildings that experienced significant energy usage discrepancies, and we did not use UNC Energy Dashboard for further assessments.

Our next list intended to take a deeper look into LEED-certified campus buildings with the purpose of determining whether the extra effort that went into their design and construction was reflected in energy cost savings. This involved comparing these buildings to their projected energy costs as well as to the energy costs of non-LEED buildings. However, we were limited when we discovered that UNC buildings constructed before 2008 did not require an energy projection. This left only two buildings, Genome and Botanical, with energy projections. Therefore, we could not compare all LEED buildings to their own projected energy use. In addition, we noted that UNC does not have a LEED-certified residence hall. We researched LEED dorms across the state and considered using Miltimore Hall, a LEED-certified dorm on UNC-Charlotte’s campus. Miltimore Hall, an apartment complex, is most similar in size and use to Ram Village Apartments. Our next building list included both Miltimore Hall and Ram Village Apartments; however, this list also caused problems as we realized Ram Village Apartments has multiple complexes, some of which share an energy meter. Energy use would have been difficult to divide between buildings given their different amenities; for example, some have washers and dryers while others do not.

After more research and discussions with UNC Energy Management, we settled on our final list: NC Botanical Garden Education Center, FedEx Global Education Center, Knapp-Sanders School of Government, Morrison Residence Hall, Carmichael Residence Hall, Ehringhaus Residence Hall, Genome Sciences Building, Venable/Murray Halls, and Genetic Medicine Building. The selection follows our original plan of choosing three buildings from three usage categories for a total of nine buildings. Additionally, the buildings selected represent an older building, a newer/significantly renovated building, and a “high-performance” building. Two of our high-performance buildings, Genome and Botanical, are LEED-certified. We planned to now compare energy use among buildings within a category to understand whether energy performance improved with newer and high-performance buildings. Additionally, we wanted to compare each building to national energy consumption averages and to compare the LEED-certified buildings to their energy-use projections.
2. General Building Data:
We then gathered general building data including the age, renovations, use type, size, occupancy, and HVAC systems for each building. We determined that these factors should all be accounted for as they impact a building’s overall energy consumption. Newer or more recently renovated buildings are likely to have more efficient designs and improved HVAC systems. We also found that each usage type has unique demands for energy consumption that are essential to account for in our analysis. Residence halls are designed to supply personalized and individual comfort to residents at all times of the day. Labs house delicate materials and appliances that must remain within a particular temperature range, thus also requiring constant temperature control. Classroom buildings, however, have systems that may be shut off at night. Moreover, building size is also a critical factor. Rather than using total energy consumption, we chose to compare energy use by square footage. By observing these characteristics for each building and controlling for building size, we have been able to better understand how and why the buildings have different energy consumption trends. Information on HVAC systems was obtained directly from UNC Energy Management, and UNC’s Plan Room website provided information on building age, renovations, use, square footage, and occupancy. Additional data on building location was gathered from UNC’s campus directory.

3. Energy Data:
The UNC Energy Management team supplied monthly energy bills starting in the year of each building’s construction, as early as 2007. The utilities tracked were chilled water, electricity, district steam, and solar electricity. We combined this data with each building’s square footage to create a fairly normalized “per square foot” average. This accounted for discrepancies in raw energy data due to the varying size of each building.

As each utility is measured in a different unit (kWh, pounds, ton hours), a common metric was needed to better quantify the data and make for understandable comparisons with regard to the energy totals. The chosen unit for comparison was the British Thermal Unit (BTU). The conversion scales for each utility are as follows:

- Electricity: .293 kWh = 1 kBtu
- Steam: 1.194 pounds = 1 kBtu
- Chilled Water: 12 ton hours = 1 kBtu

Energy Star’s Portfolio Manager application allows for normalized data readings and for filing of several different types of reports. Portfolio Manager takes the provided data such as building square footage, total energy usage, building occupancy, and number of rooms. It then calculates each building’s energy use intensity (EUI). The EUI is expressed as energy per square foot per year. The application also automatically does conversions to a common metric to remove any confusion due to measurement units (e.g. kBtu and GJ). Portfolio Manager calculates two different types of EUI: site EUI and source EUI. Site EUI takes into account all energy produced on a building’s site, while source EUI accounts for transmission, delivery, and production losses of energy manufactured offsite and purchased for consumption. Source energy represents the total amount of raw fuel required to operate buildings, and Portfolio Manager recommends using the source EUI when comparing different buildings.
The service also provides an “Energy Star score” to buildings of certain use types. The score is measured on a scale of 1 to 100, with 1 being the worst and 100 being a perfect score. It is measured in comparison to other buildings of the same use type and so a score of 50 is considered to be the national median based on comparable use buildings. Residence halls and office buildings are able to receive an Energy Star score but laboratories are not, because they vary greatly in size and use. Labs are grouped in the “other” category with several other building types, making the Energy Star EUI calculation for labs slightly misleading and provides no useful comparison.

4. LEED Submittal Templates:
As part of our analysis, we wanted to consider the projected energy use for the two LEED buildings: Botanical and Genome. For the buildings that are LEED-certified, additional baseline and proposed energy use totals were formulated in the design phase. To attain certification, buildings must be designed to use less energy than a baseline building designed to simply meet current ASHRAE standards. In simpler terms, a building must project energy savings against the normal standards. The energy total using normal standards gives a baseline number to compare against. To achieve certification, designers must also project how much energy the building is going to use. This projection along with the baseline gives two comparison points for the building’s actual energy usage. These LEED submittal templates served to further our understanding of how each building was proposed to consume energy and enabled us to draw conclusions on whether the LEED buildings are functioning at optimal levels.

In order to get the designed and baseline totals for our LEED certified buildings, we contacted the U.S. Green Building Council (USGBC) who referred us to Megan Inoyue and Isaac Panzarella, members of the design teams for Genome and Botanical respectively. Inoyue and Panzarella sent us the LEED submittal templates for their respective buildings. While many details were contained in the templates, the most important for our purposes was the Energy Cost and Consumption by Energy Type- Performance Rating Method Compliance summary. This table provided a simple breakdown of energy types, comparing the proposed design to the baseline for each type. Other information included the design team, a breakdown of the building’s uses based on square footage, and insight into the overall energy use of the buildings.

5. Temperature Collection:
Another step of our process included collecting temperature readings of the selected buildings using temperature guns or “infrared thermometers”. The goal of collecting this data was to assess air flow throughout the buildings, measure actual temperature, and find possible disparities between actual temperature and thermostat settings. The tool measures emissivity, the amount of energy radiating from an object, and was used on loan from UNC Energy Management. While in the buildings, we collected temperature data from a variety of rooms and marked the locations on floor plans, which can be found in Appendix A. We recreated the process across two separate days, a few weeks apart, to account for outside temperature differences and confirm the consistency of the temperature guns.
Several limitations with this data collection strategy were present. Each of the three use categories was measured by a different group of contributors to the study. Although directions and experiences were communicated, some user error between groups may be present. Additionally, having only one temperature gun meant buildings had to be measured on different days and during different times of the day, rather than simultaneously. The C/A buildings and one of the residence halls were measured first. During this time, the temperature gun was low on batteries, limiting the number of readings and likely impacting the accuracy of these readings. However, the second round of readings was taken with new batteries, providing more accurate data.

6. Survey:
Occupant comfort is an important aspect in considering a building’s performance. When the occupants are more comfortable, their productivity increases. One of LEED’s goals is to provide a healthier, more comfortable environment for those who use the building. The USGBC reports that its buildings reduce pollutants and have an average of 16% higher labor productivity because of improved occupant comfort. As a result, we aimed to test the comfort of the occupants through an in-person survey. The survey, Occupant Comfort in Campus Buildings, received IRB approval on March 26th, 2014 as study #14-0572 and can be found in Appendix B.

Several resources were used to create a survey that would minimize leading questions and maximize understandability. These included Learning from Strangers by Robert Weiss and Making it Count: A Review of the Value and Techniques for Public Consultation by Shipley & Utz.

Surveys were distributed in person to occupants of each building over the span of three days. Thirty surveys were collected per building, except for Botanical in which only 15 occupants were present. This totaled 255 surveys. The number 30 was chosen because, assuming the data forms a normal distribution, the central limit theorem finds 30 responses to approximate the results of the population. We entered the results into Qualtrics, a resource provided by UNC. From Qualtrics we were able to compile the surveys, view trends, and create charts.

7. Building Head Interviews:
To gain more insight into how temperature is controlled within campus buildings and to develop a better understanding of the social and behavioral trends associated with building temperatures, we chose to identify and interview key informants from each building. Casual building users, such as students or professors, may not have a complete awareness of temperature control in various buildings. Building heads or department managers would likely be able to offer more information concerning how building temperature is controlled, how it affects regular building users, and whether occupants voice concerns about it to those individuals in positions of power. This would provide us with more than just the “snapshot” style of information we would gain from the survey of building occupants.
The process of identifying building heads varied by building use. For residence halls, we were able to easily identify the community directors for each building. As full-time professional staff members who manage and oversee the operations of each residence hall, these individuals would be qualified to provide us with more detailed insight into how the temperature is controlled in their building. More importantly, they would be aware of the culture and general occupant satisfaction regarding residence hall temperature settings. For C/A and labs, we looked for departmental heads, office managers, or facilities managers through academic department and building websites.

Initial contact with each building head was conducted via e-mail in order to set up a short in-person or phone interview. If these key informants agreed to provide us with information, we scheduled an interview to be conducted by a member of the capstone team.

Limitations occurred when our selected key informants redirected our inquiries to other members of their department, or when they failed to respond to our e-mail requests for an interview. We attempted to overcome these setbacks by directly calling them or contacting the informants to which we were redirected. However, direct calls resulted in no answer and only a few of the informants continued a correspondence.
V. Data

1. General Building Data:
Data on use, size, age, occupancy, and HVAC systems were collected from UNC Energy Management and the UNC Plan Room. This information can be found in Table 1, with a written summary of the data below.

In summary, older buildings were built between 1956 and 2005, but both Knapp-Sanders and Ehringhaus have undergone renovations in the past decade. Newer or more extensively renovated buildings were built or last renovated between 2004 and 2008. Buildings considered high-performers were built or extensively renovated between 2006 and 2008. Buildings averaged in size between 100,000 and 200,000 square feet with the largest building being Genetics at 367,570 square feet and the smallest being Botanical at 32,301 square feet. Most buildings used variable air handlers as their HVAC system with the exceptions of Ehringhaus, Carmichael, and Botanical. Botanical and Carmichael use systems considered more efficient, while Ehringhaus uses older radiators and window units. Finally, most buildings have undergone renovations, some involving large overhauls of systems and others being minor adjustments such as the addition of dehumidifiers.
<table>
<thead>
<tr>
<th>Name</th>
<th>Use</th>
<th>Square Footage</th>
<th>Year Built</th>
<th>Year Occupied</th>
<th>Most Recent Renovation</th>
<th>Occupancy</th>
<th>HVAC System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botanical “high performer”</td>
<td>C/A</td>
<td>32,301</td>
<td>2007</td>
<td>2010</td>
<td>2011</td>
<td>Under 50</td>
<td>*Ground source heat pumps</td>
</tr>
<tr>
<td>FedEx “newer/renovated”</td>
<td>C/A</td>
<td>143,750</td>
<td>2004</td>
<td>2007</td>
<td>N/A</td>
<td>Unknown</td>
<td>Variable air volume air handler with terminal reheat</td>
</tr>
<tr>
<td>Knapp-Sanders “older”</td>
<td>C/A</td>
<td>131,941</td>
<td>1956</td>
<td>1956</td>
<td>2004</td>
<td>Unknown</td>
<td>Variable air volume air handler with terminal reheat</td>
</tr>
<tr>
<td>Morrison “high performer”</td>
<td>R</td>
<td>217,522</td>
<td>1963</td>
<td>1965</td>
<td>2006</td>
<td>860</td>
<td>Variable air volume air handler with terminal reheat</td>
</tr>
<tr>
<td>Carmichael “newer/renovated”</td>
<td>R</td>
<td>107,895</td>
<td>1986</td>
<td>1986</td>
<td>2008</td>
<td>485</td>
<td>*Fan coils with dedicated outside treatment</td>
</tr>
<tr>
<td>Ehringhaus “older”</td>
<td>R</td>
<td>156,315</td>
<td>1961</td>
<td>1962</td>
<td>2013</td>
<td>640</td>
<td>Radiators/Window Units</td>
</tr>
<tr>
<td>Genome “high performer”</td>
<td>L</td>
<td>220,901</td>
<td>2008</td>
<td>2012</td>
<td>N/A</td>
<td>Unknown</td>
<td>*Variable air volume air handler with terminal reheat, low lab space airflow and zone cooling augmented with chilled beams; 6 air changes per hour minimum.</td>
</tr>
<tr>
<td>Venable/Murray “newer/renovated”</td>
<td>L</td>
<td>169,499</td>
<td>2008</td>
<td>2010</td>
<td>N/A</td>
<td>Unknown</td>
<td>Variable air volume air handler with terminal reheat; 8 air changes per hour minimum; heat recovery system</td>
</tr>
<tr>
<td>Genetics “older”</td>
<td>L</td>
<td>367,570</td>
<td>2005</td>
<td>2008</td>
<td>N/A</td>
<td>Unknown</td>
<td>Variable air volume air handler with terminal reheat; heat recovery system</td>
</tr>
</tbody>
</table>

Table 1. General data for each building. C/A indicates classroom/administrative. R indicates residence hall. L indicates laboratory.
2. Energy Consumption of Each Building:
Energy data collected from utility bills provided by UNC Energy Management was entered into Energy Star’s Portfolio Manager in order to calculate each building’s energy use intensity (EUI). Charts 1-3 below summarize each building’s yearly energy consumption for each year data was available.

Classrooms/Administrative:

Chart 1.1 Annual energy consumption of NC Botanical Gardens Education Center from 2010 to present.
Chart 1.2 Annual energy consumption of FedEx Education Center from 2007 to present.

Chart 1.3 Annual energy consumption of Knapp-Sanders School of Government from 2009 to present.
Chart 2.1 Annual energy consumption of Morrison Residence Hall from 2009 to present.
Chart 2.2 Annual energy consumption of Carmichael Residence Hall from 2009 to present.

Chart 2.3 Annual energy consumption of Ehringhaus Residence Hall from 2006 to present.
Labs:

Chart 3.1 Annual energy consumption of Genome Sciences Building from 2012 to present.
Chart 3.2 Annual energy consumption of Venable/Murray Halls from 2011 to present.

Chart 3.3 Annual energy consumption of Genetic Medicine Building from 2009 to present.
3. Projected and Baseline Energy for LEED Buildings:

Our team received LEED submittal templates from the design teams for Botanical and Genome, the two LEED-certified buildings. The templates provided information on proposed energy consumption. Charts 4.1 and 4.2 below summarize this data.

Chart 4.1 NC Botanical Garden Education Center’s last year of energy consumption, projected energy use both without and with the PV solar array and the baseline design for a similar building.

Chart 4.2 Genome Sciences Building’s projected energy use, the baseline design for a similar building, and last year’s energy consumption.
The LEED submittal templates provided us with a better understanding of the buildings’ proposed energy usage, as well as the steps taken to achieve greater efficiency. The two LEED buildings received different levels of LEED certification. Botanical achieved a LEED Platinum certification under version 2.2 of LEED’s “New Construction” standards. The building also achieved 15 of 17 possible points in the “Energy and Atmosphere” section of the score sheet, meaning that the building was constructed with energy efficiency in mind. Genome achieved a LEED Gold certification under the same version of LEED. However, Genome only achieved 3 of 17 possible points in the “Energy and Atmosphere” section of the score sheet. The design might not have incorporated some of the attributes to achieve points in the “Energy and Atmosphere” category due to lab safety restraints.

4. Temperature Data:
All temperature data collected from the infrared thermometers was labeled onto floor plans of respective buildings and can be found in Appendix A. All readings were taken in degrees Fahrenheit. A written summary of the data can be found below.

Classroom/Administrative:
We visited the C/A buildings between 12PM and 4PM on Tuesday, March 4th and again Tuesday April 1st between 11AM and 4PM. The outside temperature was 30 degrees and sunny the first day and about 70 degrees and cloudy the second day.

NC Botanical Garden Education Center
Botanical consists of three buildings: A, B, and C. Building A is mainly an auditorium and large meeting room. The temperatures were consistent between the two rooms at 70 degrees. They also matched the thermostat reading. Building B consists of three classrooms: one small and two large. The classrooms ranged from 66 to 73. The thermostats were again consistent with the temperature readings. We were informed that the classrooms are kept colder when unoccupied. Prior to being used, a staff member will contact UNC Energy Management to raise the temperature. This can account for the temperature differences between the three rooms. Building C is the main building. The bottom floor is a visitors’ center and is one open room with tall windows. The temperature varied around the room. Adjacent to the windows facing the sun the temperature reached 73, while the back corner away from the sun ranged in the upper 60s. The top floor of the building contains offices with temperatures ranging from 70 to extremes of 78 and 62. It is important to note that these extreme readings were taken on different days. The colder reading was taken on a day when the outside temperature was 30 degrees, while the 78 degree reading occurred when the outside temperature was 70 degrees. However, the consensus of office workers was that the building is kept too cold. Many workers have space heaters, and one worker had on a ski jacket during the 30 degree day. One last note is most rooms had a thermostat. These generally read 70 degrees regardless of actual temperature; however, the colder classroom’s thermostat accurately read 67.

FedEx Global Education Center
During the first temperature collection round, the temperature reading gun died during our visit to FedEx. Our data, therefore, largely comes from the second collection day. The bottom floor of FedEx is mainly used as a lobby that extends up three stories. We took a temperature reading on
the bottom floor and again on the 2\textsuperscript{nd} and 3\textsuperscript{rd} floors looking down to the lobby. The readings were very consistent at 73 to 74. Additionally, an auditorium spans the first and second floors. The reading here was 73. The 2\textsuperscript{nd} and 3\textsuperscript{rd} floors are also used for office space. The offices ranged in temperature from 70 to 74. The 4\textsuperscript{th} floor has one main reception area and a few offices. The offices were locked, and we were only able to take a reading of the reception room which also read 73. The temperatures in this building were the most consistent. Workers, however, were unhappy with them, voicing that the building is kept too cold even in summer. During the first visit, one woman was wearing a ski jacket. As an additional note, workers believed that the week we visited was unusually warm, and stated that the building had been colder in previous weeks. They were also unaware of any control they may have over thermostats.

**Knapp-Sanders School of Government**

Knapp-Sanders consists of three floors. The bottom floor is mainly a basement with a hallway, cafeteria, and a few offices. The hallway temperatures ranged in the mid-70s while the cafeteria ranged in the upper-60s. It should be noted that during our visit, the cafeteria was unoccupied except for a cleaning crew. The 2\textsuperscript{nd} floor is the main level and consists of a large entrance hall, atrium with skylights, large lecture halls, small classrooms, and a library. The temperatures ranged between 71 and 75. The main discrepancies were the two large lecture halls. One faced southwest and was as cold as 66 degrees. Across from it was a larger lecture room facing northwest. The temperature here reached as high as 80. Both halls were unoccupied at the time. The third floor is mainly offices and break rooms. Here the temperature was consistent, ranging between 73 and 75. Unlike Botanical, the thermostats here do not have digital readings, but they are controllable. Workers varied in their satisfaction. One woman believed the building was too cold and she used a space heater. However, another male worker believed the temperature was suitable.

**Residence Halls:**
The first round of visits to the residence halls occurred over two days as the temperature gun’s batteries died after the first building. As a result, Morrison’s first round of temperatures was taken around 12PM on Wednesday, March 5\textsuperscript{th} when the outside temperature was about 40 degrees. Ehringhaus’ and Carmichael’s first round of temperatures were taken Wednesday, March 19\textsuperscript{th} during the afternoon while the outside temperature was around 47 degrees and cloudy. The second round of temperature collection occurred for all three buildings on Wednesday, April 2\textsuperscript{nd} while the weather was 80 degrees and sunny.

**Morrison Residence Hall**

Morrison has the overall shape of an ‘x’. Rooms are generally arranged in groups of four on a short hallway with a bathroom on one end and the exit on the other. A considerable amount of the floor space in Morrison is non-air-conditioned balconies; each suite has a door leading outside. On days with nice weather these doors are often left propped open, even if the heating or air conditioning in the rooms is still running. Temperatures ranged from the mid-50s in unoccupied interior common rooms to low-80s in the bathrooms exposed to outdoor air on warmer days. Occupied spaces tended to be around standard room temperature, with the most variation coming from a small room with vending machines, which saw a 16 degree range.
**Carmichael Residence Hall**
Temperature ranges were significant in Carmichael, largely dependent upon how directly the sunlight was coming through the large windows. Window shades in each dorm room mitigated the excess heat, allowing the rooms to maintain a more comfortable temperature on warm, sunny days. Interior common rooms tended to be cooler than either hallways or dorm rooms. Areas in close proximity to the windows were the hottest and coldest, respective to the outside temperature. These areas ranged from 52 to 90 degrees, during which time outside temperatures on the two separate days ranged from the low-40s to the mid-80s, respectively.

**Ehringhaus Residence Hall**
Ehringhaus utilizes a great deal of outdoor space, with a very similar floor plan to Morrison. Rooms are generally arranged in groups of four on a short hallway with a bathroom on one end and the exit on the other. Each suite opens out onto a balcony on one of the building wings and these doors are often propped open on fair weather days. We observed several dorm rooms where the air conditioning window units were running despite the fact that these doors were open. Readings showed that temperatures tended to increase slightly further up the building, but interior space tended to be fairly constant, ranging from mid-60s to mid-70s depending on outside temperature.

**Laboratories:**
The labs were the last buildings visited. The first round of data collection occurred over two days: Thursday, March 20th and Friday, March 21st. The weather during both days was around 50 degrees and sunny. The second round of collection occurred on April 3rd when the outside temperature ranged in the 60s.

**Genome Sciences Building**
Temperatures in Genome ranged significantly across the various uses of space within the building. They also ranged according to proximity to internal and external walls. Internally-located wet-lab spaces were generally much cooler than the lab write-up spaces. Occupants of both types of spaces, however, complained about the cold temperature. A unique feature of Genome is that its building envelope consists primarily of large windows, spanning the entire height of the building. We noted that offices located around the periphery of each floor often reflected the outdoor temperatures. The quantity of sunlight had a significant effect on the overall office temperature, particularly in corner offices. These spaces were substantially warmer than the rest of the locations we sampled throughout Genome.

**Venable/Murray Halls**
Of the three lab buildings we studied, Venable/Murray had the most consistent temperature readings. In general, temperatures throughout the building ranged between 70 and 73 degrees Fahrenheit. The lowest temperatures - ranging in the upper 60s - were measured in the bottom level of the building, which is partially underground. A few of the lab spaces in the upper floors of the building revealed slightly lower temperatures than the rest of the building. These rooms usually contained large pieces of lab equipment or machinery, such as a mass spectrometer which emits large amounts of heat during use. Therefore, temperatures in these labs were set to
remain in the upper 60s in order to balance the added heat gain. However, it was unclear whether temperature settings are adjusted regularly to ensure the space is not cooled unnecessarily when the equipment is not in use.

**Genetic Medicine Building**
Temperature readings in the Genetic Medicine Building were also fairly consistent, although they had a greater range (from approximately 70 to 75 degrees Fahrenheit). This building is structured with a large atrium at its core, spanning the five-story height of the building and ending in a glass-paneled ceiling. Temperature readings taken in this space on the various floors were surprisingly consistent. To the north and south of this atrium are two connected sets of laboratory pods. The lab rooms consist of interconnected open space, with cubicles and small offices confined to the periphery of the building, and we measured significant temperature variation within the space. This variation was often dependent on the proximity to heat-generating lab equipment, air vents, and windows. Through both our temperature readings and interactions with occupants it appeared that warm and cool air are not circulated efficiently and consistently throughout the expansive lab spaces.

### 5. Survey Results:
Our team collected a total of 255 surveys. We collected 30 per building except for Botanical which only had 15 occupants present. We were particularly interested in how LEED knowledge, discrepancies in behavior, and occupant comfort varied between buildings. Summaries of survey results can be viewed in Charts 5-7.

#### LEED Knowledge

![Chart 5.1 Occupant awareness of LEED status taken from occupant surveys of all nine buildings and reflecting occupants who reported correctly or incorrectly as to whether their building was LEED-certified, or who reported that they did not know the building’s LEED-certification status.](chart)

Chart 5.1 Occupant awareness of LEED status taken from occupant surveys of all nine buildings and reflecting occupants who reported correctly or incorrectly as to whether their building was LEED-certified, or who reported that they did not know the building’s LEED-certification status.
In summary, campus-wide LEED awareness was low. When prompted on whether their building was LEED-certified or who were unsure of its LEED-certification status. No occupants in these buildings reported that they thought their building was not LEED-certified.

In summary, campus-wide LEED awareness was low. When prompted on whether their building was LEED-certified, 80% (203) of total respondents answered “I do not know”, 14% (36) answered “yes”, and 6% (16) answered “no”. Occupants of LEED buildings demonstrated a better knowledge of their buildings, with 63% (25) accurately answering yes and 37% (15) answering “I do not know”. No occupants of LEED buildings inaccurately answered “no.”
Space Heater and Fan Use

Response for space heater use was low overall. 21.5% (55) of respondents reported using a space heater. However, we anticipate this response may not be accurate as more respondents provided anecdotal accounts of using space heaters than the number recorded on the surveys. Some respondents also acknowledged that many buildings have rules prohibiting space heaters, providing a possible explanation for discrepancies in verbal and written reports. Additionally, many respondents were students who used the buildings for studying or class and were not in the position to use a space heater.

Of the 55 that reported using space heaters, many used them regularly, with 31% (17) reporting more than once a day use at some point during the past year. 26 people acknowledged using a space heater in the summer, with seven of them using it more than once a day. This finding is fairly significant considering the opposite behavior is expected. 48 people, about 19% of all respondents, reported using space heaters in the winter, with the vast majority of them (38) reporting weekly use. Results for spring and fall are consistent with each other, with most respondents reporting space heater use of two to four times a week or less. Fan use was fairly similar to space heater use, except in dorms where fans were more commonly used.
Chart 7.1 Average comfort and satisfaction ratings across all buildings taken from occupant surveys and reported on a scale of 1-4; 4 being the highest.

Chart 7.2 Average comfort and satisfaction ratings across seasons taken from occupant surveys and reported on a scale of 1-4; 4 being the highest.
Occupants were asked to rank their comfort on a scale of 1 to 4 (with 4 being the highest) for each season. In all buildings, the majority of occupants felt most uncomfortable in summer (15) and winter (19) while a smaller number of respondents reported their lowest comfort ratings in spring (9) and fall (8). Overall, the majority of occupants in all the buildings were fairly comfortable throughout the year. Across all seasons, 113 respondents reported 4s for comfort at some point, with 47 reporting only 4s. Occupants were also asked to rank “overall satisfaction” in their building on a similar scale. The spring (7) and fall (9) had a similar number of responses reporting low satisfaction as winter (11) and summer (9); however, 121 respondents reported high satisfaction at some point during the year, with 78 reporting only 4s. It is important to note that the response rate for this question was lower than for the occupant comfort question.

Across all buildings, the three lowest reports for comfort were in Genetics, Botanical, and Genome. Knapp-Sanders and Ehringhaus scored highest in both categories. Across building types, occupants showed fairly similar results in terms of average comfort and satisfaction with labs scoring marginally lower. In general, occupants ranked satisfaction slightly higher than comfort. Overall scores were high, with no building averaging below a 2.

**Limitations in Responses**
In free response questions many respondents did not understand the goal of the survey and reported irrelevant information such as displeasure with dormitory room sizes. This indicates that aspects irrelevant to our study may have been factored into their satisfaction ratings. Additionally, a few occupants, particularly in labs, failed to turn the survey over and complete the backside. This affected the number of comfort and satisfaction responses we received from lab occupants. Finally, comfort varied as a factor of the number of hours occupants spent in the building, with longer hours correlating to higher discomfort. Overall satisfaction may be higher as a result of short-time occupants bringing up the average, inaccurately portraying the average comfort of occupants who spend more time in the building and are perhaps are more affected by its temperature.

**6. Building Head Interviews:**
Out of the nine building contacts, only three responded to our requests for interviews. The other contacts were either unresponsive, unable to be interviewed, or redirected us to another informant. One of these redirections was to Lane Adams at UNC Facilities. Two of the responses were from Peter White, Director of N.C. Botanical Garden, and Jim Ward, the Director of Horticulture at Botanical. The last interview was with Nicole Ponticorvo, Community Director of Ehringhaus. Adams’ and White’s interviews were conducted in person, and interviews with Ward and Ponticorvo were conducted via e-mail.

Adams showed us around his station, which includes five computer monitors. Each monitor shows a different energy provider and provides data for each campus building supplied by that provider. The three providers associated the nine buildings in our study are Synder Electric TAC, Johnson Controls Metasys, and DMS/Tridium. The provider does not affect the energy consumption, but is chosen based on bidding at the time of construction. Using these monitors, UNC Facilities can view the floor plans and temperature controls of each building. However, some buildings did not have updated control information and were missing floor plans. These
included each of the three dorms. This is partly due to their control being outside that of UNC Facilities. Residence halls are controlled, instead, by the Housing HVAC Department. As a result, we were able to get detailed information on only six of the buildings in our study.

Each of the labs and C/A buildings are operated centrally by UNC Energy Management with limited occupant control. Energy Management sets the temperature range from 70 to 75 degrees Fahrenheit during occupied times. During unoccupied times, defined as from 10PM to 5AM, the temperature range is automatically relaxed to 63 to 85 degrees. This range remains the same for each day of the week, during all seasons. The only exception is the labs. While the office sections of the labs are set in the same manner, lab rooms are set at the 70 to 75 degree range at all times and do not have an unoccupied setting. Within the 70 to 75 degree range, occupants have a one degree range of control. Therefore, an occupant can adjust the temperature range to either 69 to 74 or 71 to 76. Occupants can also call UNC Energy Management to request a temperature change. Employees at Botanical call frequently to request warming up a classroom in advance of its use. However, Botanical has experienced some trouble with Energy Management, as the actual room numbers do not match up with those on UNC’s floor plans. As a result, management will sometimes heat or cool the wrong room. Other buildings do not call in many requests. Additionally, occupants who do phone in requests can only appeal a temperature change within the 69 to 76 degree allowable range. If they would like to adjust the temperature outside of this range, they have to file an exemption with the Director of the Energy Management Program.

Five of the labs and C/A buildings, the exception being Botanical, use chilled water and district steam systems. In addition, all three of the lab buildings have heat recovery units to help mitigate their efficiency losses due to air handlers that take in 100% of outside air. These heat recovery units can help provide cooling in the summer, but their main advantage is providing up to 10 to 11 degrees of heating in the winter. This heating is essentially “free” as it is recovered from what would otherwise have been wasted heat. Moreover, in the winter the systems change from a “mechanical” system in which they rely only on outside energy to supply chilled water, to an “economizer” which uses outside air to help cool the chilled water and recycle heat produced in the building from both computers and people to re-heat the building in place of steam.

Additional information Adams provided included the fact that Genome can become colder on the 2nd floor due to the fact that a portion of it is cantilevered. Because of the open space below it, there are more opportunities for cold air to infiltrate. Additionally, Genome has green rooms that require a lot of lighting and warmer air. UNC has begun converting some of the fixtures to LED lighting to save energy. Adams also pointed out that FedEx has experienced “envelope” or insulation issues by the atrium. Some construction has been done to improve the problem, but Adams is not convinced it is entirely fixed.

Adams also provided information on Botanical, that was supplemented with additional information from both Peter White and Jim Ward. According to Adams, Botanical uses two ground source heat pumps that extend into the ground to chill water. This is instead of a “mechanical” system that is always piping in new chilled water. This system saves energy and money. Additionally, Botanical has a solar PV system that sells its power to Duke Energy and buys back a share of it to use. Botanical opened in 2010 and, according to Peter White, had
immediate humidity issues. The original heat pumps suggested by the design team were not available. UNC opted for a different model that did not activate as frequently. This system was paired with a carbon dioxide ventilation system that would draw in outside air to increase the oxygen. However, the building was designed to be well-insulated and the heat pumps did not come on frequently enough to dehumidify the influx of outside air; the original model was intended to turn on more regularly. This led to high humidity issues. In 2011, the building underwent renovations and the heat pumps now turn on in response to humidity levels. This may increase energy use, and there are also complaints that the system still does not sufficiently reduce humidity.

As for temperature control, Peter White and Jim Ward explained that the Botanical building was designed to allow occupant control of temperature. According to Ward, “…occupant control of their working environment was a clear vision, supported by everyone involved – staff, architect team, and UNC Facilities Planning project manager.” Both White and Ward are unsure when or why the design changed. Ward believes that central control can have large energy savings and is generally a better system. He supports limited occupant control to avoid one occupant from “cranking-up” the temperature. However, occupants are angered that they were misinformed during the process, and it was not until late in the development that Ward realized the “thermostats” were actually “thermistors” that only read the air temperature instead of providing functional control. White also said that if occupants have limited control, the staff has not been trained to understand the adjustments. Ward supported this by writing, “I was also told by UNC EMS that we could adjust the temperature by 2 degrees F colder/hotter via the wall thermistors, but I haven’t seen this ever work.” Ward added that while classrooms and office spaces are set within reasonable temperature ranges, “…what’s on paper or in the design isn’t always how things work.” The procedure to adjust temperature in Botanical is for staff to notify Ward and he will call management. Ward is generally happy with UNC EMS. However, he referenced problems with calling in adjustments including the issue with inconsistent room numbers. In addition, Ward said that while EMS is usually quick to respond, there was one occasion where he left two messages and received no response.

Ward also mentioned the Botanical HVAC system has “adjustable” air vents in each office to help increase the comfort of the occupants’ working environments. However, when one person reduces their air flow, it slightly increases the air pressure within the ducts leading to greater air flow in other offices. Others then close their vents until eventually all the ducts are closed completely. As a result, Botanical has resorted to a “hands off approach.” Now, occupants have neither temperature nor air flow control, which were both originally outlined as important parts of the vision for the building.

Finally, Ward mentioned that occupants were guaranteed an online view of real time temperatures in the Education Center. After first moving into the center, Ward was given a link to a digital floor plan but the link did not work. EMS intended to let him know when it was fixed, but to date they have not followed up with him.

Nicole Ponticorvo provided information about one of the dorms, Ehringhaus. As Community Director of Ehringhaus, she has lived in the building since July of 2013. Ponticorvo discussed how every dorm room has its own AC unit, so air conditioning can be controlled within the
room. Ponticorvo explained that as Community Director, she does not have access to heat control; heat settings are determined by the housing staff and the facilities crew. She also explained that her room has central air on a different system than the students who have radiators. Ponticorvo also indicated that she does not adjust her heat settings frequently, and did not even begin modifying her heat until November; she feels that the thermostats work effectively.

Furthermore, Ponticorvo informed us that the lounges in Ehringhaus have direct digital control (DDC) systems that allow temperature control and air-conditioning systems to be adjusted to any temperature at any time; heating, however, can only be turned on or off by residents. When asked if there are any problems with personal temperature control, Nicole mentioned that sometimes in the winter residents have set their AC too cold; this has frozen the systems, causing them to have to be replaced. She also noted that the majority of complaints regarding temperature are related to the building being too hot during the winter; during winter temperature is centrally controlled, so students cannot modify room temperature to their own preferences.

When asked if she had any questions or concerns, Nicole noted that it would be interesting to know more about how the heat is centrally controlled and who decides how it is regulated. However, she also said that she is generally comfortable with the building environment, and that she is perfectly content with how temperature is currently managed.

In addition to contacting building heads, we also contacted a team at the UNC School of Government that is currently working on a LEED-EB Operations and Maintenance project for Knapp-Sanders in order to ask about the data they have compiled and explore the potential of using the LEED-EB thresholds as a benchmark for our study of non-LEED buildings. We e-mailed the contact person, Malcolm Munkittrick, to inquire about the team’s methods for compiling energy data. We learned that one of the prerequisites for LEED-EB is achieving an EPA Energy Star rating of at least 69. After requesting that the Office of Energy Management input Knapp-Sanders’ energy information into Portfolio Manager and selecting a performance period, the team found that the building only achieved an Energy Star rating of 63. They are currently brainstorming ways to reduce energy consumption over the next year before re-applying in the future. We were able to use both the energy performance data for the period of September 2012 through September 2013, as well as the resulting EPA Energy Star rating for our analysis of Knapp-Sanders
VI. Analysis

Chart 8.1 Energy consumption per square foot of all nine buildings, 2013 data.

Chart 8.2 Total energy consumption of Genetics compared to all eight other buildings combined, 2013 data.
Chart 9.1 Average comfort score taken from occupant surveys and organized by building type. Comfort is measured on a scale of 1–4, with 4 being the highest.

Chart 9.2 Linear regression comparing EUIs and comfort ratings across all nine buildings.
1. Overarching Comparisons:
Of the three building use categories, labs consistently consumed the most energy both in total and per square foot. With the exception of Knapp-Sanders, C/A buildings consumed the least. While this was expected, what was surprising was the magnitude of Genetics’ energy consumption; it was equivalent to the other eight buildings combined. Additionally, both LEED buildings – Botanical and Genome – excelled among their use categories. Morrison was the only non-LEED building in the “high-performer” category and was also the only one of those three to not have the lowest energy consumption for its use. Instead, the lowest energy consumer of the dorms was Ehringhaus – the older building. In general, however, each of the C/A and residence hall buildings had low energy consumption compared to national averages.

In terms of comfort, while females reported being less comfortable on average than males, discrepancies between genders were small in both residence halls and C/A buildings. Labs showed the largest discrepancies, with females reporting the lowest comfort level of any use category. The difference between males and females, however, was still within 0.36 on a scale of 1 to 4. Overall, the lowest average comfort reported was in Genetics, which was also the highest energy consumer. The next two lowest comfort ratings belonged to Botanical and Genome – the two LEED buildings and smallest energy consumers for their respective use categories. Despite this finding, the overall trend shows a pattern of increased occupant comfort with increased energy efficiency.

2. Classrooms/Administrative:
According to Energy Star Portfolio Manager, the national EUI for offices is 148. Each of our three C/A buildings performed at or above this national baseline. Additionally, the buildings fell into the expected pattern with the high-performer consuming the least amount of energy and the older building consuming the most. Both Botanical and FedEx – the high-performer and newer building – consumed less energy than the national average. While Knapp-Sanders consumed the most, it was still on par with the average. This indicates that even our greatest energy consumer in the group is not consuming an abnormal amount of energy. Our small sample indicates that UNC is performing well in terms of energy consumption for C/A buildings. Occupant comfort, however, showed that buildings consuming less energy have lower comfort ratings. Botanical, in particular, displayed the second lowest satisfaction rating of all nine buildings. This indicates that energy use may not be well integrated with occupant comfort in the C/A buildings.

**NC Botanical Garden Education Center**
Botanical is the smallest building in this study in terms of square footage and also uses the least amount of energy per square foot at 28 kBtu/ft$^2$. Botanical has an EUI of 84.5, almost half the national median and is LEED Platinum certified. It consumes electricity but not district steam or chilled water, and the electricity goes towards activating two ground source heat pumps. This use of efficient heat pumps instead of district steam or chilled water contributes to Botanical’s low energy use. Another contributing factor is the solar photovoltaic (PV) array, which was projected to save 72 MBtu annually. Although Botanical is performing very well in comparison to other buildings on campus and nationally, it is actually under-performing in relation to its own proposed design, recorded on the LEED submittal templates. Currently the system is operating with the PV array, but exceeds the projected energy consumption that accounts for electricity
generated by the array. In 2013, Botanical’s electricity use totaled 910 MBtu, an amount that falls between the proposed electricity use with the array and the proposed electricity use without the array. It is unclear whether the building is using more electricity than the proposed design or if the PV array is simply operating at a lower efficiency than expected. Additionally, as Peter White noted, the heat pumps proposed for Botanical were not available during construction, and the alternative heat pumps may be responsible for the higher energy consumption.

More interestingly, one might expect a high level of occupant comfort in a LEED Platinum building as this is a core tenant of the certification standards. A significant amount of dissatisfaction, however, was expressed in comfort surveys conducted in Botanical. Seven out of 11 respondents noted a desire to have more control over the building’s temperature. With that said, most occupants were relatively comfortable in the building with an average comfort rating of 2.97 out of 4. This, however, may be largely contributed to the amount of available daylight as everyone reported access to natural daylight. In fact, while average comfort was 2.97, average overall satisfaction was 3.23. Moreover, from temperature readings taken within the building, we noted temperatures ranging from 60s to 80s, even in rooms where thermostats read 70, signifying that central control may not be provided with adequate information for making temperature adjustments. Many occupants complained that the building was too cold, even in summer. While increasing temperatures in winter to improve occupant comfort may result in more energy consumption, increasing temperatures in summer would save energy. This indicates that increasing occupant comfort through seasonal temperature adjustments may balance out and not have a large effect on overall energy consumption.

**FedEx Global Education Center**

FedEx is performing well above average with an EUI of 114.2. We also found that FedEx was only using 63 kBTu/ft² on average. Excluding Botanical, this is the lowest energy consumption per square foot of all the buildings in this study. FedEx was built in 2007 and uses a standard variable air volume handler with terminal reheat. This is the typical HVAC installation at UNC, and the building performs very well for this type of mechanical system. Part of this success can be attributed to the direct digital control of FedEx’s entire HVAC system given to UNC Energy Management, which allows for programmed efficiency. For instance, the temperature range widens during hours when the building is unoccupied, decreasing energy consumption. In addition, FedEx was built with several features that contribute to the building’s energy efficiency. Its green roof enhances energy and water efficiency through natural insulation and additional rainwater retention. The building also utilizes daylighting through increased window area. This increases natural lighting and passive solar heating. In general, occupants seemed to enjoy the building, as evidenced by its average comfort rating of 3.12 out of 4. However, when filtered by amount of time spent in the building, we found those who spent more than 12 hours a week in the building had an average comfort rating of 2.88, versus 3.44 for those who spent less than or equal to 12 hours a week. Thus, it would appear that occupants who are full-time employees or spend a substantial amount of time in the building are significantly less comfortable. In addition, a small group of respondents revealed that they do utilize space heaters and that at times the building is too cold, particularly in the winter.
Knapp-Sanders School of Government

Knapp-Sanders is on par with the national average energy consumption for buildings of its use type with an EUI of 127.5. Although Knapp-Sanders has a moderate EUI, its energy consumption based on square footage, 129 kBTU/ft², is almost double that of FedEx and is six times that of Botanical. It is also important to note that Knapp-Sanders was once three separate buildings and was renovated to create one building. This may lead to inefficiencies in air flow due to an abundance of small corridors and corners, and this inefficiency may contribute to its higher energy consumption. Additionally, of the three energy sources used at Knapp-Sanders, chilled water has the largest consumption, revealing that cooling and heating inefficiencies may be an issue worth researching further. Knapp-Sanders’ occupant surveys, however, showed the second highest level of occupant comfort of all buildings in this study. On average, the occupants of the building expressed a comfort level of 3.36 out of 4. Most intriguing about this level of comfort is that the average occupant in Knapp-Sanders spends 31 hours a week in the building, meaning the vast majority of the respondents were full-time workers. This high level of comfort for full-time workers contrasts with the lower comfort levels of full-time workers in the other C/A buildings.

3. Residence Halls:

According to Energy Star Portfolio Manager, the national EUI for dorms is 115. Carmichael was the only dorm with an EUI higher than the national average. Overall, residence halls ranked second among the three building types in terms of energy usage per square foot. Yet unlike the C/A group, the dorms did not follow the expected energy consumption pattern. The oldest building, Ehringhaus, had the highest energy efficiency, using only 67.40 kBTU/ft². Morrison, the “high-performer,” used 91.97 kBTU/ft². Carmichael consumed the most energy among the dorms at 157.78 kBTU/ft². However, it should be noted that due to Morrison’s size, it had the highest total energy consumption. As a result, building square footage played a large role in residence hall energy use; it is the only category to have a difference between the highest total consumer and per-square-foot consumer. Additionally, the largest source of energy consumption for all three residence halls was district steam, which was unique to this building type. This is likely due to the fact that dorms have a higher demand for steam to supply hot water for showering, sinks, laundry and other general residential purposes.

Based on occupant comfort survey results, the average comfort rating of residence halls was the highest of the three building types at 3.27 out of 4. Ehringhaus had the highest single average comfort rating among all buildings, at 3.37. However, we cannot assume that dorms are significantly better at meeting the comfort needs of occupants than other building types as their average comfort rating was only marginally higher than the C/A average rating of 3.15. The average comfort ratings for dorms also exhibited a wide range, from 3.08 and 3.37. It should also be noted that results may have been skewed by survey subjects who were apathetic about the survey or their building comfort in general. Moreover, residents may expect poor conditions when living in a dorm and know they will move out after one year. Nonetheless, survey results and feedback from building heads suggest that occupants are generally comfortable and content in their dorms.
Morrison Residence Hall
Morrison is the only building in the “high-performer” category that is not LEED-certified; however, it is the only dorm in this study that was built using LEED standards. While Morrison’s energy consumption is greater than that of Ehringhaus, it has an EUI of 111.4 and consumes slightly less energy than the national average for its building type. This can potentially be attributed to renovations that occurred in 2006, at which time a variable air volume handler with terminal reheat was installed to improve electricity efficiency. This new HVAC system provides centralized air-conditioning, as well as complete direct digital control (DDC) by UNC Energy Management. Morrison is also the only building on campus that has been equipped with rooftop solar thermal panels which contribute to a portion of the building’s hot water needs. Morrison’s energy consumption for heating water was totaled by adding district steam consumption and the energy produced by the solar thermal panels. The resulting total, 35.92 kBtu/ft², reveals that the building still consumes the least energy for hot water proportional to size. This low value reflects the building’s efficient systems, but also suggests that Morrison’s occupants may have greater awareness regarding energy efficiency. It is possible that many residents are more conscious of their hot water consumption simply due to the awareness that the building has garnered for being “green.” Additionally, the presence of real-time energy consumption monitors throughout the building may influence occupant behavior.

Temperature samples and occupant survey results revealed that Morrison is able to maintain fairly comfortable temperatures. During our site visits we observed that residents prop open their doors to take advantage of the days with fair weather, but the building still does a decent job of keeping temperatures near the thermostat set point during unfavorable weather days. Morrison also has occupancy sensors that prevent the building from heating or cooling common rooms that are not in use. Occupant surveys, however, revealed Morrison had the lowest comfort rating of dorms at 3.08. Yet this was only slightly below the overall average of 3.09 indicating that while Morrison may have lower comfort than the other dorms, the dorms are overall ranked highly. It is also important to keep in mind that Morrison’s lower comfort may result from the higher expectations that go along with being a “high performer.”

Carmichael Residence Hall
Of the three residence halls in this study, Carmichael was shown to be the least efficient at maintaining low energy consumption and temperature consistency, with an EUI of 170.1. Carmichael’s most recent renovation in 2008 included the installation of high quality fan coil units. This new energy efficient HVAC system has proven to reduce Carmichael’s humidity issues and energy use over the last four years, as evidenced by Energy Portfolio’s calculated EUI values from 2010 to 2013. In 2010, Carmichael’s EUI was 184.5 and steadily declined to 159 in 2013. However, some of the main factors causing increased energy demand in Carmichael can be attributed to the building’s design. Carmichael is comprised of three main, largely disconnected blocks of rooms which inhibit airflow throughout the entire building. Carmichael’s rectangular structure also houses hallways inside the building, whereas Morrison and Ehringhaus both have suite doors lining outside balconies. Thus, airflow in Carmichael may be hindered, and the building requires additional energy to heat and air-condition the indoor hallways. This was supported through temperature measurements that revealed Carmichael having the greatest range of temperature variation of the dorms. Specially, Carmichael showed clear increases in temperature at the building’s center, where large, unshaded glass windows expose the building’s
interior to sunlight. Temperature differences in the center room of each floor were very noticeable, and this likely leads to increases in air-conditioning demand during warmer months. The large unshaded windows in the hallways around the elevators also became significantly warmer on the hot days, with the highest recorded temperature being 97 degrees Fahrenheit. Interestingly, although Carmichael had large temperature variations, the occupants reported the highest level of comfort of all nine buildings, averaging 3.37 out of 4. This may be due to blinds provided in the dorm rooms that help those rooms that occupants spend the majority of their time in maintain more constant temperatures.

**Ehringhaus Residence Hall**

Ehringhaus exhibited the lowest total energy consumption among the three residence halls with an EUI of 71.4. Ehringhaus does not have a chilled water system and only consumes district steam and electricity. Yet, Ehringhaus’ electricity consumption is surprisingly comparable to Morrison’s. From 2010 to 2013, Morrison’s electricity consumption averaged 20.7 kBtu/ft², while Ehringhaus’ electricity consumption during that same period averaged 23.7 kBtu/ft². Despite such comparable rates of electricity consumption, the buildings currently have different HVAC systems. The majority of Morrison’s 35% reduction in energy use that occurred in 2010 was attributed to the installation of the new variable air volume handler with terminal reheat. This type of HVAC system is generally the standard for modern buildings on UNC’s campus. Ehringhaus, however, still uses radiators and window AC units, which generally tend to be less efficient. Because both Morrison and Ehringhaus were constructed with similar materials and design, the low energy consumption at Ehringhaus may be due to occupant behavior or other factors not examined in this study. For instance, Ehringhaus is positioned on campus in an area that is largely shaded by trees, whereas Morrison has more exposure to sunlight. Therefore, although its HVAC system is less efficient, it may not have as high a demand for cooling. Furthermore, it is possible that because residents of Ehringhaus have personal control of AC units in their rooms, they have learned to save energy by turning off their units when they are not present. However, this is only speculation and was not observed during visits or noted in any surveys. Temperature readings did show that Ehringhaus was able to maintain fairly comfortable temperatures, indicating that occupants may not need to adjust their systems frequently. Residents can also prop their doors open to take advantage of fair weather days, but we observed that the window units remained on in all of the rooms with open doors. Overall, temperatures seemed to be maintained at a rather comfortable level throughout the building. This was supported by occupant surveys that reported an average comfort of 3.24 out of 4. This was the 3rd highest average of all nine buildings. As a result, Ehringhaus is doing well in all fields measured: energy efficiency, temperature consistency, and occupant comfort.

**4. Laboratories:**

We were unable to obtain a baseline EUI for labs as they are grouped under “other,” a category that incorporates too broad a field of uses to make it specifically applicable to energy-intensive lab buildings. As a result, we were only able to compare the three lab buildings to the other six campus buildings in this study. As expected, labs averaged the highest energy consumption. Additionally, the buildings fell into the expected pattern, with the “high-performer” consuming the least amount of energy and the older building consuming the most. Yet, Genetic Medicine consumed a surprisingly large amount of energy with its total consumption equaling that of the
other eight buildings in the study combined. It should be noted, though, that Venable/Murray and Genome were not operating at full capacity which may influence their energy demand. Additionally, we were only able to obtain two years of energy data for Genome and three years for Venable/Murray, making it difficult to complete a comprehensive analysis. Occupant comfort in labs was also the most variable, especially between genders with females reporting an average comfort of 2.73 and males an average of 3.09 out of 4. Overall, Genetics had the lowest comfort ratings and Venable/Murray had the highest.

**Genome Sciences Building**

Genome is operating at an EUI of 371.7. While this value is relatively high in comparison with C/A buildings and dorms, it is the lowest of the three labs we studied. Energy data analysis also revealed that in 2013, Genome used only 214.74 kBtu/ft², much less than the other two labs. In 2013, Genome used a total of 47,437 MBtu, compared to its proposed design value of 63,277 MBtu and the baseline of 67,222 MBtu, as reported in the LEED submittal templates. This confirms that Genome is operating at a greater efficiency than originally projected. This is primarily seen in Genome’s significantly lower use of chilled water than projected. In 2013, Genome used 20,000 MBtu less than the proposed chilled water consumption, illustrating that one of Genome’s energy efficient systems is working effectively. While we cannot definitively attribute the low use of chilled water to Genome’s active chilled beam system, a large use of energy in both Venable/Murray and Genetics stems from their chilled water systems. Active chilled beams work to heat and cool large buildings by separating the heating and cooling of air from delivery. This allows a building to save energy and money by running fewer air circulation fans at lower speeds. Another important energy-saving system used in Genome is a low lab-space airflow. With a minimum of just six air changes per hour, this system enables the building to use less energy to maintain safe air quality. While the building’s energy use is low, survey results show Genome falls slightly below the average comfort of the buildings in this study. The average comfort rating for Genome was 3.05 out of 4, compared with the overall average of 3.09. Additionally, this rating is lower than the average for Venable/Murray. Therefore, while Genome does well to uphold LEED objectives involving energy efficiency, there is room for improvement in occupant comfort – another LEED objective.

**Venable/Murray Halls**

Venable/Murray has an EUI of 383.3, a number slightly above Genome’s EUI, but still about half that of Genetics. Of the three lab buildings investigated, Venable/Murray contains the most mixed-use space. It is interesting, therefore, that it has a higher EUI than Genome since it contains significantly less space devoted to purely laboratory use. Not only does Venable/Murray contain substantial classroom and office space, we observed it operating at roughly 90% capacity with the entire first floor of Murray Hall under construction. Due to its low occupancy and space devoted to labs, the building may be using energy less efficiently than its score indicates. In addition, occupant comfort surveys revealed an average comfort rating of 3.17 out of 4. This was the highest rating of any lab building, and the sixth highest of the nine buildings. Many respondents reported that Venable/Murray was “better than most” when compared to other campus buildings. Through further investigation, our temperature readings revealed that of all the labs, Venable/Murray’s ambient air temperature was the most consistent across the entire building. As a result, Venable/Murray shows positive performance for its use category among all aspects that we measured: energy use, occupant comfort, and temperature measurements. Given
its current occupancy, however, a follow-up with Venable/Murray’s utility bills under full capacity may provide a better analysis of its energy consumption.

**Genetic Medicine Building**

Genetic Medicine Building’s energy consumption proved to be extremely high with an EUI of 717.2, nearly double the EUIs of both Genome and Venable/Murray. Further analysis revealed that Genetics is using approximately 468.71 kBtu/ft². This is 100 million more kBtu per year than both Venable/Murray and Genome. Although this appears to be an excessive rate of energy consumption, there are several potential explanations for the discrepancy between Genetics and the other two lab buildings in this study. The building encompasses approximately 100,000 more square feet than the other lab buildings, and it is currently operating at 100% capacity. Within Genetics, the primary usage is lab and office space, with little other mixed-use space. It is important to note that, according to Chris Martin of UNC Energy Management, scientific research taking place in the building comprises the largest scientific revenue stream for the university via grants and patents. This indicates a potential barrier to reducing energy, as it will likely be neglected by UNC as long as it brings in significantly more revenue than it spends.

Another important factor contributing to the overall performance of Genetics is occupant comfort. Genetics was by far the worst performing building in terms of comfort, with an average rating of 2.48 out of 4. The other lab buildings, Venable/Murray and Genome, together had an average comfort rating of 3.11 out of 4. This means Genetics was 20% less comfortable than other labs buildings we analyzed. Notably, only 1 out of 28 respondents used the building less than 40 hours a week. Moreover, seven occupants wrote complaints in the comments section about ventilation and air flow. Another fifteen complained of the temperature being too cold, even in summer. This reveals Genetics has significantly poor satisfaction for full-time workers, especially concerning the ventilation and temperature.
VII. Recommendations

1. Classrooms/Administrative:

*Leverage energy efficiency success with a stronger emphasis on occupant comfort*

From the data collected, we determined that the C/A buildings are performing above or beyond the baseline established by Energy Star, yet there are still discrepancies between efficiency and occupant comfort. To compensate for the extreme temperature ranges, occupants of C/A buildings often resort to using personal space heaters, potentially offsetting any energy savings created by the overall building temperature settings. For Botanical, consider giving more control to occupants by allowing them to adjust indoor temperatures by a few degrees. Similarly, consider giving FedEx occupants more control over their indoor temperature to avoid the unnecessary use of space heaters. For Knapp-Sanders, keeping doors that link the main parts of the building open will help distribute heating and cooling efforts in the building more efficiently by preventing temperature buildups behind closed doors.

2. Residence Halls:

*Further investigate why Ehringhaus is so efficient*

The fact that Ehringhaus, the oldest building analyzed in this study, used the least amount of energy per square foot of all the residence buildings was a surprise. Further investigation into reasons for this occurrence could potentially inform solutions for improving other residence halls. One possible reason for Ehringhaus’ high efficiency might be the window units and radiators; these do not dehumidify the air like central HVAC systems, and dehumidifying can be a significant energy draw. Other explanations could include the behavior of the occupants or the building’s location where it is surrounded by trees. Additionally, only some of the residence halls are occupied during the summer. It is possible that the much higher energy use in Carmichael is largely accounted for by its use during the summer while the other residence halls are unoccupied. Investigation into the energy use during the summer season could help determine the role that summer occupancy plays on the buildings’ annual energy consumption. Overall, occupants were fairly satisfied with the dorms. However, various low-cost actions could be implemented in order to help reduce energy consumption and increase occupant comfort. One such action could be installing shades in the hallways and common areas in Carmichael. This would reduce direct sunlight and prevent the overheating of these spaces.

3. Laboratories

*Prioritize energy efficiency during the design and planning phase for future lab buildings and pursue LEED standards*

Since labs are the most energy intensive, efficiency must be made a greater priority for these buildings. The Department of Energy Management should implement more energy efficient systems within lab buildings and educate regular occupants on ways to save energy. Additionally, Genome should be looked into as a first step for designing labs that promote energy conservation and efficiency. Genome is LEED Gold certified, signifying that many hours of planning were dedicated to making this building energy efficient; however it is worth noting, as referenced earlier, that Genome only achieved 3 out of 17 possible points in LEED’s “Energy and Atmosphere” category, indicating that there is room for improvement. This may be due to the difficulty planners can have with anticipating the energy loads of labs as demonstrated in the
University of Minnesota study. However, the low airflow lab design with a minimum of 6 air changes per hour and chilled beams appears to be working effectively. It is important to note that this does not necessarily imply that these specific design decisions are right for other lab buildings since each is designed according to the type of laboratory activities that take place. Additionally, it is worth acknowledging that buildings as complex as labs are difficult to renovate. Due to this complexity, the planning process for lab buildings is critical. This added challenge, in addition to the difficulty of predicting lab energy demand, emphasizes the significance of Genome’s design as a first step toward improving the design of lab buildings on UNC’s campus. Due to the importance of energy efficiency for labs and the complex design process, LEED certification currently appears to be worth the time and money for this category of building use. One thing to note, however, is that Genome is not currently operating at full occupancy. Future studies, therefore, may be needed to further confirm these findings.

**Address poor occupant comfort in all lab buildings**

Along with a greater focus on energy efficiency, the lab buildings should make occupant comfort and satisfaction more of a priority. Labs in particular received significant negative feedback throughout our surveys, specifically related to temperature and ventilation. In Genetics, one man reported being so uncomfortable he had to stop working and go home. Occupant feedback should provide the basis for learning how to make future lab buildings more accommodating of occupants, whether through increased amenities or improved air flow. For instance, the Department of Energy Management could consider either increasing temperature, as occupants consistently reported temperatures being too cold, or provide personal control in individual office spaces. Additionally, adjusting the ventilation in Genetics would improve comfort as many of the occupants complained of the smell near lab holding areas. Further analysis into reasons for discomfort in labs could provide more specific insight.

**Address poor overall building performance in Genetic Medicine Building**

As Genetics had the worst combination of energy efficiency and occupant comfort, the Department of Energy Management should devote special attention and effort to improving the performance of this building. As mentioned earlier, significant energy usage in labs is inevitable. As a result, consideration should be given to pursuing energy efficiency in other ways. This might include structural changes to the building, such as upgrading Genetics to LEED standards as was accomplished with Morrison. As Genetics is very large in size, it is important to note that even a small reduction in its energy use would have significant impact. Further research and investigation should be done into potential ways in which the building can reduce its energy demands without sacrificing occupant comfort or equipment functionality.

**Encourage more energy awareness and promote a culture of conservation**

Often cited as centers of innovation that bring significant funding and grant money to the University, these buildings still have an obligation to contribute to UNC’s efforts to save energy. A potential strategy for the Department of Energy Management to consider would be making an effort to raise energy awareness within these buildings. For lab buildings specifically, the Department of Energy Management could consider establishing energy usage goals. In general, occupants should be encouraged to make an effort to get as close to this lower energy consumption goal each month as possible. These standards could be carried out as requirements or through a competition. As competition drove both renovations and occupant behavior
adjustment in Morrison, this type of strategy may also prove effective for Genetics. Additionally, simple actions such as ensuring that fume hood sashes are closed can significantly reduce energy, as found by the study conducted at the California Institute of Technology.

4. Future Data Collection

Streamline future data collection

In order for more thorough future analyses and continued monitoring, it is important to make sure all necessary energy data is accessible. Between UNC’s two resources – UNC Energy Dashboard and the data on file with UNC Energy Management – we discovered that a significant amount of data is not closely monitored. For instance, Energy Dashboard only takes data in 15 minute increments. A step for improvement in this area would be to make sure that information is up to date by entering it into the system on a more regular basis. Entering the data incrementally will help cut down on gaps in the available data and keep it current. Also, analyzing the contents of UNC’s Energy Dashboard and comparing it to the official UNC Energy Management data would reveal which access points are accurate and could cut down on the need for manual entry.

Ensure energy data is available for every building

One of our main struggles throughout this investigation was with determining a list of buildings which could be compared. Difficulties were partially due to a lack of complete energy data on some of the buildings we originally selected. Although we went through approximately fifteen to twenty campus buildings before settling on our final nine, some of our required data was still unavailable. The main example is Knapp-Sanders. With Knapp-Sanders, we were originally given no electricity data on the building. Upon a later request, we were given one year of electricity data for the building. Whether this data had merely not been compiled at the time of original inquiry is unknown, but it demonstrates the overarching problem that complete data is not readily available for all campus buildings.

Another step for UNC Energy Management to take is to break up buildings that share meters where applicable. Shared meters often gave one total of energy data for two or more buildings. Moreover, some energy meters on the Energy Dashboard are shared but not designated as such, making some buildings appear significantly more energy intensive. It is therefore impossible to know exactly how much energy each individual building is actually using. Assigning each building its own meter would create a more accurate monitoring system. Finally, ensuring that this data is readily available to UNC and affiliated individuals is important in providing transparency and greater access. Greater accuracy would have made our research and analysis more comprehensive and should be a priority for the future.
VIII. Conclusions

UNC Chapel Hill is a large university campus with many buildings built over hundreds of years, incorporating a wide range of systems, styles, and uses. As environmental responsibility becomes an increasingly important part of the university’s mission, the energy performance of its buildings is of concern. This study investigated the energy performance of nine buildings of varying ages and uses in order to gauge whether performances were meeting expectations. We found this to generally be the case. Speculation as to why some buildings performed better or worse than expected raises questions about factors such as location, intrinsic higher use intensity, and HVAC system differences.

As for location, while the buildings are all located in Chapel Hill which controls for climate, buildings differ in factors such as exposure to direct sunlight, which may make a significant difference in energy efficiency. For example, Ehringhaus had the lowest energy consumption of the three residence halls studied and is also surrounded by trees.

Building usage differed in ways that may also be significant. For the three labs we studied, some have a higher concentration of laboratories and are at full occupant capacity while others have a larger proportion of classrooms and are not entirely filled yet. Additionally, only one of the three residence halls we studied, Carmichael, is occupied during the summer.

HVAC systems also had a great deal of variation in age and incorporation of other aspects such as dehumidification, which can greatly influence energy consumption. Additionally, while occupant surveys revealed the buildings with the three lowest occupant comfort ratings to be both the highest and lowest energy consumers – Genetics, Botanical, and Genome – there was a slight overall correlation between increased energy efficiency and increased occupant comfort. Overall, the buildings investigated displayed relatively high levels of performance when compared to the national median and also had relatively high occupant satisfaction. The LEED buildings also proved to consume energy at or below their proposed levels.

While these performance results are encouraging, UNC Energy Management can use these findings and recommendations to implement specific energy saving measures and occupant comfort improvements in the nine buildings highlighted in this study, as well as extrapolate these findings to cover others on campus.
IX. Works Cited


X. Appendix A. Building Floor Plans with Temperature Readings

Graphic 1.1 Botanical Garden Education Center First Floor

Actual Temperature Readings
1st Day: 3/4/14 (30° outside, sunny)
Indoor temp; reading marked in BLUE
2nd Day: 4/1/14 (70° outside, partly cloudy)
Indoor temp; reading marked in GREEN

*Notes: Thermostats in each room are readable. The first day every thermostat read 70, although temperatures varied. The second day, the thermostats were more accurate.

Graphic 1.2 Botanical Garden Education Center Second Floor

Actual Temperature Readings
1st Day: 3/4/14 (30° outside, sunny)
Indoor temp; reading marked in BLUE
2nd Day: 4/1/14 (70° outside, partly cloudy)
Indoor temp; reading marked in GREEN

*Notes: Thermostats in each room are readable. The first day every thermostat read 70.
Graphic 2.1 FedEx Global Education Center First Floor

Notes: No thermostats (readable or controllable). Workers do not have control over thermostats. Temperature gun died on the first day so number of readings was limited.

Graphic 2.2 FedEx Global Education Center Second Floor

Notes: No thermostats (readable or controllable). Workers do not have control over thermostats. Temperature gun died on the first day so number of readings was limited.
Graphic 2.3 FedEx Global Education Center Third Floor

*Notes: No thermostats (readable or controllable). Workers do not have control over thermostats. Temperature gun did not function on the first day so number of readings was limited.

Graphic 2.4 FedEx Global Education Center Fourth Floor

*Notes: No thermostats (readable or controllable). Workers did not have control over thermostats. Temperature gun did not function on the first day so number of readings was limited.
*Notes: Thermostats in each room are controllable, but cannot read temperature.

Graphic 3.1 Knapp-Sanders Building First Floor

Graphic 3.2 Knapp-Sanders Building Second Floor
Graphic 3.3 Knapp-Sanders Building Third Floor

Graphic 4.1 Morrison Residence Hall First Floor
Graphic 5.1 Carmichael Residence Hall First Floor

Graphic 5.2 Carmichael Residence Hall Third Floor
Graphic 5.3 Carmichael Residence Hall Sixth Floor

Graphic 6.1 Ehringhaus Residence Hall Ground Floor
Graphic 6.2 Ehringhaus Residence Hall Third Floor

Graphic 6.3 Ehringhaus Residence Hall Sixth Floor
Graphic 7.1 Genome Science Building Ground Floor

Graphic 7.2 Genome Science Building First Floor
Actual Temperature Readings
1st Day: 3/20/14 (50° outside, sunny)
Indoor temp; reading marked in BLUE
2nd Day: 4/3/14 (60° outside, sunny)
Indoor temp; reading marked in GREEN

Graphic 7.3 Genome Science Building Second Floor

Actual Temperature Readings
1st Day: 3/20/14 (50° outside, sunny)
Indoor temp; reading marked in BLUE
2nd Day: 4/3/14 (60° outside, sunny)
Indoor temp; reading marked in GREEN

Graphic 7.4 Genome Science Building Fourth Floor
Graphic 8.1 Venable/Murray Halls Ground Floor

Actual Temperature Readings
1st Day: 3/20/14 (50° outside, sunny)
Indoor temp; reading marked in BLUE
2nd Day: 4/3/14 (60° outside, sunny)
Indoor temp; reading marked in GREEN

Venable/Murray Halls
Ground Floor Plan
Bldg. #745/#674

*Note: Lots of sunlight through window

Graphic 8.2 Venable/Murray Halls Second Floor

Actual Temperature Readings
1st Day: 3/20/14 (50° outside, sunny)
Indoor temp; reading marked in BLUE
2nd Day: 4/3/14 (60° outside, sunny)
Indoor temp; reading marked in GREEN

Venable/Murray Halls
Second Floor Plan
Bldg. #745/#674
*Note: Lab room with upper-60 degree measurements contains a mass spectrometer (huges heat source that they offset with lower temperatures).

Actual Temperature Readings
1st Day: 3/20/14 (50° outside, sunny)
Indoor temp; reading marked in BLUE
2nd Day: 4/3/14 (60° outside, sunny)
Indoor temp; reading marked in GREEN

Graphic 8.3 Venable/Murray Halls Third Floor

Graphic 9.1 Genetic Medicine Building First Floor
Graphic 9.4 Genetic Medicine Building Fifth Floor
XI. Appendix B. Occupant Comfort in Campus Buildings Survey
Thank you for participating in this study conducted by students from UNC-Chapel Hill and supervised by faculty. This study seeks to understand how occupant comfort varies across campus building design. All responses are anonymous. If you have questions, please email ssnc21@live.unc.edu

Occultant Comfort in Campus Buildings Survey

1. What is your status?  
   undergraduate  graduate  faculty  staff  other

2. What do you use this building for? (Circle all that apply)  
   class  office  studying  living space  lab  work

3. How many hours per week on average do you spend in this building?  

4. Is this a LEED Certified building?  yes  no  I do not know

5. Do you know how the temperature is managed in your building?  
   yes / no : if yes then how:  
   personal control  central control  no control  unknown

6. How often do you adjust the thermostat in your building? If never, skip section  
   more than once a day  once a day  2-4 times a week  once a month  once a year

7. How often do you use a space heater in this space? If never, skip section  
   **Summer**  
   more than once a day  once a day  2-4 times a week  once a month  once a year  
   **Winter**  
   more than once a day  once a day  2-4 times a week  once a month  once a year  
   **Spring**  
   more than once a day  once a day  2-4 times a week  once a month  once a year  
   **Fall**  
   more than once a day  once a day  2-4 times a week  once a month  once a year

8. How often do you use a fan in this space? If never, skip section  
   **Summer**  
   more than once a day  once a day  2-4 times a week  once a month  once a year  
   **Winter**  
   more than once a day  once a day  2-4 times a week  once a month  once a year  
   **Spring**  
   more than once a day  once a day  2-4 times a week  once a month  once a year  
   **Fall**  
   more than once a day  once a day  2-4 times a week  once a month  once a year
9. Rate how comfortable you are in the building on average for each season (1-4; 1 being very uncomfortable, 2 uncomfortable, 3 comfortable, 4 being very comfortable)

<table>
<thead>
<tr>
<th>Season</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Winter</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Spring</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Fall</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

10. Do you have access to natural light in your space?
   yes / no

11. How often do you utilize the natural light from the windows instead of electric lights?
   never | occasionally | sometimes | often | always

12. When you are working in this building, do you find that this space prohibits your productivity in any way?
   If yes, please explain:

13. What is your overall satisfaction with this building? (1-4; 1 being very unsatisfied, 2 unsatisfied, 3 satisfied, 4 being very satisfied)

<table>
<thead>
<tr>
<th>Season</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Winter</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Spring</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Fall</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

14. How would you compare its comfort with other campus buildings?

15. Is there anything about this building you would like to change?

16. Any other comments or observations concerning your building environment?

Thank You
XII. Appendix C. Individual Building White Papers
The Botanical Garden Education Center was built in 2007 and houses operations in 2010. It houses a visitor center, office space, and classroom space. The center was the state’s first public LEED Platinum building and was projected to use 4% less energy than a traditional building. The building uses two ground source heat pumps and a solar PV system. Because the original heat pumps suggested by the architect were unavailable, the university opted instead for models that were less responsive to humidity changes. As a result, the building underwent renovations a few years later to add a dehumidifier to the ventilation system. Occupant control of temperature was a key selling point of the original plan. However, the temperature has always been centrally controlled by UNC facilities.

Energy Data
The Botanical Garden Education Center consumed a total of 910.7 mBtu last year, slightly below its average of 943.1 mBtu. While the classroom/administrative category of this study had the lowest energy consumption values of the three categories, the Botanical Garden building consumed significantly less than both Fed-Ex and Knapp-Sanders, making it the lowest energy consumer of the nine buildings. In terms of energy consumption per square foot, Botanical again was the lowest consumer at 28 kBtu. The building uses about half of the energy of its baseline, and is consuming more than projected with the solar PV arrays.
**TEMPERATURE DATA**

<table>
<thead>
<tr>
<th>Temperature Measurements (°F)</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor Temp</td>
<td>30°</td>
<td>70°</td>
</tr>
<tr>
<td>High</td>
<td>73°</td>
<td>78°</td>
</tr>
<tr>
<td>Low</td>
<td>62°</td>
<td>66°</td>
</tr>
<tr>
<td>Average</td>
<td>68.9°</td>
<td>70.6°</td>
</tr>
</tbody>
</table>

Temperatures averaged in the lower 70s. The main visitors center experienced a temperature gradient, with warmer temperatures closer to the south-facing windows. Upstairs offices could get as warm as 78° as the day 62, although thermostats read 7° degrees. The classrooms varied between 6° and 7°, with the colder classrooms having been used less recently.

**KEY INFORMANT INTERVIEWS**

*Peter White, Director of NC Botanical Gardens and Jim Ward, Director of Horticulture*

Both White and Ward explained how the original vision for the building has not been entirely upheld. The different heat pump models have resulted in humidity issues and user control over the thermostats has never been realized. While Ward believes in the need for thermostat control, he has not been trained to use it. According to Ward, occupants were given a link to an online view of real-time temperatures that did not work and has never been fixed.

**OCCUPANT SURVEY RESULTS**

While most occupants enjoy the Botanical’s abundance of windows and natural lighting, some say their productivity is hindered by cold indoor temperatures and their inability to adjust the thermostat as promised. Most occupants use space hats, especially during fall and winter.

“Love opening the windows.”

Occupants frequently contact UNC facilities to adjust temperatures. Classrooms, especially, are kept cold when unoccupied and are only warmed prior to lessons. Overall, occupants are generally satisfied with the building, and all survey respondents were aware that it is LEED Platinum certified.

“Wish we had control over the thermostats.”

**SUMMARY OF RESULTS**

- **Energy**: Consumption on par with projections, due to renewable energy production.
- **Temperature**: Not always consistent with thermostats.
- **Comfort**: Occupants generally satisfied, but desire more control over temperatures.

Generally, occupants feel happy and productive, but sometimes cold temperatures and lack of control may affect comfort.

**RECOMMENDATIONS**

1. PROVIDE INFORMATION TO OCCUPANTS ON HOW TO CONTROL THE TEMPERATURE WITHIN A FEW DEGREES.
2. UPDATE FLOOR PLANS SO THAT ROOM NUMBERS MATCH WITH UNC FACILITIES’ MAPS.
3. PROVIDE WEBSITE THAT SHOWS REAL-TIME TEMPERATURES, AS PROMISED.
FedEx Global Education Center
AN ANALYSIS OF ENERGY EFFICIENCY, TEMPERATURE, AND OCCUPANT COMFORT

INTRODUCTION & OVERVIEW
Completed in 2007, UNC’s FedEx Global Education Center is a mix of both office and classroom space. The building houses numerous UNC departments and offices dedicated to global learning. Designed by Leers Weinzapfel Associates, the building uses harvested rainwater for flushing to conserve water. FedEx is also home to a green roof that enhances energy and water efficiency through natural insulation and additional rainwater retention. The building also contains a massive amount of space that utilizes natural daylighting through increased window area. The decreased necessity for artificial light creates a more energy efficient building through natural lighting and heating.

ENERGY DATA
FedEx Global Education center has a current source energy use intensity (EUI) of 102.6 kBTU per square foot. The estimated annual energy consumption from district steam, district chilled water, and electricity usage for the past twelve months. Between 208 and 212, the building had an average source EUI of 103.86 kBTU/sq.ft., though this value has been trending upward in more recent years. FedEx also has a current Energy Star score of 97, compared with a baseline score of 96. This number suggests that the building is among the highest performers for office buildings, performing better than 9% of similar buildings nationwide.
TEMPERATURE DATA

<table>
<thead>
<tr>
<th>Temperature Measurements (°F)</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor Temp</td>
<td>30°</td>
<td>70°</td>
</tr>
<tr>
<td>High</td>
<td>72°</td>
<td>74°</td>
</tr>
<tr>
<td>Low</td>
<td>70°</td>
<td>70°</td>
</tr>
<tr>
<td>Average</td>
<td>70.8°</td>
<td>73°</td>
</tr>
</tbody>
</table>

Temperatures averaged in the low to mid 70’s. The temperature of the open lobby space was consistent throughout all three floors, revealing that heat is dispersed relatively evenly throughout the large area. Office temperatures varied by room, with two particular interior rooms sharing a common wall showing a four degree difference. One room was using a fan while the other was using a space heater, so the actual difference could be much greater than observed.

OCCUPANT INTERVIEWS

While key informant interviews proved unsuccessful for FedEx, many occupants provided insights during the survey process. We learned that a sizeable amount of the full-time building occupants cope with temperature fluctuations using space heaters and fans. Several of the occupants interviewed even spoke of utilizing space heaters in the summer to counteract the low building temperatures.

Lane Adams, of UNC Energy Management, noted that FedEx has experienced envelope issues around the damper in the atrium. While the building has been renovated to address the issue, insulation may still be an issue around this area.

OCCUPANT SURVEY RESULTS

Most of the students who occupy the building for classes a few hours per week are very pleased with the building. However, those who have offices and work full time are less comfortable with the varying temperatures and the dysfunction of the thermostats. This difference in comfort level is visible in the survey results, as respondents who spent between 0 and 20 hours per week in the building had an average comfort rating of 3.36 (out of 4 per season), and those who spent 20 hours or more had an average comfort rating of 2.83 per season.

“I’d hoped that a new building would be a great advantage. But budgetary constraints resulted in poor planning and shortcuts that have seriously undermined comfort.”

SUMMARY OF RESULTS

FedEx is very energy efficient as evidenced by its outstanding Energy Star score and EUI.

While temperatures did not fluctuate greatly and the EUI is good, it seems as though occupant comfort has been sacrificed for energy savings.

RECOMMENDATIONS

1. WORK WITH OCCUPANTS TO DETERMINE DESIRED TEMPERATURE RANGES.
2. TAKE HEAT GAIN FROM NATURAL LIGHTING INTO ACCOUNT WHEN REMOTELY ADJUSTING TEMPERATURES.
3. MAKE OCCUPANTS MORE AWARE OF TEMPERATURE SETTINGS AND WHAT THEY ARE ABLE TO CONTROL.
Knapp-Sanders School of Government:

An Analysis of Energy Efficiency, Temperature, and Occupant Comfort

Introduction & Overview

Knapp-Sanders houses U C's School of Government. The building is also home to many classrooms and offices where students and staff, as well as elected and appointed officials, research the latest developments within their field. Knapp-Sanders was most recently renovated in 2004, which resulted in 21 new classrooms, an expanded library, a dining area, and a 3-story atrium. Currently, efforts are being made by another UNC team to attain LEED for Existing Buildings Certification (LEED-EB). One of the prerequisites for this certification is attaining an EPA Energy Star rating of at least 69 through Portfolio Manager. Based on their selected energy performance period, the team found that the building only received a rating of 63. They are currently brainstorming ways to reduce the building's energy consumption over the next year before re-applying for the future.

Energy Data

It should be noted that only one year of electricity data was available to analyze the energy use and efficiency of Knapp-Sanders in its entirety. Using this data, we determined that the building's Energy Use Intensity (EUI) score was 148.4 from April 2012 to the end of March 2013. This was on par with the national median EUI score of 148.1.

Knapp-Sanders Energy Consumption 2009-2013

- District Water
- Electricity
- Chilled Water

[Graph showing energy consumption from July 2009 to December 2013]
TEMPERATURE DATA

Temperatures were taken in small offices that were most representative of the area where the majority of building occupants spend their time.

Classrooms were also selected to sample the spaces where large quantities of students are present for shorter periods of time throughout the day.

Temperature samples from the building followed no apparent pattern. There were, however, buildups of air pockets with large temperature differentials created by doors or walls separating spaces. As described by faculty and staff within the building, oftentimes doors will be closed between areas that link different parts of the building. This results in large buildup of heat, and consequently, pockets of cold air on the other side of the door. This reveals that heat meant to reach occupants in certain areas of the building does not always arrive, and thus results in the overheating of other areas.

SUMMARY OF RESULTS

While performing on par with similar office spaces nationally, Knapp-Sanders is less efficient than other campus buildings.

<table>
<thead>
<tr>
<th>Temperature Readings</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>80°</td>
<td>75°</td>
</tr>
<tr>
<td>Low</td>
<td>67°</td>
<td>66°</td>
</tr>
<tr>
<td>Average</td>
<td>72.8°</td>
<td>71.9°</td>
</tr>
</tbody>
</table>

Temperature readings collected from the building followed no apparent pattern.

Generally, occupants are comfortable, though some noted it is too cold in some parts of the building and too hot in winter.

Though most occupants are comfortable, data suggest that this is aided through the use of space heaters in the summer, and by preventing airflow through certain parts of the building with coiled doors.

RECOMMENDATIONS

1. **Keep doors linking main parts of building open to create better airflow, and prevent the buildup of temperature pockets.**

2. **Use less air conditioning in summer and less heat in winter.**

3. **Allow occupants to adjust thermostats within two degrees.**

Occupant Survey Results

Overall, individuals surveyed in Knapp-Sanders were relatively satisfied with their building. Survey results concluded that people were the most comfortable in the fall and spring, grading their buildings on average a 3.4 on a 4-point scale (1 being very uncomfortable, 4 being very comfortable). Comfort ratings dropped to 3.3 during summer and winter months, but still stayed above the ‘comfortable’ margin. A few people noted the need for space heaters in the summer, mentioning the more extreme temperatures during the winter and summer seasons.

“Want thermostats that are easier to adjust.”
Morrison is an award winning South Campus residence hall and home of UNC’s Sustainability Living Learning Community. It has earned multiple awards, including the top energy reducer (18% reduction) in the 2013 Campus Conservation N tionals and winning the EPAs first National Building Competition in 210 . The dorm has ten stories, and each floor has balconies leading out to suites of four separate wings. These balconies comprise a significant portion of the dorm’s floor space that is not being air conditioned or heated. Morrison also uses 172 rooftop solar thermal panels for hot water heating. The building also uses real-time consumption meters to monitor electricity, steam, and chilled water use in each of the building’s twelve zones.

Energy Data

Morrison is almost 50 years old, despite undergoing renovations in 2006. In 2013, it used 5,121,234.6 ktu of electricity, which is approximately 23.5 ktu per square foot. Though this is the highest per square foot for any dorm on campus, it is also the largest dorm. Morrison uses significantly less energy per square foot than Carmichael, and a similar quantity to Ehringhaus, which is built in a similar style. Steam and chilled water use showed higher efficiency than the other dorms used for comparison. Morrison used 32.5 ktu per square foot for chilled water, and 35.9 ktu per square foot for steam.
TEMPERATURE DATA

<table>
<thead>
<tr>
<th>Temperature Measurements (°F)</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor Temp</td>
<td>42°</td>
<td>75°</td>
</tr>
<tr>
<td>High</td>
<td>78°</td>
<td>81°</td>
</tr>
<tr>
<td>Low</td>
<td>55°</td>
<td>70°</td>
</tr>
<tr>
<td>Average</td>
<td>68.8°</td>
<td>69.7°</td>
</tr>
</tbody>
</table>

A considerable amount of Morrison’s floor space is air-conditioned balconies, with doors leading into each suite. On nice days, these doors are often left open, even if the heat or air-conditioning is running. Temperature measurements ranged from the mid-50s in occupied interior common rooms, to low 80’s in the bathrooms exposed to warm outdoor air. Occupied spaces tended to be at a comfortable level, around standard room temperature, with the most variation coming from the small rooms containing the vending machines, which revealed a sixteen-degree range.

KEY INFORMANT INTERVIEWS

Lane Adams, Manager UC Energy Management Department

Though the selected key informant from Morrison was unavailable for interview, we were able to gain additional insights about the dorm from Lane Adams of UNC Energy Management. According to Adams, Morrison is the only one of the four South Campus dorm towers to have centrally controlled temperatures. This central control is a much more efficient method of managing temperatures, and would reduce Morrison’s energy use.

SUMMARY OF RESULTS

Relatively low energy consumption at 23.5 kBTU/sqft. Energy Star score of 86.

Energy

Temperatures are affected by location of rooms and exposure to outside air.

Temperature

Residents were generally pleased with the building, and desire additional sustainable features.

Comfort

This award-winning residence hall is a high energy performer with a fairly consistent temperature range and satisfied occupants.

RECOMMENDATIONS

1. PROVIDE REMINDERS FOR RESIDENTS TO BE MINDFUL OF LEAVING DOORS OPEN WHEN HEAT OR AIR CONDITIONING IS RUNNING.

2. KEEP AREAS WITH HIGH ELECTRICAL LOADS, LIKE THE VENDING MACHINE ROOMS, WELL-VENTILATED TO REDUCE TEMPERATURE VARIATION.

3. IMPLEMENT MORRISON’S SUCCESSFUL ENERGY SAVING INITIATIVES IN OTHER RESIDENCE HALLS.

“THERMISTORS CAN BE USED TO INDICATE THE TEMPERATURE IN THE ROOM FOR MORE ACCURATE CONTROL.”

“Very neat, fresh.”

I want more control of heating ad a r.”
CARMICHAEL:  
AN ANALYSIS OF ENERGY EFFICIENCY, TEMPERATURE, AND OCCUPANT COMFORT

INTRODUCTION & OVERVIEW

Carmichael is a six-floor student dormitory building, which was completed in 1986. The dorm currently houses 485 residents. Carmichael home to mostly underclassmen, who reside in 13' by 18' style dorm rooms with interior corridor access. Carmichael also houses one living-learning community, UNITAS. Central HVAC controls the heating and cooling for the rooms. It was most recently updated in 2008, and usually provides housing for summer months. The buildings located on Stadium Drive on mid-campus, which overlooks the pool, soccer field, and various other sports facilities.

ENERGY DATA

At 157.7 kBTU per square foot, Carmichael was the last energy efficient of all the buildings in this study, excluding the labs. However, low performance in residence halls is not inherent to their design, as comparable buildings on campus are using significantly less energy. In 213, the building used 17,023,877 kBTU of energy for chilled water district steam and electricity. On average, the building uses twice a much chilled water and district steam than electricity. Since 2009, total energy consumption has been decreasing marginally. However, variations in consumption among the three types of energy use between years does not reveal a consistent decrease in any one type.
In C. Michael, we observed thermometers that were set at constant temperatures throughout the building, with temperatures increasing with floor number. In colder weather, temperatures in rooms with large windows were lower than average. However, these spaces heated up much more quickly than less-exposed rooms when outdoor temperatures were high.

Additionally, Carmichael has obvious increases in temperature at the building’s center, where large, unshaded glass windows expose the building’s interior to solar night. Temperature differences in this area on each floor are very noticeable, and this undoubtedly increases air conditioning demand during warmer months. This area becomes significantly warmer on hot days, with our highest recorded temperature at this location being 90 degrees Fahrenheit.

The shaded lunge, while still rather warm, were cooler than the hallways, maintaining temperatures in the mid-70s. Each dorm room also appeared to maintain a more comfortable temperature despite shades that block direct daylight. However, several fans were observed in the dorm rooms as well.

**SUMMARY OF RESULTS**

| Building ranked 4 out of 9 for energy consumption—the highest of all non-lab buildings. |
| Temperature increases up through the building, and varies the most around large windows. |
| Highest level of occupant comfort of all buildings with an average rating of 3.37 out of 4. |

Carmichael occupants are comfortable and satisfied in the building, but energy efficiency performance remains quite low.

**RECOMMENDATIONS**

1. **Install occupant sensors to decrease instances of wasted heating/cooling/lighting.**
2. **Add blinds to large windows near elevators to reduce extreme temperature fluctuations.**
3. **Limit thermostat variability to a more narrow range to reduce energy consumption but still provide some occupant control.**

Most survey respondents were underclassmen living in the dorm. Although most feedback reflected desire to have larger rooms, residents were generally comfortable year round. Because occupants have personal control over their room temperatures, the bathrooms and hallways were more frequently criticized for less comfortable temperatures. In addition, the office occupants reported that it is often too cold.

“[We need] lower temps...the building only goes down to 68 degrees. Too warm!”

“It would be nice to have motion-activated lights, especially in the stairwells, because they get left on a lot when no one's around.”
EHRINGHAUS
AN ANALYSIS OF ENERGY EFFICIENCY, TEMPERATURE, AND OCCUPANT COMFORT

INTRODUCTION & OVERVIEW

Ehringhaus dorm is one of UNC’s many student residence halls, located at the intersection of Ridge Road and Manning Drive on South Campus. Ehringhaus was constructed in 1962 and has a hall population of 640 residents. In order to meet the personal comfort needs of its residents, Ehringhaus uses window air conditioning units in each bedroom so that residents may adjust temperatures to a comfortable level. The front entrance to Ehringhaus faces almost directly west, with its back entrance facing east. Similar to some of UNC’s other residence halls, the structure of Ehringhaus has four wings extending from its center, much like the shape of an “X”. The building’s bedrooms were remodeled in 2012 and bathrooms in 2013, representing nearly two-thirds of the building’s total square footage of 156,315 square feet. The remaining space is used for lobbies, communal kitchens, study rooms, and recreation rooms on each floor.

ENERGY DATA

In 213, Ehringhaus consumed 70.1 kBTu per square foot. The building has averaged an annual energy consumption of 68.3 kBTu per square foot over the last seven years by Energy Star Portfolio et inmates. This estimate is based on annual consumption of both district steam and electricity usage of the building. Due to the design of the building, the vast majority of electricity demand comes from the window air conditioning units in each room, which serve as a way for occupants to personalize their comfort. Despite this additional electricity demand, Ehringhaus has a calculated baseline Energy Star score of 93, suggesting that the dorm performs better than 9% of similar buildings nationwide.
**TEMPERATURE DATA**

<table>
<thead>
<tr>
<th>Temperature Measurements (°F)</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor Temp</td>
<td>40°</td>
<td>80°</td>
</tr>
<tr>
<td>High</td>
<td>76°</td>
<td>78°</td>
</tr>
<tr>
<td>Low</td>
<td>66°</td>
<td>69°</td>
</tr>
<tr>
<td>Average</td>
<td>69.9°</td>
<td>74.6°</td>
</tr>
</tbody>
</table>

Collected temperature data revealed that in general, temperature tends to increase higher up in the building. Also, temperatures were generally the coolest on each floor near the core of the building, and increased as measurements were taken further out on each wing.

**KEY INFORMANT INTERVIEWS**

*Nicole Ponticorvo, Ehringhaus Community Director*

Community Director and a resident of the building since July 2013, Ponticorvo provided us with additional information about Ehringhaus’ temperature control. She explained that as Community Director, she does not have access to the control, as these settings are managed by the housing staff and facilities department. When asked if there were any problems with personal temperature control, Ponticorvo mentioned that sometimes the winter residents set their AC too low, freezing the systems and causing them to have to be replaced. She noted that the majority of temperature complaints are related to the building being too hot in the winter, the season when temperature is centrally controlled, so students cannot modify room temperatures to their own preferences.

**SUMMARY OF RESULTS**

- Low energy consumption and high Energy Star score reveal high energy performance.
- Temperatures ranged from 71 to 75. Building design exposes rooms to outside air.
- Occupants are generally satisfied, though surveys revealed a trend of discomfort in winter.

The EUI and Energy Star scores are surprisingly high, suggesting that the building is very efficient.

**RECOMMENDATIONS**

1. **Further investigate how the building is achieving such a high level of performance.**
2. **Determine if Ehringhaus’ strengths can be implemented in other residence halls.**
3. **Adjust heating intensity in winter in response to low comfort ratings for this season.**

**OCCUPANT SURVEY RESULTS**

Overall, residents of Ehringhaus are generally content with their building comfort. However, survey responses varied greatly, with some subjects feeling that “everything is great,” while others noted dissatisfaction with the quality of heating during the winter.

“I love having direct control of my air conditioning unit.”

The survey results also suggested that Ehringhaus’ residents tend to have additional fans more often than space heaters. Finally, nearly all of the residents surveyed claimed to use ambient light instead of artificial light when available.

“Ehringhaus is the best.”
**GENOME SCIENCES BUILDING:**

**AN ANALYSIS OF ENERGY EFFICIENCY, TEMPERATURE, AND OCCUPANT COMFORT**

**INTRODUCTION & OVERVIEW**

Completed in 2012 by the architect firm Skidmore, Owings & Merrill, UNC’s Genome Sciences Building (GSB) comprises an ambitious LEED Gold Certified center for interdisciplinary scientific research. Sustainable solutions for energy-intensive laboratory equipment and systems was a core objective of the building’s design scheme. Efficient HVAC systems were chosen for dry-lab spaces, which are full of heat-generating computers. The building is also one of the first of its kind to utilize chilled beams as a way to save energy in wet labs by pumping cold water instead of air. GSB also employs the use of natural daylighting, moderated by high-performance glazing and sun shades. Finally, a 50,000-cubic-foot cistern provides the building with reclaimed rainwater.

**ENERGY DATA**

In Genome’s first full year of operation, 2013, the building consumed 24,425,498 kBu of electricity—approximately 110.6 kBu per square foot. However, Genome is performing approximately 8-10% better than the baseline electricity consumption for a building of this size. Genome is also using significantly less chilled water than both the baseline and projections.
**TEMPERATURE DATA**

Temperatures in Genome ranged significantly across the various uses of space within the building, and based on proximity to internal and external walls. Wet-lab spaces were generally much cooler than the lab write-up spaces, which contained heat-producing computers. In addition, offices with significant window space were affected by outdoor temperatures.

**KEY INFORMANT INTERVIEWS**

While the selected key informants for Genome were not available for interviews, we obtained additional information about the building in an interview with Luke Adams of UNC Energy Management. Adams thought it was important to note that Genome’s second floor includes a room with a large outside overhang. As the floor of this room connects to the outside, the area is therefore less insulated. This can cause problems with temperature moderation on that floor. Additionally, Genome’s top floor consists of a green house that requires warmer temperatures and lots of lighting. The lighting is gradually being switched to LED, but the room still requires extra energy.

**SUMMARY OF RESULTS**

Energy: Efficiency is better than projected, and the building is performing better than the baseline.

Temperature: Temperature varied greatly throughout the building, a deficiency in the building’s design and layout.

Comfort: Most occupants expressed strong dissatisfaction with temperature fluctuations and overall comfort.

High efficiency, but still room for improvement. Other problems, including temperature fluctuations and poor occupant satisfaction, need to be addressed.

**RECOMMENDATIONS**

1. Utilize lab-specific energy reduction strategies, such as closing fume hoods, to achieve even greater energy savings.

2. Address temperature fluctuation issues, especially in perimeter office spaces.

3. Consult with occupants to understand their concerns regarding poor lab building design, which will inform future projects.

**OCCUPANT SURVEY RESULTS**

While occupants seemed generally pleased about the aesthetic design of their space, the majority were dissatisfied with Genome’s amenities and temperature fluctuation. Survey respondents cited poor building design as the source of discomfort, as lab write-up space is cramped and warm. Occupants of offices on the periphery of the building often noted that extreme outdoor temperatures affected their office temperature, and consequently their personal comfort. Many respondents noted that the building lacks proper bathroom and conference space.

“The building is visually pretty but not functional.”

“Way better than any of her building.”
INTRODUCTION & OVERVIEW

Used primarily as a laboratory building, but secondarily as office and classroom space, the $95 million Venable/Murray addition marked the completion of the Carolina Physical Science Complex. The entire project totaled nearly $250 million and to this day is the largest construction project undertaken by the University. Venable/Murray Hall was built with second- and third-level labs and offices located on the first through fourth floors, with a few classrooms interspersed, while the ground floor contains exclusively classrooms and a library. The two buildings create a “U” shape surrounding a courtyard.

ENERGY DATA

Consistent with the other lab spaces in the study, energy consumption in Venable/Murray was very high. In 213, Venable/Murray used 5,692,176.1 kBtu, roughly 299.1 kBtu per square foot. This was the second largest overall energy consumption value of the nine buildings in the study. Chilled water use requires the most energy, but has remained constant over the past seven years along with electricity consumption. District steam energy consumption, however, has increased significantly over the past two years.
**TEMPERATURE DATA**

Temperature samples taken in Venable/Murray were consistent with those taken in other campus buildings, ranging from 70 to 75 degrees Fahrenheit. A couple of unusually high temperature readings were those taken around east-facing windows with ample sunlight. Additionally, temperature sampling revealed that some lab rooms are kept at significantly cooler temperatures to offset heat-producing equipment, such as a mass spectrometer.

<table>
<thead>
<tr>
<th>Temperature Measurements (°F)</th>
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<tbody>
<tr>
<td>Outdoor Temp</td>
<td>50°</td>
<td>60°</td>
</tr>
<tr>
<td>High</td>
<td>77°</td>
<td>72°</td>
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<tr>
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<td>69°</td>
</tr>
<tr>
<td>Average</td>
<td>70.9°</td>
<td>70.5°</td>
</tr>
</tbody>
</table>

**KEY INFORMANT INTERVIEWS**

Neither of the two selected key informants that work in the building cooperated for an interview. However, Lane Adams of UNC Energy Management, provided additional details about temperature control in the building. He noted that the office spaces in Venable/Murray maintain different temperature settings for occupied and unoccupied hours, whereas labs maintain the “occupied” temperature setting 24/7.

**SUMMARY OF RESULTS**

- **Energy**: High energy consumption per square foot, especially for chilled water.
- **Temperature**: Very consistent temperature samples, but slightly warmer on east side of building.
- **Comfort**: The majority of surveyed occupants are very comfortable in the building.

It appears that Venable-Murray successfully balances efficiency, temperature consistency, and occupant comfort, but still has room for improvement.

**OCUPANT SURVEY RESULTS**

Most occupants described Venable/Murray as one of the more comfortable buildings on campus...[with] windows and natural light.

“I like the natural lighting ads the temperature i usually nice whether it’s hot or cold out”

**RECOMMENDATIONS**

1. CHECK INTO THE FEASIBILITY OF CHILLED BEAMS AND WHETHER THIS WOULD BE A COST-EFFECTIVE RETROFIT OPTION.

2. FURTHER INVESTIGATE HIGH CHILLED WATER DEMAND AND EXPLORE REDUCTION OPTIONS.

3. EXAMINE THE POSSIBILITY OF ON-SITE POWER GENERATION TO OFFSET HIGH ENERGY DEMAND FOR THIS CATEGORY OF USE.
INTRODUCTION & OVERVIEW

The UNC Eshelman School of Pharmacy and the UNC School of Medicine began construction of the Genetica Medicine Building in early 2005. Located off of Mason Farm Road, the Genetica Medicine Building houses research for both departments in approximately 75,000 square feet of laboratory space. The building also houses three research centers: UNC Institute for Pharmacogenomics and Individualized Therapy, the Center for Integrative Chemical Biology and Drug Discovery, and the Center for Nanotechnology in Drug Delivery. The building has a large atrium which separates the building into two sections of laboratory pods. The HVAC system is centrally controlled.

ENERGY DATA

Genetic Medicine is a relatively new building with modern systems. However, due to its size and primary use as a research laboratory, it has a significant energy demand. In 2013, the building consumed 61,373,025.9 kWh of electricity, with an average of 167 kWh per square foot of building space. This value is significantly higher than the other lab buildings in this study, Venable-Murray and Genome Science Building. That being said, Genetics operates at a greater capacity than the other two buildings. Genetics used more chilled water and steam, at 175.8 kBtu per square foot and 16 kBtu per square foot for 2013, respectively.
TEMPERATURE DATA

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<td>50°</td>
<td>60°</td>
</tr>
<tr>
<td>High</td>
<td>73°</td>
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<tr>
<td>Low</td>
<td>63°</td>
<td>70°</td>
</tr>
<tr>
<td>Average</td>
<td>67.6°</td>
<td>72.9°</td>
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</table>

Generally, the temperatures in Genetic Medicine were relatively consistent, ranging from 70 to 75 degrees Fahrenheit. This pattern was observed for both the north and south-facing laboratory pods. However, design contributed to cooler temperatures around the perimeter of building, as HVAC vents in these areas expel air from slanted ceilings.

OCCUPANT SURVEY RESULTS

In general, occupant surveys conducted in Genetic Medicine revealed a decent amount of dissatisfaction with the building. While some viewed it as functional but cold, others thought it was comfortable but not functional. Many occupants expressed concern that the space is too cold, particularly in the winter, but also in the summer. This is likely due to a lack of ventilation being situated directly above the desk spaces. Space heating usage in the winter seemed fairly common, despite being unauthorized.

“It’s usually a bit too cold in here all year round.”

“We need more room for lab space.”

OCCUPANT INTERVIEWS

The selected key informant for Genetic Medicine was unavailable for interview, however, many building occupants provided comments during the survey process. Severable occupants pressed concern that there is not enough space in the labs for proper storage and working room. One interviewee cited the atrium in particular as being away potential work space. Multiple occupants also revealed that ventilation is especially lacking near the animal holding labs, which often causes undesirable odors to drift into their work space.

Lane Adams, Manager of UC Energy Management also provided additional details about Genetic Medicine in an interview. He noted that the building houses walk-in coolers with cooling water for condensers, which can greatly increase energy consumption.

SUMMARY OF RESULTS

Energy
Extremely high energy consumption per square foot, due in part to its category of use.

Temperature
Temperatures were generally consistent, but noticeably colder near air vents.

Comfort
Occupants were generally dissatisfied. Primary concerns were temperature and inadequate building design.

RECOMMENDATIONS

1. EXPLORE LAB-SPECIFIC ENERGY SAVING STRATEGIES, SUCH AS CLOSING FUME HOOD SASHES, TO REDUCE ENERGY DEMAND.

2. RETROFIT HVAC SYSTEM AIRFLOW SO THAT VENTS ARE NOT LOCATED DIRECTLY ABOVE OCCUPANT DESK SPACE.

3. CONSULT WITH OCCUPANTS TO UNDERSTAND THEIR CONCERNS REGARDING POOR LAB BUILDING DESIGN, WHICH WILL INFORM FUTURE PROJECTS.