

ENERGY EFFICIENCY AND OCCUPANT COMFORT IN UNC BUILDINGS

Caleb Cates, Katelyn Costa, Lila Fleishman, Andrew Flinchum, Jamie Linden,
Sarah Lowder, Shane Shields, Michael Titus, Rachel Tove-White

ENST/ENVR 698—Environmental Capstone
Spring 2014



INTRODUCTION



- **CLIENT:** UNC-CH Energy Management
 - Monitoring, controlling, and reducing water and energy use
 - Vision: Continuously improve building performances
- **RESEARCH PROBLEM:** Follow-up studies on LEED and high-performance buildings have not been thoroughly conducted
- **RESEARCH QUESTION:** Understand variations in performance among different building types

INTRODUCTION



- **GOALS:**

- Understand performances of buildings among use type
- Explore performance of “high performers”
- Integrate energy efficiency with occupant comfort
- Discover gaps in UNC’s data collection


- **PRODUCTS:**

- Presentation
- Report
- White papers

INTRODUCTION - WHITE PAPER EXAMPLE



From the UNC Sustainable Triangle Field Site Capstone



Source: UNC Housing and Residential Education

MORRISON: AN ANALYSIS OF ENERGY EFFICIENCY, TEMPERATURE, AND OCCUPANT COMFORT

Spring 2014

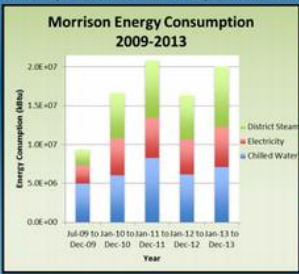
INTRODUCTION & OVERVIEW

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 Nationals and winning the EPA's first National Building Competition in 2010. The dorm in ten stories, and each floor has balconies leading out to balconies comprise a significant portion of the dorm's floor plate that is not being air conditioned or heated. Morrison also uses 172 rooftop solar thermal panels for hot water heating and uses real-time consumption meters to monitor electricity, steam, and chilled water use in each of the building's twelve zones.

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 also showed higher efficiency than the other two dorms used for comparison. Morrison used 32.5 kBtu per square foot for chilled water and 35.9 kBtu per square foot for steam.

ENERGY DATA

Morrison is almost 50 years old, despite undergoing renovations in 2006. In 2013 it used 5,121,234.6 kBtu of electricity, which is approximately 23.5 kBtu per square foot. Though this residence hall used the most electricity of the three in the study, it is also the largest. Morrison uses



Renovations: 2006

AT A GLANCE:

- Residence Hall
- 217,522 Square Feet
- Built 1965
- Occupancy 860
- Notable Systems: Variable air volume handler with terminal reheat and complete direct digital HVAC control

Page 1

TEMPERATURE DATA

Temperature Measurements (°F)		
	Day 1	Day 2
Outdoor Temp	42°	75°
High	78°	81°
Low	55°	70°
Average	68.8°	69.7°

A considerable amount of Morrison's floor space is non-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 unoccupied 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.

OCCUPANT SURVEY RESULTS

Most of the residents were generally comfortable in Morrison, with the majority of comments stemming from desires to have larger rooms. Many residents like having the balconies where they can prop their suite door open to enjoy weather on nice days.

"I want more control of heating and air."

The use of natural light in the place of artificial light was rather uncommon, possibly because not enough light could filter into balcony-side rooms where blinds typically remain closed to prevent passersby from looking into these rooms.

"Very nice and fresh."

KEY INFORMANT INTERVIEWS

Lane Adams, Manager of UNC 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 should decrease Morrison's energy use.

SUMMARY OF RESULTS

Energy	Temperature	Comfort
Relatively low energy consumption at 23.5 kBtu/sqft. Energy Star score of 86.	Temperatures are affected by location of rooms and exposure to outside air.	Residents were generally pleased with the building, and desire additional sustainability measures.
This award-winning residence hall is a high energy performer with a fairly consistent temperature range and satisfied occupants.		

RECOMMENDATIONS

- PROVIDE REMINDERS FOR RESIDENTS TO TURN DOWN THEIR AIR CONDITIONING WHILE DOORS ARE OPEN, PERHAPS WITH STICKERS BY THE CONTROLS AND FEATURES ON THE RA BOARDS.
- KEEP AREAS WITH HIGH ELECTRICAL LOADS, LIKE THE VENDING MACHINE ROOMS, WELL-VENTILATED TO REDUCE TEMPERATURE VARIATION.
- IMPLEMENT MORRISON'S SUCCESSFUL ENERGY SAVING INITIATIVES IN OTHER RESIDENCE HALLS.

Page 2

BACKGROUND



HIGHLIGHTS:

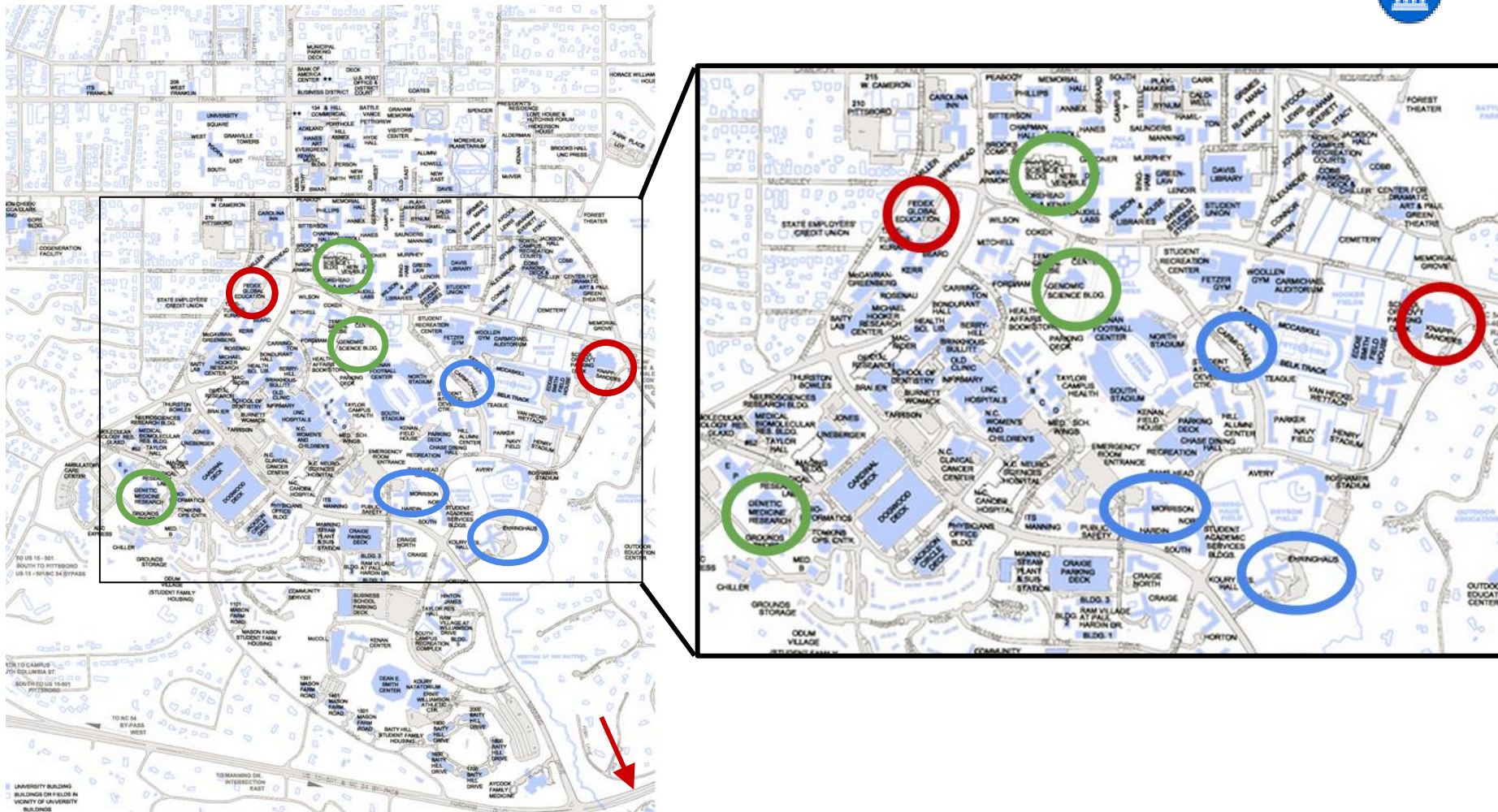
- UNC-CH has LEED-certified and LEED standard buildings with unknown performing status
- NC Senate Bill 668 specifies standards
- Energy use varies across building types
- Occupant comfort & behavior patterns are critical components

METHODS - BUILDING SELECTION



Category	Classroom/ Administrative	Residential	Labs
Older	Knapp-Sanders School of Government	Ehringhaus	Genetic Medicine
Newer/ Renovated	FedEx Global Education Center	Carmichael	Venable/Murray
High Performers	Botanical Garden Education Center	Morrison	Genome Science

METHODS - BUILDING SELECTION



METHODS - DATA COLLECTION



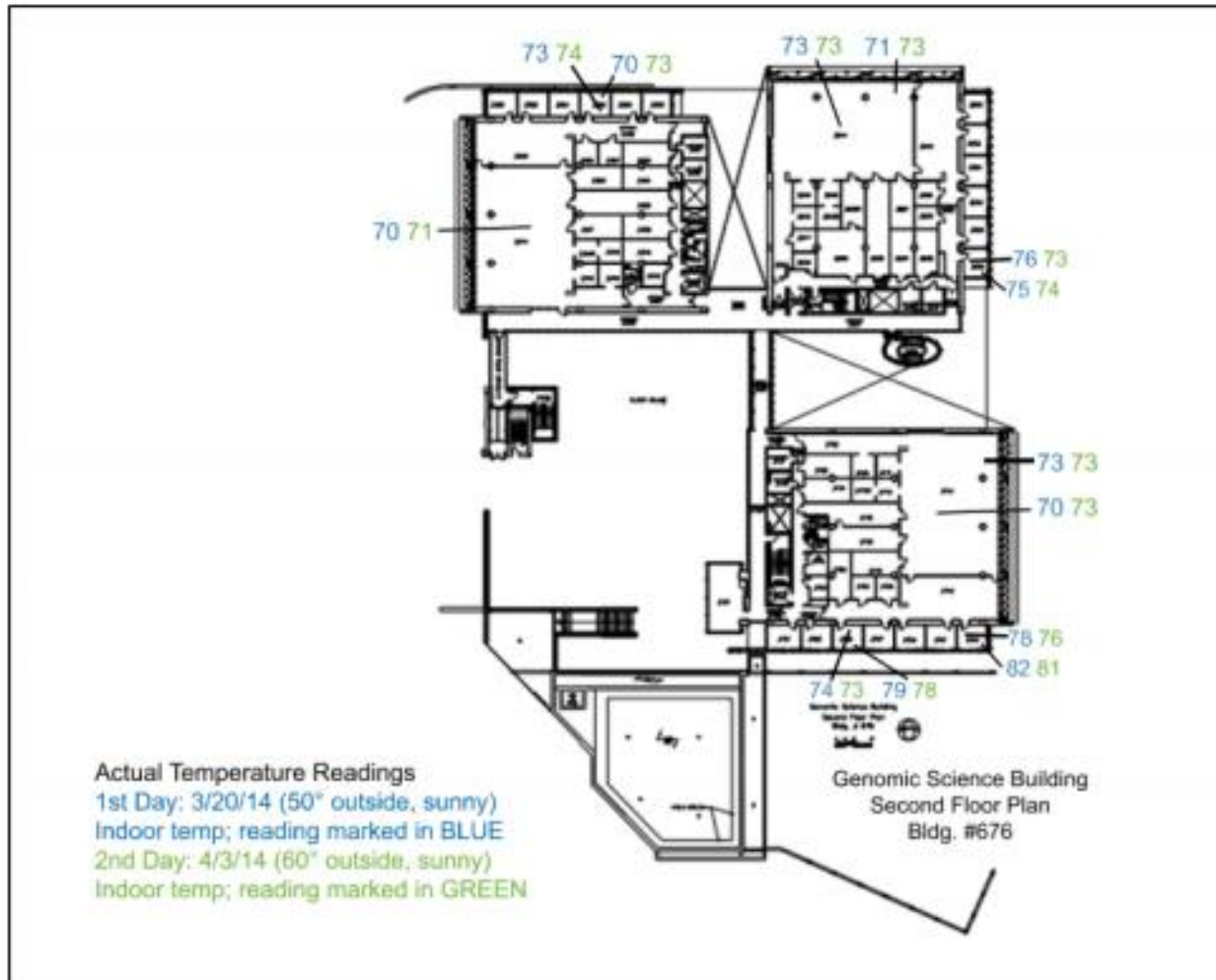
Energy Data: utility bills & LEED templates; EnergyStar's Portfolio Manager

Temperature Data: read with infrared temperature guns

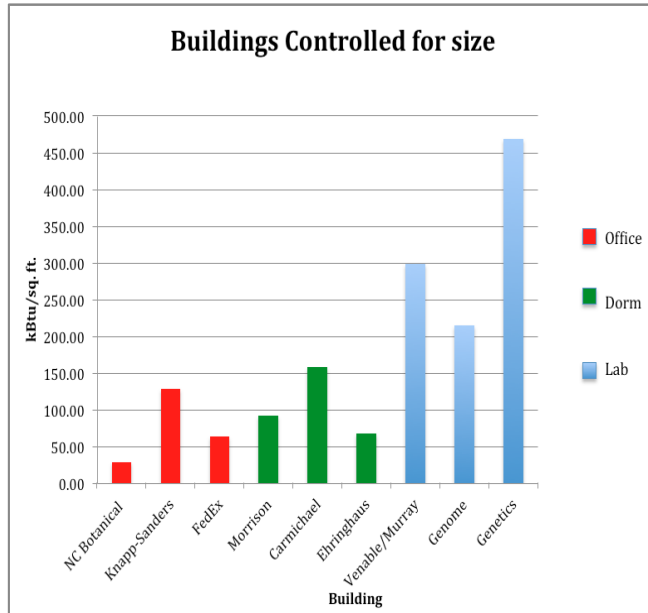
Occupant Survey: investigated comfort; n=255

Building Head Interviews: more detailed information on building temperature controls

METHODS - FLOOR PLAN EXAMPLE

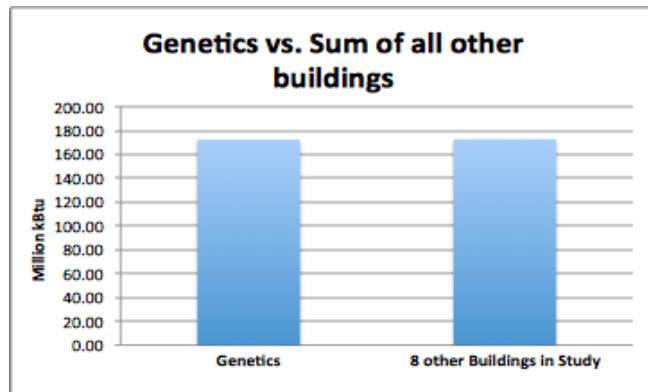


DATA & ANALYSIS: OVERALL

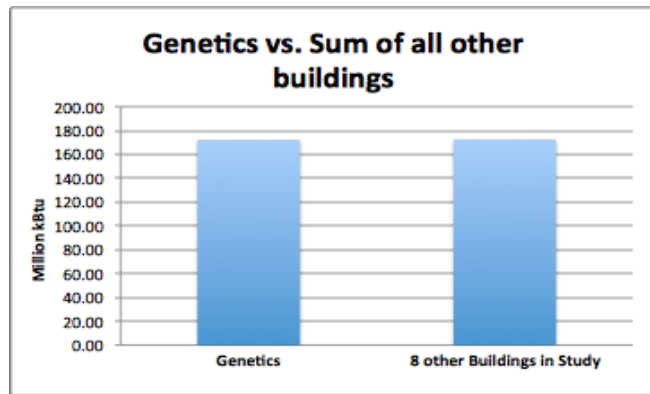
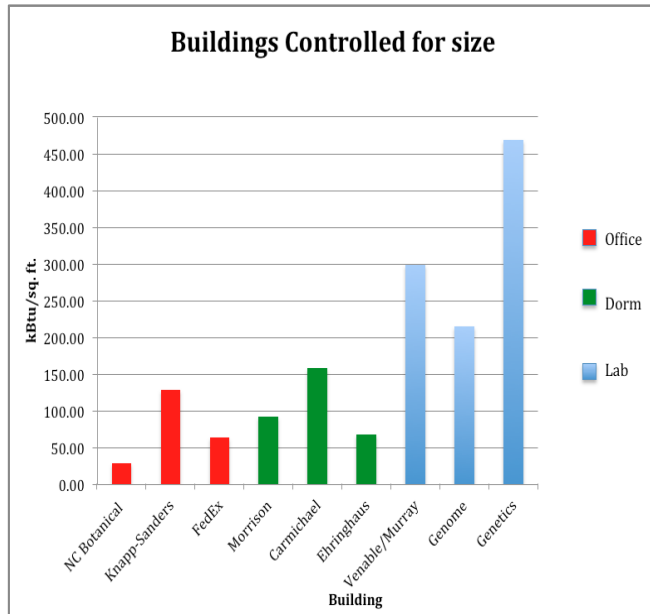


OBSERVATIONS:

- Lowest Total Energy Consumers: **LEED Buildings**
- Highest Total Energy Consumers: **Labs**
- Trends:
 - Labs use the most energy both in total and per square foot
 - The two LEED-certified buildings, Genome Sciences and NC Botanical Gardens, excel at energy efficiency



DATA & ANALYSIS: OVERALL



OBSERVATIONS:

- Lowest Total Energy Consumers: **LEED Buildings**
- Highest Total Energy Consumers: **Labs**
- Trends:
 - Labs use the most energy both in total and per square foot
 - The two LEED-certified buildings, Genome Sciences and NC Botanical Gardens, excel at energy efficiency

SURPRISES:

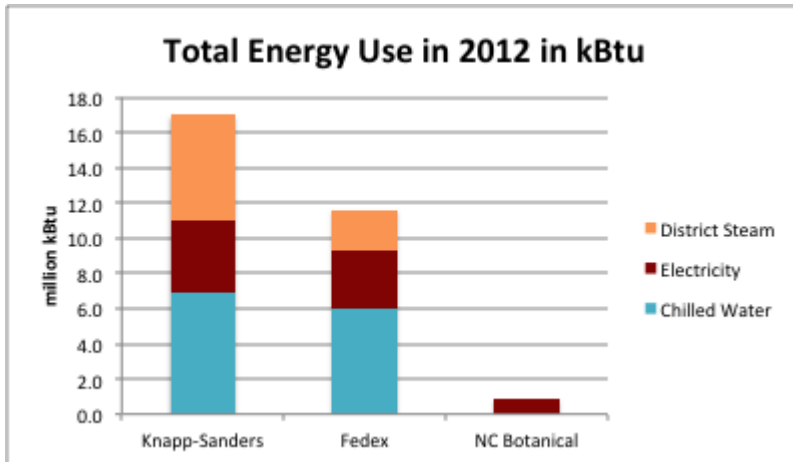
- Anomaly: Ehringhaus - oldest building in sample but one of least energy intensive per ft²
- Genetics consumed as much energy as the other 8 buildings combined

DATA & ANALYSIS: CLASSROOMS/ADMINISTRATIVE



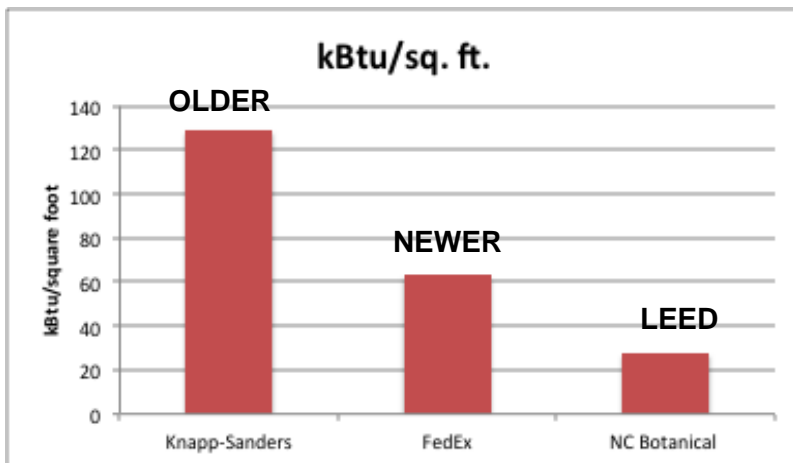
Category	Classroom/ Administrative	Residential	Labs
Older	Knapp-Sanders School of Government	Ehringhaus	Genetic Medicine
Newer/ Renovated	FedEx Global Education Center	Carmichael	Venable/Murray
High Performers	Botanical Garden Education Center	Morrison	Genome Science

DATA & ANALYSIS: CLASSROOMS/ADMINISTRATIVE

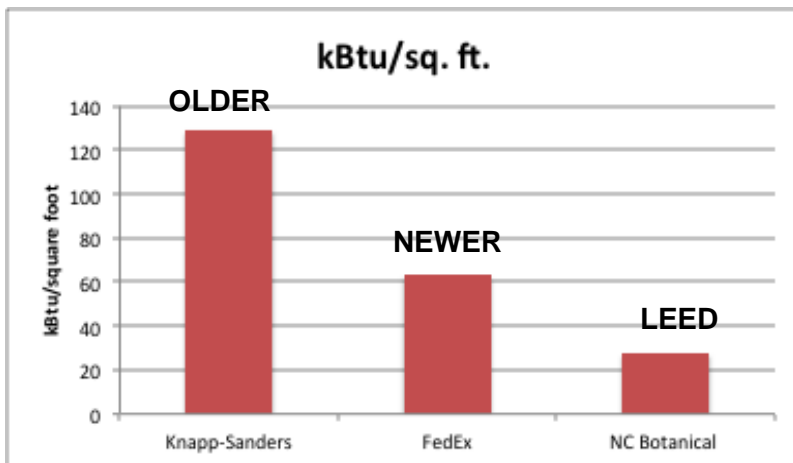
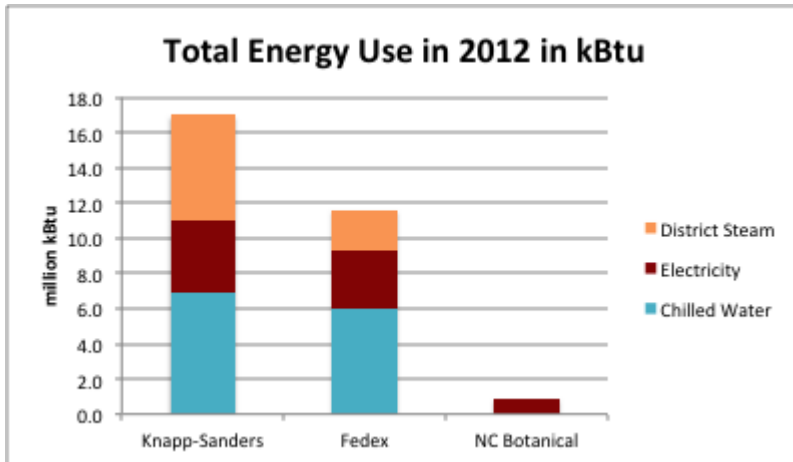


OBSERVATIONS:

- Lowest Energy Consumer:
 - Total: **NC Botanical**
 - Per square foot: **NC Botanical**
- Highest Energy Consumer:
 - Total: **Knapp-Sanders**
 - Per square foot: **Knapp-Sanders**
- Trends:
 - Fedex and NC Botanical are well above the national median for energy consumption
 - Knapp-Sanders lags behind
 - Infrastructure and renovations



DATA & ANALYSIS: CLASSROOMS/ADMINISTRATIVE



OBSERVATIONS:

- Lowest Energy Consumer:
 - Total: **NC Botanical**
 - Per square foot: **NC Botanical**
- Highest Energy Consumer:
 - Total: **Knapp-Sanders**
 - Per square foot: **Knapp-Sanders**
- Trends:
 - Fedex and NC Botanical are well above the national median for energy consumption
 - Knapp-Sanders lags behind
 - Infrastructure and renovations

SURPRISES:

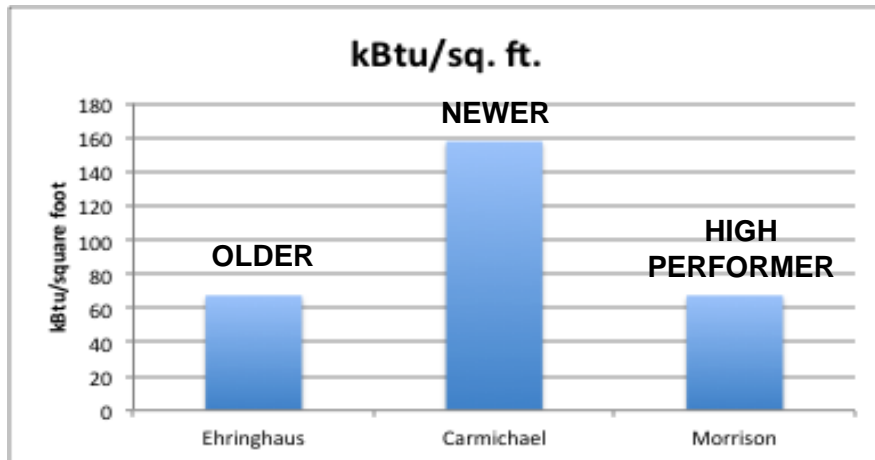
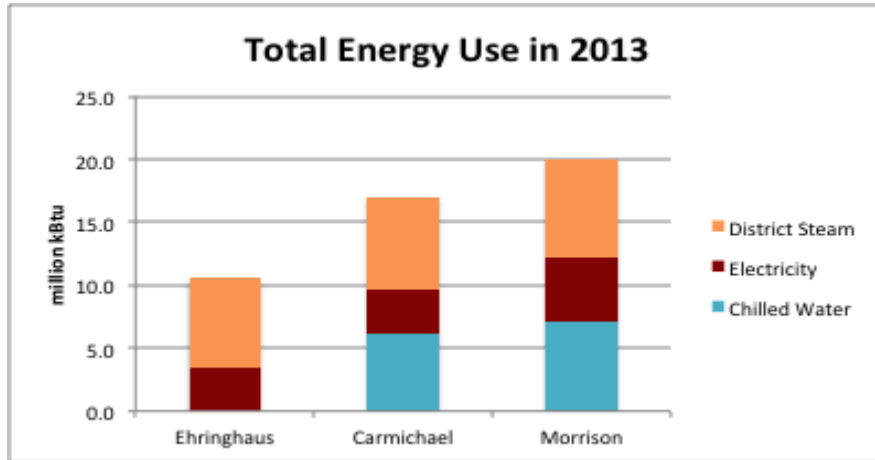
- The highest energy consumer was still at the national median

DATA & ANALYSIS: RESIDENTIAL



Category	Classroom/ Administrative	Residential	Labs
Older	Knapp-Sanders School of Government	Ehringhaus	Genetic Medicine
Newer/ Renovated	FedEx Global Education Center	Carmichael	Venable/Murray
High Performers	Botanical Garden Education Center	Morrison	Genome Science

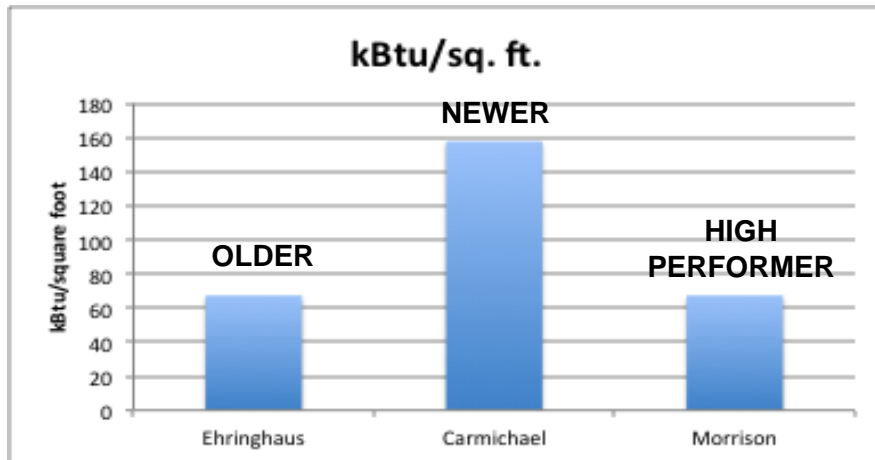
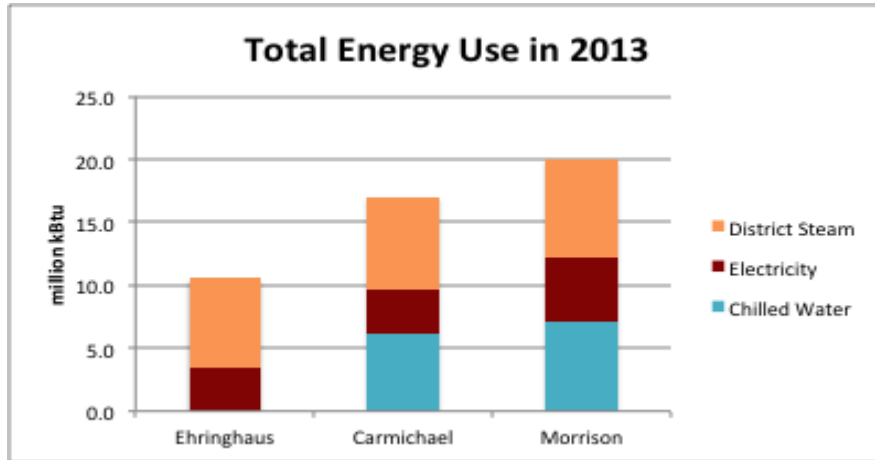
DATA & ANALYSIS: RESIDENTIAL



OBSERVATIONS:

- Lowest Energy Consumer:
 - Total: **Ehringhaus**
 - Per square foot: **Ehringhaus**
- Highest Energy Consumer:
 - Total: **Morrison**
 - Per square foot: **Carmichael**
- Trends:
 - High use of district steam across all buildings
 - Heating/cooling units are especially important here

DATA & ANALYSIS: RESIDENTIAL



OBSERVATIONS:

- Lowest Energy Consumer:
 - Total: **Ehringhaus**
 - Per square foot: **Ehringhaus**
- Highest Energy Consumer:
 - Total: **Morrison**
 - Per square foot: **Carmichael**
- Trends:
 - High use of district steam across all buildings
 - Heating/cooling units are especially important here

SURPRISES:

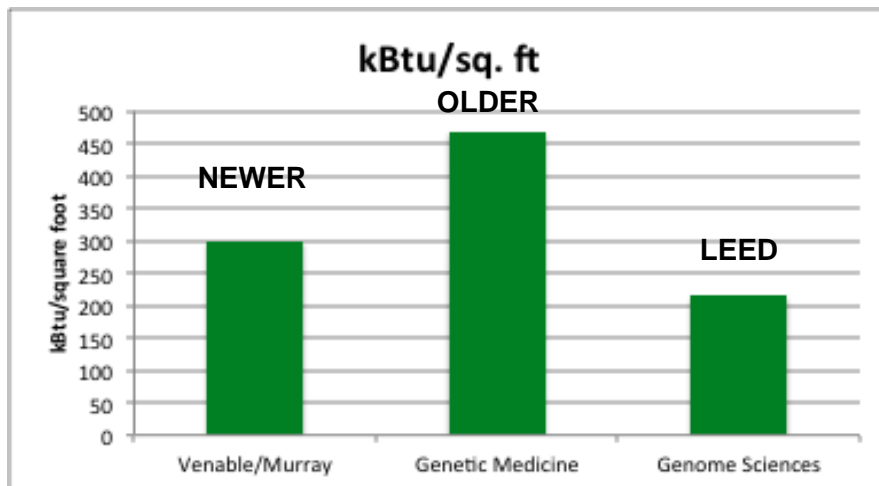
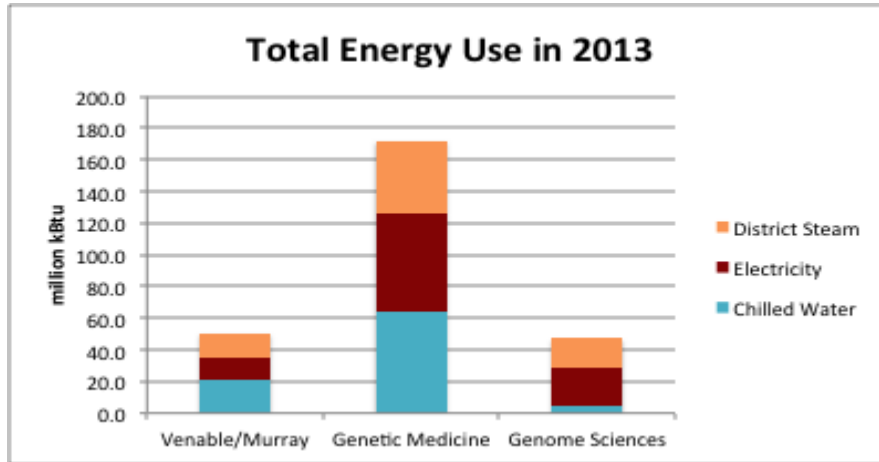
- Per square foot, Ehringhaus uses slightly less energy than Morrison

DATA & ANALYSIS: LABS



Category	Classroom/ Administrative	Residential	Labs
Older	Knapp-Sanders School of Government	Ehringhaus	Genetic Medicine
Newer/ Renovated	FedEx Global Education Center	Carmichael	Venable/Murray
High Performers	Botanical Garden Education Center	Morrison	Genome Science

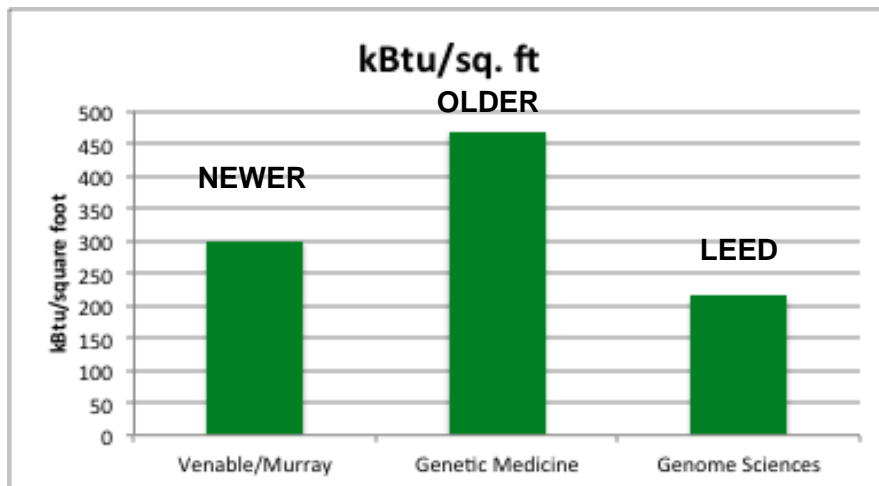
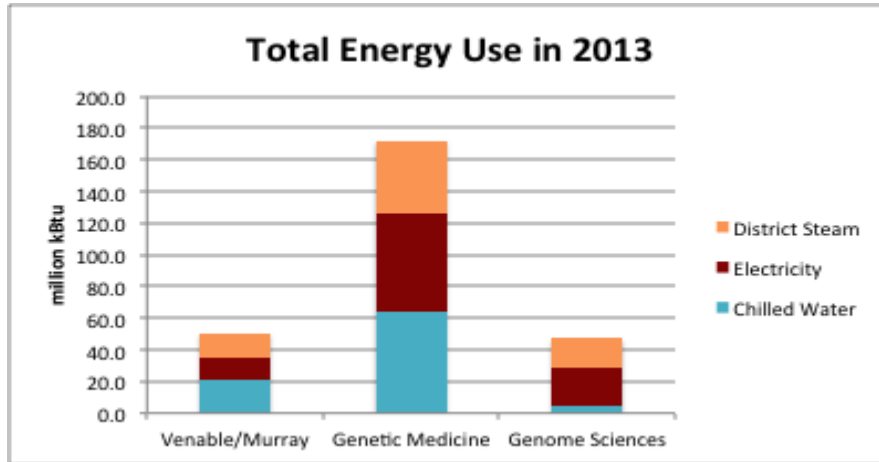
DATA & ANALYSIS: LABS



OBSERVATIONS:

- Lowest Energy Consumer:
 - Total: **Genome Sciences**
 - Per square foot: **Genome Sciences**
- Highest Energy Consumer:
 - Total: **Genetic Medicine**
 - Per square foot: **Genetic Medicine**
- Trends:
 - Genome Sciences benefiting from LEED standards
 - *Occupancy percentage* plays a key role in energy usage

DATA & ANALYSIS: LABS



OBSERVATIONS:

- Lowest Energy Consumer:
 - Total: **Genome Sciences**
 - Per square foot: **Genome Sciences**
- Highest Energy Consumer:
 - Total: **Genetic Medicine**
 - Per square foot: **Genetic Medicine**
- Trends:
 - Genome Sciences benefiting from LEED standards
 - *Occupancy percentage* plays a key role in energy usage

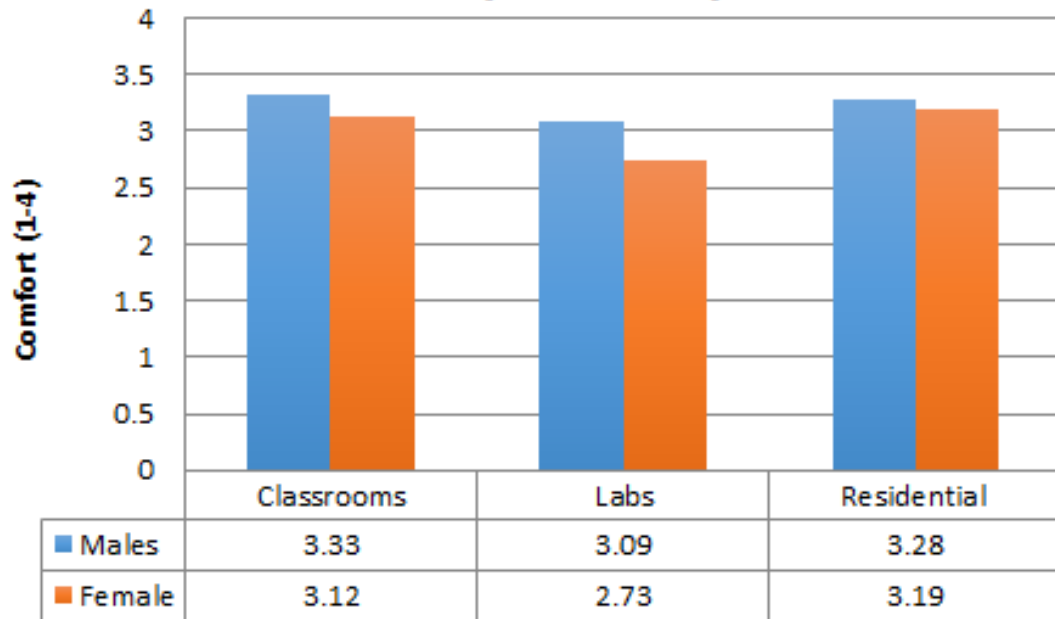
SURPRISES:

- Genetic consumes the most energy
- Genome is performing better than projected

DATA & ANALYSIS: COMFORT



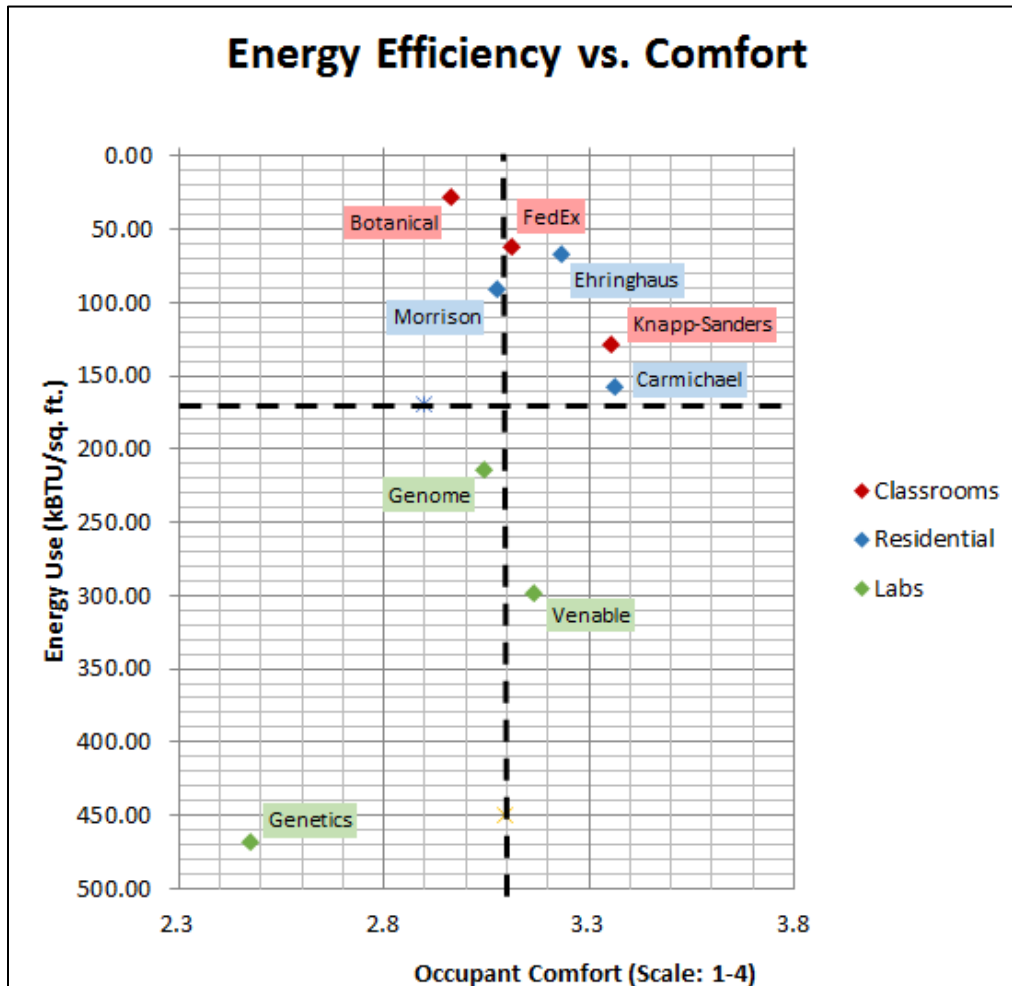
Average Comfort by Building Use and Gender (1-4 scale)



OBSERVATIONS:

- Trends:
 - Males report slightly higher average comfort than females.
 - Labs have the widest range of comfort

DATA & ANALYSIS: COMFORT



OBSERVATIONS:

- Lowest Average Comfort:
 - Genetics
 - The 2 LEED buildings
- Highest Average Comfort:
 - Carmichael
 - Knapp-Sanders
- Trends:
 - Building with least efficiency had least comfort
 - Building with highest efficiency had 2nd least comfort
 - “High performers” all had comfort ratings under the average

A DEEPER LOOK: BOTANICAL



QUICK FACTS:

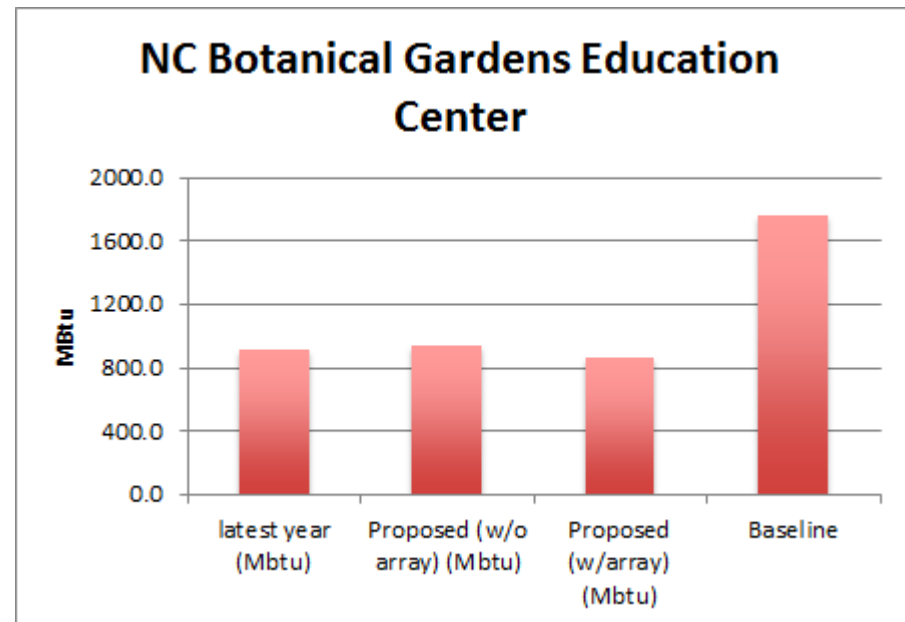
- Built 2007; opened 2010
- LEED Platinum
- Two geothermal heat pumps
- Solar PV array

OBSERVATIONS:

- Consumes half the national average
- Performs worse than expected
 - Heat pumps?
 - Humidity issues?

TEMPERATURE & COMFORT:

- Great daylighting
- Poor temperature
- Inaccurate thermostats



RECOMMENDATIONS



- **Classroom/Administrative:**
 - Consider giving more control back to occupants, particularly Botanical
- **Residence Hall:**
 - Further investigate why Ehringhaus is so efficient
- **Labs:**
 - Energy efficient systems such as those in Genome Sciences
 - Address energy use in Genetic Medicine
- **LEED Buildings:**
 - Genome Sciences
 - NC Botanical
- **Future Data Collection:**
 - Streamline compilation
 - Ensure data is available for every building

ACKNOWLEDGMENTS



Amy Bullington, Department of City and Regional Planning

Susan Caplow, Curriculum for the Environment and Ecology

Chris Martin, Energy Management

Jessica O'Hara, Energy Management

Elizabeth Shay, Institute for the Environment

QUESTIONS?

