JOINING THE CAMPUS

SUSTAINABILITY MOVEMENT:

AN ENVIRONMENTAL AUDIT OF

THE DUKE UNIVERSITY MARINE LAB

by

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Abstract

The Sustainability Revolution commenced as a reaction to the environmental degradation caused by the Industrial Revolution. The Sustainability Revolution introduced the general public to the three pronged approach of sustainability: uniting economics, the environment, and society. The Campus Sustainability Movement represents one of the sub-movements within the Revolution. This Movement introduced the trend to evaluate and audit campus environmental practices and policies, and monitor their impacts on the environment. In 1989, the University of California at Los Angeles conducted the first campus environmental audit in the United States. Their audit looked at various campus practices such as water and energy consumption, waste management, and procurement practices. This audit paved the way for several colleges and universities worldwide.

In the fall of 2006, the Duke University Marine Lab, located in Beaufort, NC, embarked on a *Green Initiative*. In order to facilitate the process of the Initiative, the Marine Lab called for an environmental audit of their current practices. Due to time constraints, this masters project focuses solely on energy consumption at the Lab, in the form of electricity consumption. Previous campus audits conducted at other universities were referenced to guide the audit's research questions. Financial records and kilowatt-hour meter readings from 1999 through 2006 were collected as a means to identify exactly where the Marine Lab must make adjustments. Although some of the data appears to be flawed, it still reveals some encouraging trends at the Marine Lab, namely that *energy consumption has decreased* over the past 6 years. This masters project recommends that in order to see additional improvements, all buildings at the Marine Lab must have meters on them. Furthermore, this masters project suggests that communication between the Marine Lab and the Facilities Management Department in Durham be improved.

Table of Contents

BACKGROUND AND CONTEXT:

Located on Pivers Island in Beaufort, North Carolina, the Duke University Marine Lab operates as a research and education facility. More specifically, "[its] mission is education and research in the basic ocean processes, coastal environmental management, marine biotechnology and marine biomedicine."[1] It is a separate part of Duke University's main campus, located approximately 200 miles outside of Durham, NC, and is affiliated with the Nicholas School of the Environment and Earth and Ocean Sciences. The Duke Marine Lab occupies 32.5 acres of Pivers Island's total 54.4 acres.[2] It shares the island with the National Oceanic and Atmospheric Administration's Center for Coastal Fisheries and Habitat Restoration.

The Marine Lab was founded in 1938 as a biological research station and has since transformed into a comprehensive marine research laboratory and teaching facility. While some of the Marine Lab's buildings date back to 1938, such as the dining hall, others were built in more recent decades, many following a Dutch Architecture style. Most of the campus buildings consist of lumber framing construction with plywood and cedar shake exterior[3]. The older buildings have interior walls made of Tung and grove pine, some with wood paneling while other more recent ones have sheet rook interior walls. The oldest laboratory, Bookhout, is composed of concrete, block, brick, and steel.

The annual temperature averages 62.0 degrees Fahrenheit, with sunny days 60% of the year.[4] The moderate climate and abundant sunshine of Beaufort, NC, make the Marine Lab a wonderful place to install solar panels and implement energy efficiency

[1] http://www.nicholas.duke.edu/marinelab/about/thelab.html
[2] Duke Marine Lab Map, obtained from Regis Koslofsky, 11/06.
[3] Based on email correspondence with Dominick Brugnolotti, 3/26/07.
[4] http://www.beaufort-county.com/stats.htm; accessed 3/19/07.

programs. As with any university campus, the faculty, staff, students and visitors use its resources and facilities, thus influencing the Marine Lab's waste generation, energy and water consumption, and contributing to a large ecological footprint.[5] Although these specific impacts are difficult to quantify, a reexamination of current policies and practices can assist in defining exact effects.

In the fall of 2006, the Duke University Marine Lab started the early stages of a Green Initiative, outlining their mission in a Green Statement. Their primary objective is "to improve not only lab consciousness and the lab's everyday practices but also to create a greener image for the Marine Lab."[6] In order to help facilitate the appropriate changes at the Marine Lab, an environmental audit needs to be conducted to assess key areas which require attention. Various topics need to be considered in order to maximize the efforts of the Green Statement which include sustainability practices, energy consumption, energy sources, recycling capacity, dining practices, landscaping, efficient technologies, general campus awareness of environmental issues, etc. Due to the required depth of research and lack of time, my environmental audit focuses primarily on energy consumption at the Marine Lab.

While there are several components that constitute an environmental audit, one definition states that at colleges and universities "An environmental audit typically refers to a methodical examination and review of the environmental policies and practices on campus."[7] As evidenced by universities like Bishops University in Quebec, in addition to

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[5] According to the Global Footprint Network, an ecological footprint can be defined as "a resource management tool that measures how much land and water area a human population requires to produce the resources it consumes and to absorb its wastes under prevailing technology." http://www.footprintnetwork.org/gfn_sub.php?content=footprint_overview; accessed 3/19/07

[6] Duke University Marine Lab Green Statement, October 13, 2006.

[7] Velazquez, Luis, Munguia, Nora, Platt, Alberto, and Jorge Taddei. 2006. Sustainable University: What can be the Matter? *Journal of Cleaner Production*, 14, 810-819 (p 816).

reviewing current policies, "the audit also is a primary source of information used for determining priorities for campus environmental policy formulation and implementation."[8] By performing an environmental audit on energy consumption at the Duke Marine Lab, I can determine which areas are currently the most efficient and which areas require the most attention in the Green Initiative at the Lab.

There are approximately 25 buildings at the Beaufort campus. From the campus auxiliaries' assistant director, Dominick Brugnolotti, I discovered that the energy bill for the Marine Lab is partitioned by building. This made it possible to isolate individual building's energy behavior. After contacting the Facilities Management Department at Duke, I obtained the utilities bills for the Marine Lab for fiscal years 1999, 2001, and 2006.[9] In addition to financial data, I also obtained whatever meter reading data was available for those same years. The meter reading data provided information on kilowatt-hour consumption per building.[10] These two sources of data represent significant information and permitted me to analyze both the energy consumption patterns at the Marine Lab, as well as uncover the inherent problems with the current billing and metering systems.

While my MP initially began as an energy audit of the Marine Labs practices, it has slowly transitioned into something more comprehensive. The research I have conducted places my energy audit in the context of the campus sustainability movement. So while an audit of energy consumption at the Duke Marine Lab remains the primary

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[8] Bardati, Darren R. 2006. The integrative role of the campus environmental audit: experiences at Bishop's University, Canada. *International Journal of Sustainability in Higher Education*. 7 (1), 57-68. (pg 58)
[9] Fiscal Years at Duke University commence on July 1 and end on June 30.
[10] A watt is an SI unit of power that equals one joule of work performed per second. A kilowatt equals 1,000 watts. A kilowatt-hour (kWh) equals 1,000 watt-hours, which is a power rate and how most electricity consumption is measured. (The New Encyclopaedia Britannica (2007) 12, 15, p.528.

focus of this MP, its secondary focus examines the Marine Lab from the perspective of sustainability and makes recommendations of how the Lab can immerse itself in the Sustainability Revolution. In order to understand how the Duke University Marine Lab can accomplish this, it is important to understand the history and meaning of both the Sustainability Revolution and the Campus Sustainability Movement.

The Sustainability Revolution:

The Sustainability Revolution did not commence in a vacuum, but in fact began as a reaction to the environmental problems wrought by the Industrial Revolution.[11] The Industrial Revolution promoted rapid expansion of industries and functioned as though the earth's resources were infinite. However, during the environmental movement of the 1970s, people began to realize nature's bounds and limitations. The United Nations Conference on the Human Environment, held in 1972 in Stockholm, Sweden, marked the beginning of both this changed outlook and the Sustainability Revolution.[12] In 1983, eleven years after the Stockholm conference, the United Nations General Assembly passed the Resolution A/RES/38/161 which outlined the "Process of preparation of the Environment Perspective to the Year 2000 and Beyond."[13] This resolution was the precursor to the Brundtland Report.

The United Nations organized the Brundtland Commission, formerly referred to as the World Commission on Environment and Development.[14] In 1987, the Commission

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[11] Edwards, Andres R. 2005. *The Sustainability revolution: portrait of a paradigm shift.* Gabriola, BC: New Society Publishers. (p. 6)
[12] Edwards, Andres R. 2005. *The Sustainability revolution: portrait of a paradigm shift.* Gabriola, BC: New Society Publishers. (p 3)
[13] http://www.un.org/documents/ga/res/38/a38r161.htm; accessed 3/20/07.
[14] http://en.wikipedia.org/wiki/Brundtland_Commission; accessed 3/20/07.

released the Brundtland Report, which addressed the concept of sustainable development. The report, also known as *Our Common Future*, defines the concept of *sustainable development* as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[15] The Brundtland Report provided a concrete definition of sustainable development and helped further the momentum of the Sustainability Revolution.

Following the Brundtland Report, in 1992 the United Nations hosted the Earth Summit in Rio de Janeiro, Brazil, with representatives from 172 countries and approximately 2,400 non-governmental organizations.[16] The two-week summit was the culmination of two and a half years of negotiations and a planning process between all United Nations Member States regarding future sustainable development.[17] The resulting document and agreement was Agenda 21, which according to the UN website, is "a wide-ranging blueprint for action to achieve sustainable development worldwide."[18] All the media coverage and global participation guaranteed that the Summit would have a far-reaching impact.

The Earth Summit in Rio paved the way for the Sustainability Revolution and allowed the concepts of sustainability to enter the mainstream. Although concrete definitions of the Sustainability Revolution elude many, its value system remains consistent, always revolving around the three pronged approach of the environment,

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[15] The World Commission on Environment and Development. *Our Common Future.* Oxford University Press, 1987, p. 43. cited in Edwards, Andres R. 2005. *The Sustainability revolution: portrait of a paradigm shift.* Gabriola, BC: New Society Publishers. (p. 4)
[16] http://www.un.org/geninfo/bp/enviro.html; accessed 3/20/07.
[17] Ibid.
[18] Ibid.

society, and the economy.[19] Once the Sustainability Revolution got a strong foothold, many other sub-revolutions appeared. One of these sub-revolutions, or movements within the greater Sustainability Revolution, was that of the Campus Sustainability Movement.

The Campus Sustainability Movement:

In the 1980s, the Campus Sustainability Movement started to take hold on college and university campuses. Several academics began to publish work on the idea of whole-systems learning and approaches. One person in particular, David Orr, wrote extensively on the concept of ecological literacy. According to Orr,

> "The ecologically literate person has the knowledge necessary to comprehend interrelatedness, and an attitude of care or stewardship…….Ecological literacy, further, implies a broad understanding of how people and societies relate to each other and to natural systems, and how they might do so sustainably."[20]

This concept started to gain footing at college campuses nationwide, where students, staff, and faculty began to see their part in the grand scheme of campus operations. The initial acceptance of ecological literacy resulted in the first campus environmental audit.

In 1989, the University of California at Los Angeles conducted the first campus environmental audit, targeting eleven different campus issues and their impacts on the environment. UCLA's audit focused on various forms of waste, runoff, pesticide use, water use, energy use, procurement, and the workplace environment. The introduction of

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[19] Edwards, Andres R. 2005. *The Sustainability revolution: portrait of a paradigm shift.* Gabriola, BC: New Society Publishers. (p. 8)
[20] Orr, David W. 1992. *Ecological literacy: education and the transition to a postmodern world*. Albany: State University of New York Press. (p 92)

the audit paved the way for many other campuses to follow suit. It also prompted many to research and write on this idea of a *sustainable university*. Concurrently, while the auditing phenomena began to take off, an international conference held in Talloires, France, put the goals of the campus sustainability movement to words. The resulting Talloires Declaration of 1990 united hundreds of university presidents from around the world in an official commitment to sustainability in higher education.[21] This official declaration fostered more awareness of the sustainability movement on college campuses.

In order to become a sustainable university, each university or college must outline a sustainability mission specific to its location, practices, size, etc. According to one study, the generic idea of a sustainable university can be defined as:

> "A higher educational institution, as a whole of as a part, that addresses, involves and promotes, on a regional or a global level, the minimization of negative environmental, economic, societal, and health effects generated in the use of their resources in order to fulfill its functions of teaching, research, outreach and partnership, and stewardship in ways to help society make the transition to sustainable lifestyles."[22]

By using this as a starting place, many universities can shape their environmental goals and overall missions. Fortunately, the Duke University Marine Lab is already one step ahead of this, since its Green Initiative outlines its sustainability mission.

In an attempt to provide some type of framework from which universities can operate, various studies, like the ones conducted by Sharp (2002) and Velaquez et al (2005), have examined the sustainability efforts occurring at several universities around

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[21] http://www.ulsf.org/programs_talloires.html; accessed 4/2/07.

[22] Velazquez, Luis, Munguia, Nora, Platt, Alberto, and Jorge Taddei. 2006. Sustainable University: What can be the Matter? *Journal of Cleaner Production*, 14, 810- 819. (p 812)

the globe. Although most universities employ divergent tactics, the idea of active learning can be seen across many campuses. Active learning presents an opportunity for colleges and universities to carry the sustainability conversation outside of the classroom. Through this method, students, faculty, and staff can apply what they learn to hands-on efforts. For example, at Ball State University, people actively participate in the campus greening efforts by hosting conferences and faculty workshops on campus greening, as well as maintaining green committees and a community task force to get the local area involved.[23] The Green Waves Initiative at the Marine Lab serves as an example of this type of active learning encouraged by the Campus Sustainability Movement, as is the undertaking of this environmental audit.

Maintaining A Commitment to Sustainability: The Duke University Marine Lab:

The Marine Lab already actively follows the mission behind its Green Initiative. For future development, all new buildings at the Marine Lab will be "green" and meet some level of LEED certification, be it certified, silver, gold or platinum. Last November, the Marine Lab opened the new Ocean Conservation Center on campus, which meets the LEED standard. While the United States Green Building Council has not yet designated what official certification the building will achieve, many at the Lab believe it will meet the Gold ranking. Future development will strive for the greenest possible outcome, including the durability of materials and efficiency in waste disposal.

In addition to development, procurement practices further exemplify the Marine Lab's commitment to sustainability. One instance which conveys this green commitment

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[23] Koester, Robert J., Elfin, James, and John Vann. 2006. Greening of the Campus: a Whole-Systems Approach. *Journal of Cleaner Production*, 14, 769-779.

comes from the procurement of brown (recycled) paper towels. Although the Lab can purchase white (bleached) paper towels for $0.68 per roll, they are less sustainable than recycled paper products, which cost five and a half times more, at $3.68 per roll. This cost difference reveals the Marine Lab's promise to the greening of its campus. Furthermore, this visible practice has forced people to be more conscious of their behavior and has resulted in a more conservative use of paper towels. Although these two examples show how the occupants of the Marine Lab live their values, many other improvements can be identified and worked on. This audit will help further the effort.

METHODS:

Although this may be the first environmental audit of the Duke Marine Lab, it certainly is not the first university campus to conduct one. In 1988, the School of Architecture and Urban Planning at the University of California Los Angeles performed what is now known as the first campus environmental audit. The graduate students performing the audit looked at 11 key environmental issues, concerning water, energy, and waste.[24] The section of the audit on Energy Use outlines specific questions that one must answer while conducting an energy audit. Using this UCLA environmental audit as a template for performing environmental audits helped direct the various aspects of energy consumption and efficiency I needed to observe at the Marine Lab. Although it would have been beneficial to examine all areas of environmental practices, due to time constraints and the limited scope of my MP, I focus solely on electricity consumption at the Marine Lab.

In order to conduct an energy audit of the Duke Marine Lab, various crucial data needed to be obtained. Data in the form of financial information, building square footage information, kWh meter readings, occupancy and student enrollment numbers, total annual visitors, and campus maps. Collecting this type of information would help the energy consumption patterns of each building on the Marine Lab campus become well understood.

While performing some preliminary research, I found some campus environmental audits conducted by other universities. One audit, conducted by the University of Pennsylvania, included an energy audit in their analysis. Three of the five

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[24] Smith, April A., Gottlieb, Robert. (1992). Campus environmental audits: the UCLA experience. *New Directions for Higher Education*. 77. 9-17.

questions they focused on apply to the Marine Lab: (1) "What are the sources of energy for the electric utility serving your school?"; (2) "How much energy did campus buildings and grounds consume in the last academic year and what were the costs associated with each type of fuel?"; and (3) "How has campus energy use changed over the past five years?"[25] I employed these questions as a starting point for my analysis, and to commence the energy audit. In addition to these previous questions, I referenced questions from the first campus audit at UCLA and the *Campus Ecology* guide to steer my research in the correct direction (see Appendix B).

I collected all data either via email or in-person interviews. Leigh Torres, the PhD candidate with whom the Marine Lab audit concept originated, helped me learn who I would need to contact at the Lab. Leigh directed me to Dominick Brugnolotti, the Assistant Director of Auxiliaries at the Marine Lab, who answered several questions and offered data on annual Lab visitors. He then directed me to Regis Koslofsky, the Director of Facilities Administration, in the Facilities Management Department in Durham. From Mr. Koslofsky, I obtained financial data concerning electricity consumption during Fiscal Years 1999, 2001 and 2006. I needed to collect data on multiple years in order to provide some basis for comparison. Additionally, Mr. Koslofsky provided building code data and square footage information for the buildings at the Marine Lab. I needed to acquire the building code information so that I could understand what building costs corresponded with what buildings on the campus map. I also needed to know the various sizes of each building, and hence square footage represented the most precise way to compare building size.

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[25] http://dolphin.upenn.edu/~pennenv/audit/Energy/index.html; accessed 12/06.

Due to the importance of supplementing financial data with kilowatt-hour consumption, it became necessary to acquire meter data. This is because of the fact that costs do not necessarily reflect energy consumption, but rather, electricity rate spikes. Kilowatt-hour data is never influenced by electricity rates and can therefore reveal the exact energy consumption. To obtain this information, Mr. Koslofsky directed me to Bob Friedman, a computer project manager with Facilities Management, who holds all meter data for the Marine Lab buildings. Mr. Friedman provided meter data in an excel spreadsheet format. The only meter data that currently exists for the Duke Marine Lab Buildings comes from the Dining Hall, and Dormitories 1, 2, and 3. Since meter data only exists for four campus buildings, the energy audit became even more focused.

I contacted Barbara Howard at the Marine Lab regarding a connection at Progress Energy, the provider for the Marine Lab. I then contacted Helen Nearing in Durham for student enrollment numbers (both graduate and undergraduate) at the Marine Lab for the years 1999, 2001, and 2006. Unfortunately at this time, I have not received any data from these contacts. Therefore, the energy audit is limited to an analysis of building costs and a few meter readings. Much of the energy audit revolved around the actual data collection process, since this audit involved much redirecting and maneuvering through the Duke University system. In addition to the data collection process, once the desired data was acquired it only led to more questions.

What commenced as a comprehensive energy audit to examine and review the current energy practices at the Duke University Marine Lab was complicated by limited available data. It is important to point out that this energy audit solely analyzes electricity use at the Marine Lab (supplied by a Progress Energy combustion turbine plant) and not any gas fuel use. The data I did manage to obtain, both financial information and meter readings, assisted my analysis of the energy consumption at the Beaufort campus. Within that data, I looked for trends and notable discrepancies over the course of the years. Although some of the data appears flawed, and thus influenced my findings, those flaws inspired some of my recommendations.

RESULTS AND OBSERVATIONS:

This section is split into two focal areas: financial data and meter data.

FINANCIAL DATA:

Table 1: Comparison of Financial Data for the Marine Lab for Three Different Years[26] (Marine Lab buildings listed in alphabetical order, to accommodate quick referencing.)

ELECTRICITY COSTS IN DOLLARS FOR FISCAL YEARS (FY) 2006, 2001, AND 1999

*** Data obtained from Facilities Management Department in Durham

BUILDING NAME	FY 2006	FY 2001	FY 1999
Administration Building	4,232.12	5,476.59	3,891.83
Boathouse	5,482.10	2,364.66	4,411.85
Bookhout Laboratory	14,071.57	101,460.97	85,853.78
Bradley House (sold in April 2006)	3,933.01	6,490.53	no data
Caretaker's Residence	7,158.38	2,658.26	1,772.85
Dining Hall	5,366.82	12,671.03	no data
Dorm #1	116.63	256.22	no data
Dorm #2	42.67	134	no data
Dorm #3	407.27	424.05	no data
Dorm #4	2,085.35	2,698.44	3,935.83
Dorm #5 (formerly Lab #3 and got renovated in 2003)	10,584.76	4,565.60	3,935.83
Garage	1,863.64	803.92	710.85
Lab #1	4,067.62	1,754.54	3,070.85
Lab #2	7,914.85	3,413.94	3,503.85
Lab #5	4,287.35	5,545.98	3,070.85
Library and Auditorium	9,712.89	30,784.47	4,694.84
Maintenance and Storage Building #2	no data	no data	710.85
Oceanographic Storage/EPA	5,476.52	2,362.23	3,070.85
Pier	7,383.41	7,625.64	710.85
Seawater Tank / Lab #4	2,046.48	2,648.26	710.85
Service Building	11,675.60	5,036.16	6,658.85
Student Recreation Center	1,991.13	N/A (was not yet built)	N/A (was not yet built)
Volatile Storage	52,210.56	500.46	344.84

[26] I derived these results from Financial Data from Fiscal Years 1999, 2001, and 2006, in addition to personal communication with Dominick Brugnolotti, Leigh Torres, Regis Koslovsky, and Tommy Davis.

Table 2: Total Annual Electricity Costs (Summing Only the Buildings in Table 1)

	FY 2006	FY 2001	FY 1999
Annual Total Electricity Costs	162,110.73	199,675.95	131,060.30

Description of Data:

For various reasons, a few buildings at the Marine Lab do not appear in Table 1. One of these, the Ocean Conservation Center, completed construction and officially opened in November 2006. It has been in existence for less than one year and thus no fiscal data currently exists for it. Another building, the Lift Station, does not materialize on any map for the facility, and only FY 1999 offers any financial data on it. While the Transformer emerges on one of the maps for the Marine Lab, no financial data exists for it, and its functions remain unclear. The Paint Storage building, while visible on both maps, lacks financial data from FY 2001 and FY 2006. Therefore, no analysis could be conducted regarding its energy consumption and use. The Marine Lab Colonial House also does not appear on the spreadsheet in Table 1. The reasons behind its absence stem from the fact that the Marine Lab no longer owns this off-campus building, rendering it obsolete for analysis.

In 1998 the Nicholas School handed over facilities management rights to the Facilities Management Department in Durham[27], an event from which many changes and improvements ensued. Prior to the switch of management rights, financial data was not as abundant or specific to a particular building. This explains why the data for FY 1999 shows many cells with "no data" and why so many of the annual building costs appear to be the same exact number. This phenomenon is no coincidence and can only be

[27] Based upon personal communication with Regis Koslofsky and Tommy Davis on 2/15/07.

described by the fact that meters did not exist on the individual buildings and the way to calculate costs per buildings would be to add up electricity costs for a collection of buildings and divide by total square footage. The summation of costs and division by square footage explains why Labs # 1 and 5 and the Oceanographic storage have the same electricity annual costs, the Garage, Maintenance Building, Seawater tank and Service Building all display identical annual costs, and Dorm # 4 and 5 have the same costs. The recognition that none of these annual electricity costs appear to be specific, point out that the data for FY 1999 does not inform the reader of anything substantial, other than the fact that these practices need to change.

The data from FYs 2001 and 2006 show greater variation of annual electricity cost per building. While the costs for all buildings on the Marine Lab campus fluctuate annually, a few key buildings exhibit the most significant differences. The costs for Bookhout Lab, the Dining Hall, the Library and Auditorium, Lab #2, Dorm #5 and Volatile Storage each bring new questions and observations to light. Not surprisingly, when talking to some of the staff and graduate students at the Marine Lab it becomes apparent that among all the buildings on campus, students and visitors use these most frequently.

Individual Building Analysis:

Bookhout Lab:

Bookhout Laboratory consistently exhibits a significantly larger electricity cost over all three years of data. Constructed in 1974 out of concrete, brick, block, and steel, Bookhout Lab houses the campus computer labs, working labs, and offices. According to the Office of Financial Services at Duke, the building's square footage equals 24,141 ft^2.

The size of Bookhout far surpasses that of any other building on the Marine Lab campus. Bookhout's material composition and size coupled with old and inefficient heating ventilation and cooling (HVAC) systems help explain the annual electricity costs for FY 1999. However, because every other building on the campus has seemingly incorrect data, the validity of the costs for Bookhout in 1999 remains questionable.

Looking at the three years of data for Bookhout, one can easily see how expensive it is to operate. While Bookhout's reported electricity costs were $85,853.78 in 1999, they continued to increase by 2001, when the total amounted to an alarming $101,460.97! This cost represents approximately 50% of the total annual electricity costs at the entire Marine Lab for 2001. The fact that one building has the ability to cost such an exorbitant amount necessitates further scrutiny. When one compares the data from 2001 to the data from 2006, the difference is almost difficult to believe. By the end of FY 2006, the annual electricity costs for Bookhout only amount to $14,071.57, a cost reduction of nearly 86% from 5 years prior (without adjusting for inflation).

This noteworthy behavior can be attributed to multiple things. One difference comes from the fact that in FY2005 facilities management implemented some equipment changes. The former HVAC system in Bookhout functioned on three separate chillers. According to the 2004 Buildings Energy End-Use Data, space heating and cooling account for 33% of total building energy consumption.[28] Therefore, these outdated, inefficient chillers needed to be replaced, as they constituted a major part of the costly energy bills. Approximately 2 years ago, facilities management decided to take two of the three chillers off-line, and replace the third one with a brand new, efficient chiller.[29]

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[28] http://buildingsdatabook.eere.energy.gov/images/charts/2006/2004_BuildingsEnd-Use.pdf; accessed 7/06
[29] Ibid.

The difference, as evidenced by the reduction of the building's annual electricity costs, was staggering. In addition to the new chiller, new insulation, new lights and cabinets have all been recently installed to improve overall building performance and subsequently, operating cost reductions.

In a meeting with the Facilities Management Department in Durham, some other possible explanations for such drastic reductions came about. One of these explanations comes from the fact that not all buildings at the lab have meters on them, thus resulting in building electricity use being grouped together for billing purposes. There are approximately 6 transformers that feed electricity to the Lab. Several of the buildings share the same transformer and thus get grouped together. If all buildings had individual meters, then the costs reported for each building could be attributed to individual building's energy consumption. However, due to the lack of individual building meters, campus buildings either in close proximity to one another or which share a transformer would often be allocated a group annual budget. Therefore, the proposed annual budget, as well as reported costs, could fluctuate depending on how buildings collectively performed that year. Bookhout has historically been linked to the Library and Auditorium, and if energy consumption decreased in one of the two buildings, it did not necessarily mean it did in both. However, the per-building budgets were not readjusted to correspond to the actual energy consumption.

Whether or not Bookhout Laboratory's budget is linked to some other building, the significant cost reduction cannot be entirely attributed to the reallocation of Bookhout's costs to other buildings. This stems from the fact that the total campus energy bills were $37,565.22 less in 2006 than in 2001. Therefore, it is very important to note the impressive cost reductions for Bookhout due to its renovations. Facilities Management should recognize this difference and consider it positive feedback due to its efforts to make the building operate more efficiently. These results should also encourage Facilities Management to undertake more renovations for other campus buildings.

Dining Hall

The Dining Hall on the Marine Lab campus represents the next building to require an analysis. Although Table 1 lacks dining hall data for FY 1999, the difference between FY 2001 and FY 2006 follows the same trend as Bookhout Lab. According to the data, the annual electricity costs drop from $12,671.03 in 2001 to less than half of that to $5,366.82 in 2006. While neither discussion with Dominick Brugnolotti or Regis Koslofsky made mention of specific improvements enacted on the dining hall, Mr. Koslofsky did mention that over the last few years FMD has been fixing up various parts of the campus. One of the improvements has been the replacement of all sidings of buildings. Although this may not alter the insulation or performance of each building, it does improve the overall aesthetics of the Marine Lab. However, this would not account for the cost reduction of the dining hall, and thus the reasons for this improvement are still unknown.

Many of the buildings on the Marine Lab campus display easily recognizable problems to its occupants. The campus Dining Hall, with its cedar shake exterior and occupation of 3,696 square feet, represents no exception to this.[30] Among its problems,

[30] Square footage information from a data sheet provided by Regis Koslofsky in November, 2006 and online at http://www.finsvc.duke.edu/finsvc/budget/CostAlloc/Cost_psf_details.html#79; accessed 2/25/07.

none of the floors or walls has proper insulation, all the windows are single-paned glass, and both the air conditioner and hood system are old and inefficient. To quote Dominick Brugnolotti, one of the biggest problems with the dining hall is the “conflict of utilities within the space.” What this means is that while the outside temperature prompts the HVAC system to control indoor temperatures, the heat generated by the kitchen in the Dining Hall represents something else that needs be monitored and regulated. Some quick fixes to this building would be to install double paned glass windows, and the purchase and installation of a new, efficient hood for the kitchen. While the solutions may be known, the constant battle between accessible money and the Marine Lab’s priorities for that money still reigns. However, the Dining Hall has one notable advantage over most of the other campus buildings: its kilowatt-hour meter. The meter allows the faculty and staff at the Marine Lab to know exactly how much energy the building consumes. This will be discussed in greater detail later.

<u>Dorm #5</u>

Four years ago, Facilities Management converted the building formerly known as Laboratory #3 into what the campus currently recognizes as Dormitory #5. Therefore, the distinct annual electricity costs differences between FY 1999, 2001 and 2006 can be attributed to the change in building function. The difference in annual electricity costs between FY 1999 and FY 2001 only results in an increase of $629.77. While the difference does exhibit a higher cost, one potential explanation could simply be due to higher electricity costs and not any change in building use. However, the difference between FY 2001 and FY 2006 amounts to a cost increase of $6,019.16. This significant price hike implies a change that cannot merely be explained by more expensive electricity, but the function of the building.

In 2003, when the Facilities Management Department decided to convert the building from a lab into a dorm, they also decided to make some improvements by adding solar panels.[31] They installed solar panels on the roof of Dorm #5 in order to help offset electricity costs. While the solar panels generate electricity for Dorm #5 and lower the costs of the total electricity bill, the annual costs continued to rise from 2001 to 2006. The higher costs can be explained by a difference in building function as well as a change in the number of building users.

Total occupancy corresponds with the function of a building, which together influence total annual electricity costs. Electricity costs amplified when Dorm #5 changed its function from a lab to a dorm. This price magnification validates the assumption that dormitories typically cost more to operate. The explanation for this comes from the fact that occupants of a lab usually *work* within the building eight hours a day, whereas dormitory occupants *reside* within the building and have the potential to use the building at all hours of the day. Furthermore, residents of the dormitories use the building for various energy taxing activities, such as turning lights on constantly and using hot water in showers.

Every semester the student enrollment changes at the Marine Lab, thus changing the number of people who occupy the dorms on campus. For instance, currently there are 5 undergraduate students living in a dorm. The maximum occupancy specifically for Dorm #5 is limited to 33 people. Dorm #5 typically reaches its capacity during the summer months when air conditioning use is in full effect. From approximately mid-

[31] Based on personal communication with Dominick Brugnolotti, on 2/12/07.

May to the beginning of September the lab dormitories remain full.[32] Capacity can be quantified as two beds per room, and with 76 beds in the dormitory quad and an additional 36 beds on the trailer, the maximum number ranges from 96-108 students.

Faculty, staff and graduate students (both PhDs and Masters) remain more consistent throughout the year. Their impact does not shift too much throughout the year because they tend to limit their presence to standard business hours, Monday through Friday from 9 am until 5 pm. The fact that this group of people does not live on campus implies that they do not contribute to any part of the energy consumption in the dorms, particularly Dorm #5. However, they are still responsible for occupying other buildings like the Bookhout Lab, the Dining Hall, and the Library/Auditorium and Laboratory #2.

Lab #2

Graduate student offices occupy Laboratory #2. Based on personal communication with several staff and students at the Marine Lab, it appears that the function of the building has remained consistent over the past eight years. This consistency means that no drastic changes have occurred that would significantly alter Lab #2's energy consumption. However, Lab# 2 exhibits some interesting behavior with regards to annual electricity costs. While it remained relatively stable over FY 1999 and FY 2001, it more than doubles in FY 2006. From FY 1999 to FY 2001 the annual electricity costs actually decreased by $89.91, from $3,503.85 to $3,413.94. Then in FY 2006, the annual electricity cost soared to $7,914.85, resulting in a price swell of $4,500.91. Behavioral components can have an effect on the operating costs of the building, but graduate students in Lab #2 regulate the thermostat, which helps keep costs

[32] Ibid.

down[33]. While behavioral changes in the graduate students and pricier energy could account for some of the inflated costs, it most likely is a direct result of a budget reallocation for various buildings.

The Library and Auditorium:

All faculty, staff, and students utilize the public space of the Library and Auditorium. While each user group may not occupy the building as frequently as other campus buildings, the total energy consumption of the building can often be significant due to the number of users. When looking at the financial data over the three fiscal years, the range of electricity costs fluctuates drastically. The costs soar from $4,694.84 in FY 1999 to $30,784.47 in FY 2001, constituting a price escalation of $26,089.63. This jump in costs would carry a lot more credence if the electricity costs remained that high or relatively close to that amount over the next few years. However, in FY 2006, the annual electricity costs dropped back down to a more reasonable $9,712.89. The structure's use has remained the same over the last eight years, rendering this cost difference unique and worthy of analysis.

The name of the Library and Auditorium describes the purpose of it: the library houses books and reference material and provides a place to do work, while occupants of the Marine Lab use the auditorium to host many talks and symposia. The HVAC system seems to be the biggest energy strain on the building and would most likely constitute much of the electricity costs. The auditorium remains notoriously frigid and overcooled

[33] Personal communication with Leigh Torres, a Marine Lab PhD student and member Green Waves, on 2/12/07.

in the summer months.[34] This perpetual use of the HVAC system can get very costly, especially during typically warm summer months. While the HVAC system definitely contributes a significant portion of the annual electricity costs for the building, consistent use would not logically result in the annual cost pattern which the building exhibits for FYs 1999, 2001, and 2006. The price spike and then subsequent drop may be linked to the addition of meters to campus buildings.[35] This may account for an adjusted budget and explain why certain buildings formerly linked to the annual electricity costs of the Library and Auditorium in 2001, had their own meters by 2006 and no longer contributed to its annual electricity costs.

Volatile Storage:

The building called Volatile Storage provides a storage area for the Marine Lab. People do not work, live, research or attend talks in this building and the building requires little electricity to function. However, the financial data for the building, which takes up only 389 square feet of space, sounds off many alarms. The annual electricity costs for FYs 1999 and 2001 remain relatively constant, increasing by a reasonable $155.62. However, from FY 2001 to FY 2006, the disparity reveals a staggering price escalation of $51,710.10! Since the function of the building has always been that of a storage unit, the only explanation can be that the FY 2006 budget was incorrectly readjusted for Volatile Storage.

[34] Personal communication with the PhD student Leigh Torres, on 2/12/07
[35] Personal communication with Tommy Davis and Regis Koslofsky, on 2/15/07

Cost Comparison Among Buildings:

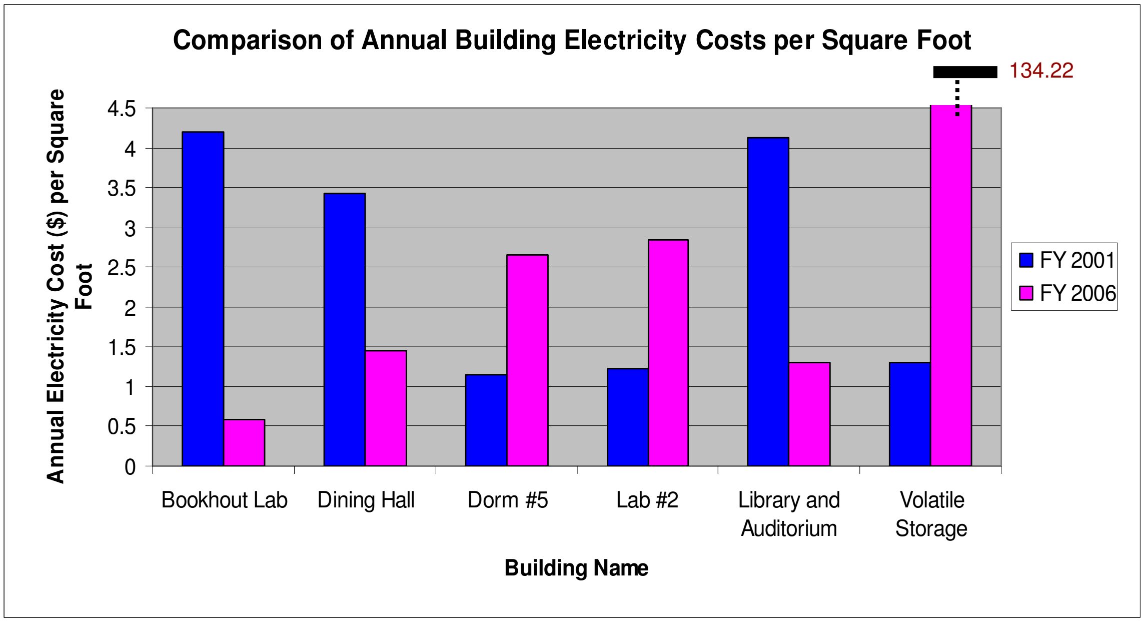

Figure 1: Cost per Square Foot Comparison for Six Selected Buildings

This graph compares two different fiscal years (2001 and 2006) and the annual electricity costs per square foot of each building. I chose to omit data from FY 1999 because it was either incomplete or appeared flawed. I only looked at the six previously mentioned buildings, since they represent the most frequently used campus buildings. I opted to include the Volatile Storage building in this visual analysis because the data that existed for it had an obvious flaw and this graph calls attention to that flaw. Noting this problem now, and rectifying it, will help ensure the problem does not occur again when the budgets are being determined for the Marine Lab in the future. Despite the flaw with the Volatile Storage fiscal records, there appear to be encouraging trends between the two fiscal years regarding the annual electricity costs per square foot of each building.

The Library/Auditorium, Dining Hall, and Bookhout Lab each exhibit decreasing overall annual costs, from 2001 to 2006.[36] The decrease in annual costs (in dollars) for these three buildings can be attributed to a plethora of causes: renovations to building exteriors conducted by the Facilities Management Department (perhaps creating better insulation), the decline in electricity rates, or a more efficient allocation of funds and budget from 2001 to 2006. While two buildings, Dorm #5 and Lab #2, display an increase in annual costs, there could also be a variety of explanations for this behavior. The increase in annual costs could be due to building function changes, inflation, electricity rate spikes, or altered budget records. As one can see, several possible reasons exist for why the building financial records appear the way they do. Due to the multitude of probable explanations, a mere financial analysis proves to be insufficient and actually necessitates an analysis based on kilowatt-hour consumption.

METER DATA:

It turns out that the most important discovered result was not within the kilowatt-hour data itself, but in the lack of available meter data. In 2001, facilities management began retrofitting individual buildings at the Marine Lab in order to equip them with electric meters. This step is crucial as it represents one of the ways that the Facilities Department at the Marine Lab can learn about their kilowatt-hour (kWh) usage. Currently, the only buildings known to have meters on them are the Dining Hall, Dorm 1, Dorm 2, and Dorm 3. That number represents four buildings out of the twenty-five that

[36] This comparison does not incorporate deflation into the analysis. It is a simple comparison of financial records for the two years.

are presently operated as part of the Marine Lab. All campus buildings, even the buildings with meters, are connected to six separate transformers, and supposedly some of these transformers have meters on them. However, since several buildings link up to each transformer, it becomes difficult to decipher from the meter which building consumes what kWh amount. Therefore, in order to analyze the meter data most accurately, I decided to focus on the buildings directly linked to a meter. Unfortunately, despite the fact that the following meter data come directly from meter readings and the Facilities Management Department, they seem to lack accuracy.

The table below displays meter readings for the Dining Hall on the Marine Lab campus. While Table 3 displays all the available meter readings to date, it remains consistent with the previously mentioned financial data by highlighting the readings from FY 2001 and FY 2006 (readings were not available from FY 1999).

Table 3: Dining Hall –Meter Readings in kWh[37]

_	FY99/00	FY00/01	FY01/02	FY02/03	FY03/04	FY04/05	FY05/06
Jul	0	24659	22000	35000	35000	60000	10000
Aug	0	16692	20458	25000	20695	53000	360
Sep	0	21758	34542	32000	17066	41000	11696
Oct	0	14292	25000	43000	12151	25991	9988
Nov	0	8187	21000	40000	40000	33009	7128
Dec	0	16743	21000	31000	4732	43048	9112
Jan	0	23205	28000	30000	34356	29952	7604
Feb	0	15714	25000	29000	51000	12000	8521
Mar	0	13997	22000	27000	47000	21000	7322
Apr	10030	13139	28000	33000	42000	24000	7435
May	11617	18778	23000	25000	31000	22000	7274
Jun	21967	22222	27000	30000	37000	34000	9943

Two observations concerning Table 3 come across as being very peculiar. The first observation involves the inconsistency in meter readings between FY 2001 and FY

[37] I obtained this meter data via email communication from Bob Friedman on 2/22/07

2006. While the overall trend in kWh consumption is decreasing (which is the desired outcome), it also shows inconsistency between monthly comparisons. In particular, August exhibits dramatic variation, which is surprising since that is typically when the Lab reaches maximum enrollment capacity. Furthermore, August traditionally represents one of the warmest calendar months, requiring more energy to power the HVAC system. I do not know what to specifically make of this observation but it does lead me to believe that the reading may be incorrect.

The second remarkable observation concerns the other fiscal years (FYs 2002 - 2005). Each kWh reading seems too perfectly rounded for these years. This prompted me to ask Bob Friedman, of Facilities Management, how the meter readings were collected and who reported them. Bob Friedman contacted Aurel Selezeanu in order to find out that the maintenance department provides the meter reading data. While knowing who provides the data takes my research one step closer to an answer, it also underlines how complicated the data collection process can be at Duke University, due to the involvement of several parties. This highlights the need for better communication and information sharing among departments.

The subsequent three tables follow the same format as Table 3, and highlight the kWh consumption for Dorms 1, 2, and 3 in fiscal years 2001 and 2006, but also display the electricity usage for the remaining fiscal years.

Table 4: Dorm 1- Meter Readings in kWh.[38]

	FY99/00	FY00/01	FY01/02	FY02/03	FY03/04	FY04/05	FY05/06
Jul	0	760	520	1040	1000	1280	680
Aug	0	400	400	560	960	32480	4600

[38] Ibid.

Sep	0	560	480	440	720	40	360
Oct	0	600	720	240	440	760	40
Nov	0	480	200	4960	4960	33360	360
Dec	0	640	160	840	880	280	0
Jan	0	560	240	80	80	120	80
Feb	0	600	680	1920	80	120	40
Mar	0	440	80	120	1040	120	160
Apr	200	440	240	320	200	120	80
May	360	520	280	440	200	280	640
Jun	760	400	200	960	80	920	40

Table 5: Dorm 2 – Meter Readings in kWh[39].

	FY99/00	FY00/01	FY01/02	FY02/03	FY03/04	FY04/05	FY05/06
Jul	0	400	280	560	280	120	200
Aug	0	160	160	280	240	8560	160
Sep	0	280	280	40	160	0	40
Oct	0	160	440	80	560	80	40
Nov	0	240	160	40	40	8680	40
Dec	0	160	200	40	40	0	0
Jan	0	280	40	40	120	0	40
Feb	0	160	160	40	120	0	0
Mar	0	80	120	40	160	40	0
Apr	240	80	80	120	240	40	40
May	360	40	120	80	200	120	80
Jun	560	160	120	200	40	400	80

Table 6: Dorm 3 –Meter Readings in kWh[40].

	FY99/00	FY00/01	FY01/02	FY02/03	FY03/04	FY04/05	FY05/06
Jul	0	240	200	200	360	200	320
Aug	0	200	120	80	320	520	360
Sep	0	200	240	80	40	40	0
Oct	0	40	480	120	40	12800	40
Nov	0	40	240	40	40	13280	40
Dec	0	280	200	80	80	13000	80
Jan	0	40	200	160	80	0	120
Feb	0	680	320	40	120	80	40
Mar	0	360	200	40	80	160	80
Apr	400	640	160	120	40	80	40
May	480	440	840	80	320	280	160
Jun	680	200	920	200	520	520	720

[39] Ibid.
[40] Ibid.

Table 7: Total Annual kWh Meter Readings for FY 2001

	Total kWh Consumption FY2001
Dorm 1	6,400
Dorm 2	2,200
Dorm 3	3,360

The annual kilowatt-hour consumption per dorm in 2001 seems particularly low, especially when compared to the annual electricity consumption of a typical U.S. household. This prompted an investigation regarding the average household kilowatt-hour consumption. According to the Energy Information Administration, the **average electricity consumption per household** for the year 2001 was **10,656 kWh**[41]. The EIA derived this number by conducting Residential Energy Consumption Surveys (RECS), which surveys household owners, rental agents and energy suppliers.[42] The surveys provide data on energy consumption by looking at housing characteristics, demographics, the type of appliances used, and the various energy sources.[43] When comparing data on the typical U.S. household to the dorms at the Marine Lab, it is crucial to understand how the two building types are similar enough to merit a comparison. The typical U.S. household and a dorm at the Marine Lab share similarities in both the types of appliances used and in the space occupied (which is measured in square footage).

The RECS incorporate an extensive list of appliances. The average household and the dorms at the Marine Lab share similarities between the major appliances such as lights, HVAC systems and water heaters. Although these only represent three appliances, together they comprise a large percentage of total kWh usage. In addition to similar

[41] http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html
[42] http://www.eia.doe.gov/emeu/recs/contents.html; accessed 3/8/07.
[43] Ibid.

appliance use, the dorms are comparable in size to the average household. Financial Services at Duke University provides net square footage data on all buildings at the Marine Lab. All three dorms differ only slightly in size, where Dorm 1 occupies 1,128 square feet, Dorm 2 occupies 1,117 square feet, and Dorm 3 occupies 1,017 square feet[44]. Out of the houses surveyed in the RECS, 22.7% occupied a total floor space of 1,000 to 1,499 square feet[45]: a range which matches the size of the marine lab dorms.

While a dorm may differ from a household in a several ways, they are similar enough in size and in several appliance uses that the annual kWh rates should be comparable. However, the annual totals are nowhere close to one another, with the overall dorm kWh utilization being significantly less consumptive than the average household in 2001. Since data is currently unavailable for 2006, my analysis was limited to 2001. After establishing that the data from the dorms could be appropriately compared to the EIA information on households, it becomes interesting to see how different the kWh usage is. In fact, it is interesting to see that the dorms actually use less. This is a good thing and an important accomplishment to note, as well as a behavior that the Marine Lab should continue to monitor.

[44] http://www.finsvc.duke.edu/budget/CostAlloc/Cost_psf_details.html#79; accessed 3/7/07.
[45] http://www.eia.doe.gov/emeu/recs/recs2001/hc_pdf/housunits/hc1-4a_housingunits2001.pdf; accessed March 9, 2007

Meter Comparison Among Buildings:

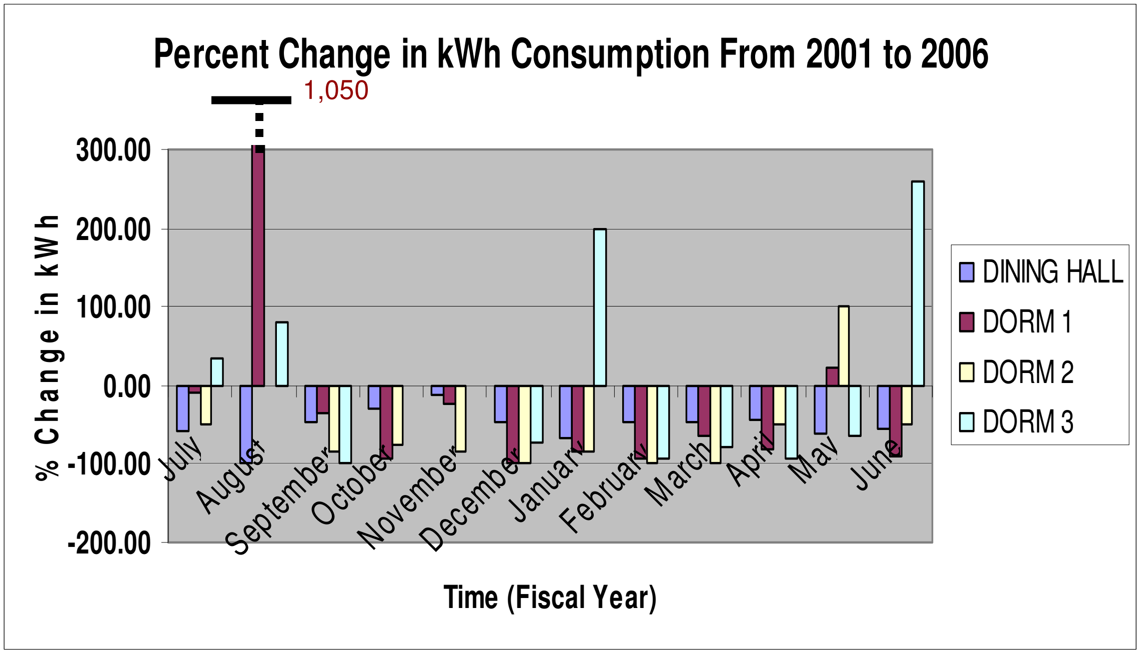

Chart 2: Percent Change in Kilowatt-hour Consumption from 2001 to 2006

Chart 2 shows the percent change in kilowatt-hour consumption per month from 2001 to 2006, for each of the four metered buildings.[46] It is important to note that the Duke University fiscal year commences on July 1 and ends on June 30. Hence, if reading the chart from left to right, the first month listed is actually July and not January. This chart breaks down the annual comparison between 2001 and 2006 by month to highlight how some of the percent change differences vary. The fact that the majority of the changes are negative changes (below zero) indicates an overall REDUCTION in kWh consumption! This overall decreasing trend is extremely encouraging, and good news for the Marine Lab's greening efforts. Similar to the explanations for costs variance, this phenomenon can be attributed to many things: fewer student enrollment, better on-

[46] Percent Change was calculated by subtracting the 2001 values from the 2006 values and then dividing by the 2001 value. Those values were then multiplied by 100 to find the percentage.

campus practices, etc. However, it is difficult to say for certain about the declining enrollment because enrollment data could not be attained.

Since I observed an overall decreasing trend in total kWh consumption from 2001 to 2006, I decided to subtract exactly what the difference was. Using the number of actual kWh reduced, and not the percent change, I multiplied it by the relevant carbon intensity factor to see how much was actually averted from the atmosphere. In this case, since the Marine Lab's energy supply is generated by coal power plants, the **relevant carbon intensity factor is 0.92 kg CO2 / kWh.**[47] Table 8 below shows the total amount of carbon dioxide averted from the atmosphere due to the electricity consumption reduction from 2001 to 2006. Dorm 1 actually displays an INCREASE in CO2 emissions from 2001 to 2006. However, when combined with the three other buildings, that increase is negligible.

Table 8: Kilograms of Carbon Dioxide Averted per Marine Lab Building

Building Name	Kilograms of CO_2 Averted
Dining Hall	104,000
Dorm 1	-625
Dorm 2	1,360
Dorm 3	1,250
Total	**106,000**

[47] http://www.bp.com/sectiongenericarticle.do?categoryId=9008658&contentId=7016688; accessed 4/2/07.

FOCAL AREA CONCERNS:

While conducting research for this audit, I came across an interesting dilemma regarding utility bills. The assistant director of auxiliaries at the Marine Lab, Dominick Brugnolotti, and Barbara Howard, receive monthly bills but do not have access to why the Lab is billed a particular price. Mr. Brugnolotti administrates the dorms, the dining hall, the student center, while Ms. Howard administrates all other buildings. While all the faculty, staff, and students at the Marine Lab use the energy, the Duke University Financial Services pay the bills and the Facilities Management Department in Durham sets the annual budget. Due to confidentiality restrictions, the Facilities Department at the Lab does not have access to the individual monthly cost breakdown per building. They simply receive a statement, tallying the total costs of maintenance and utility divided by square footage, saying how much the Marine Lab pays each month.

At present, this system is inefficient and leaves the Marine Lab at a significant disadvantage when attempting to advocate change for greater sustainability. Not knowing specific costs or meter readings renders it more difficult to monitor change and improvement, if changes are made. Similar to utility payment, energy policy is written by decision makers on Duke University's main campus in Durham. While those policy writers work out of an office in Durham, the individuals at the Marine Lab actually manage that policy. Currently, the Director of the Lab and several PhD students are pushing for more environmental policies, as evidenced by the Green Waves efforts.

Many factors contribute to a building's electricity consumption, namely occupancy, equipment, behavior of the occupants, insulation, lighting, HVAC systems, and square footage. Unfortunately, only four buildings at the Marine Lab have meters on them. Without the ability to meter the Lab's electricity consumption in its entirety, it is difficult to say what buildings could be more wasteful or inefficient than others. While costs may be a nice indicator of what was most expensive in that fiscal year, it does not alert the auxiliaries staff to what is most consumptive.

RECOMMENDATIONS AND CONCLUSIONS:

The Duke University Marine Lab has enjoyed much environmental progress over the past few years. Ever since the Facilities Management Department (FMD) took over the facility operations of the Lab, many changes have been implemented which help further the Lab's commitment to the environment. In 2001, FMD began renovating the outside of the dorm and lab buildings, in order to render them more efficient. In 2003, when Lab # 3 transitioned into Dorm # 5, solar panels were added to the building to help generate electricity for the building.

The fall of 2006 brought about the most significant changes. With the official opening of the Marguerite Kent Repass Ocean Conservation Center and the creation of the Green Waves, the Marine Lab fully immersed itself in the Campus Sustainability Movement. The brand new Ocean Conservation Center is a fine example of green design, with its pending LEED Gold certification, use of sustainable building materials, and efficient natural lighting. The official opening of the Ocean Conservation Center occurred in conjunction with the initiation of the Green Waves effort on campus. This Green Waves effort appeals to many aspects of the Campus Sustainability Movement, bringing education, conservation, and action to the forefront of the Lab's daily practices and policies.

The idea of the environmental audit for the Marine Lab originated out of this Green Waves effort. In order to assess the current state of the Lab's sustainability performance, an audit needed to be conducted. Due to time constraints, this audit narrowed its focus on campus electricity use and consumption patterns. Based on both financial data and kilowatt-hour meter readings, the overall consumption trends appear to be decreasing over the last eight years. However, much of the analyzed data appears to be flawed, either because it is seemingly rounded or semi-contrived. Therefore, this audit represents more of a preliminary energy audit for the Marine Lab.

In order to conduct a full scale energy audit, several changes must occur. The first of these changes revolves around meters. Every building on campus must have a meter on it. As of now, only four campus buildings have meters: the dining hall, dorm 1, dorm 2, and dorm 3. The only way that occupants of the Marine Lab and the Facilities Management Department can successfully monitor their electricity consumption is by actually knowing the total of kilowatt-hours consumed. The only way to achieve this accuracy is via individual building meters. Ergo, when Facilities Management begins to reconfigure their annual budget, they must incorporate individual meters into the budget. Furthermore, FMD should eradicate their previous practices and seek out new methods of allocating building budgets. Instead of grouping buildings budgets together based on location or transformer sharing, FMD should turn to previous bills and individual building costs in order to determine what each building annual budget should be.

Along the lines of budgeting and billing, the monthly electricity bills need to be more transparent to the Marine Lab's occupants. Currently, bills go to and get paid by Duke Financial Services and records are kept by Facilities Management, both located in Durham. Based on the structure and set-up of the University, there are specific reasons why bills from a campus in Beaufort get paid by an office located 200 miles away. While it may be too difficult and inefficient to change that current practice, it would behoove both offices to inform the Marine Lab of their monthly electricity costs. To include the occupants of the Marine Lab in the billing process would make the most sense, since they are the ones consuming the electricity. If the Marine Lab could become more involved in its electricity billing process, it would help the occupants feel more accountable for the campus energy practices.

Other recommendations for future success target the behavior of the occupants at the Marine Lab. Faculty, staff and students need to campaign in conjunction with the Green Waves values. That translates into a campus movement which serves to remind people to modify wasteful behavior. One example of this type of action would be to post signs to remind people to turn off lights when leaving an empty room. This visible campaign will not only help occupants of the Marine Lab become more conscious of their daily energy behavior, but also will be important for when visitors come to the Marine Lab. Another pattern people should be aware of is the tendency to overcool buildings. To prevent that behavior from occurring, occupants must pay attention to each building, particularly the Library and Auditorium, and Bookhout lab. No good reason exists for why this happens and users of the Lab should exert more control over building thermostats.

The last recommendation concerns the energy source for the Marine Labs' electricity. The Marine Lab obtains its power from Progress Energy. The Progress Energy Plant in Morehead City, which is closest to the Marine Lab, generates electricity via a combustion turbine plant. This method of electricity generation is unsustainable and contributes to the total carbon dioxide emissions released into the atmosphere. One way to remedy this occurrence is by getting involved with NC GreenPower. Progress Energy is a participant in NC GreenPower, a program which generates funding for renewable energy development for North Carolina through voluntary contributions. The

Duke Marine Lab can opt to participate in the NC GreenPower Program, where they will pay slightly more per month in order to contribute to the statewide development of renewable energy. As their website states:

> this program allows larger electricity users to contribute $2.50 per month for a 100-kilowatt-hour block of green power. These customers make a minimum commitment of 100 blocks (10,000 kWh) per month for one year. The $2.50 per block monthly fee is added to the customer's regular electric bill. This block of renewable energy will come from solar, wind, water and biomass resources[48].

In other words, the Duke Marine Lab can voluntarily sign up to pay $250 more each month in order to provide financial backing for the development of renewable energy sources in North Carolina. Although this would add to annual expenses and require an annual budget increase for the Marine Lab, it would ensure the occupants of the Lab lived and practiced their values.

Duke University already touts a strong reputation for sustainability. An article highlighting campus energy practices recognized Duke University for its purchasing guidelines and its transportation fleet.[49] Furthermore, on the first annual Sustainability Report Card released in January 2007 by the Sustainable Endowments Institute, Duke received an "A" in the categories of *Climate Change and* Energy and *Green Building*[50]. In order to maintain this reputation, Duke must continue to go above and beyond the status quo. This translates into pursuing options that Duke has yet to act on. With the

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48 http://www.progressenergy.com/custservice/carres/greenpower/index.asp; accessed 3/19/07

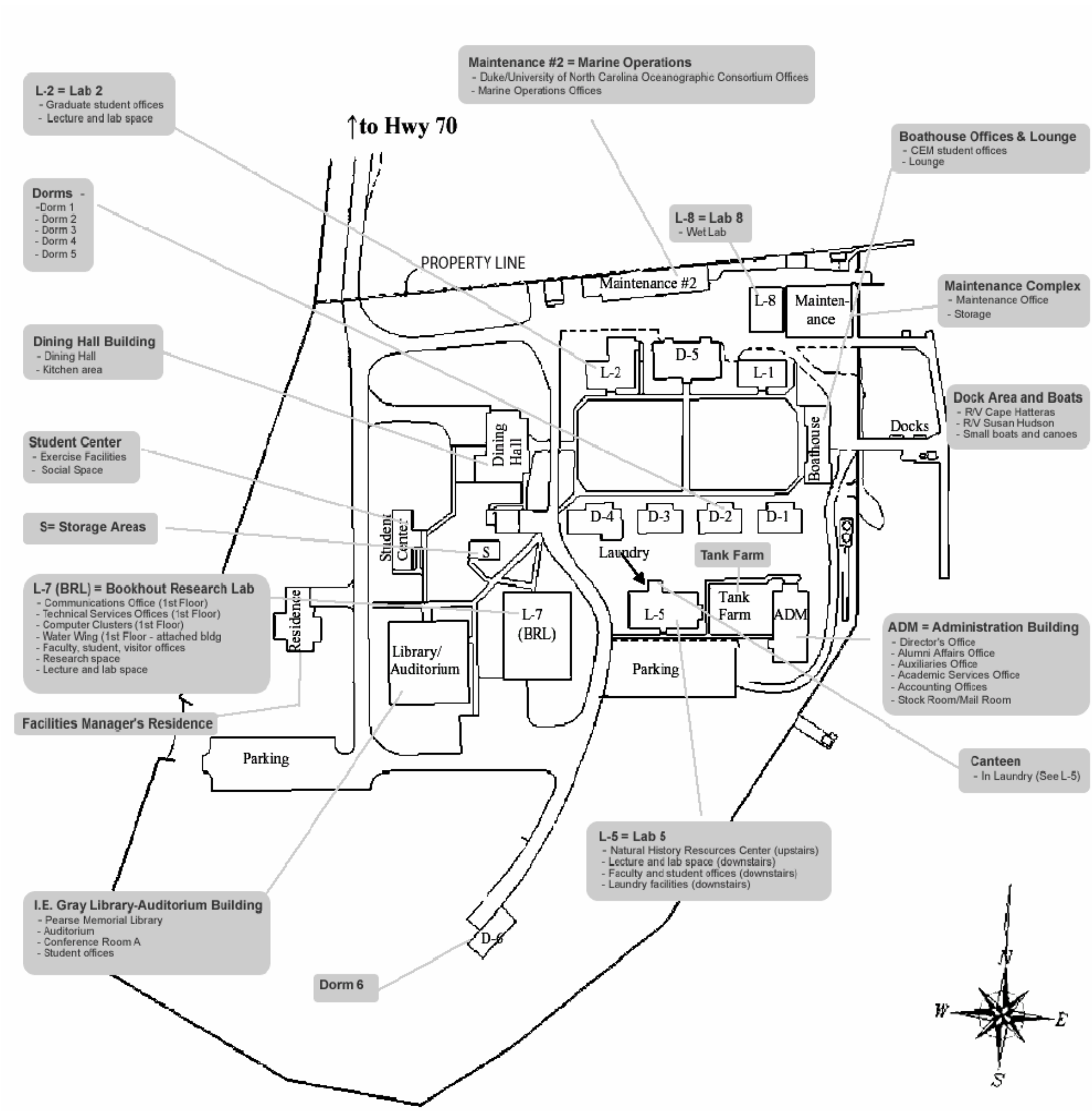
49 *Rhodes-Conway, Satya, Siu, Brian, and Billy Parish. 2005. New Energy for Campuses: Energy Saving Policies for Colleges and Universities. Available from http://www.energyaction.net/documents/new_energy.pdf.

50 http://www.endowmentinstitute.org/sustainability/profile31.pdf; accessed 2/07

prospect of contributing to green power, the Marine Lab can further its own sustainability mission while taking part in the ongoing effort at Duke University.

While the information provided in this report delineates energy consumption trends at the Marine Lab, it also calls attention to areas that require change. Therefore, it functions mainly as a preliminary audit. Before a full-scale energy audit can be conducted both the Facilities Management Department and the occupants of the Marine Lab need to administer necessary improvements. It is only after these developments are put in place that energy consumption patterns can be monitored. This audit outlines these appropriate changes. The task of an environmental audit of the Marine Lab should become an ongoing assignment, carried out year-to-year by a different Masters of Environmental Management student. Although this audit focused solely on energy, there are many other resource areas that require examination and auditing. Additionally, a masters project that picks up where this audit leaves off would be a great way to see results regarding energy consumption at the Lab.

APPENDIX A: Campus Map of the Duke University Marine Lab
(source: http://www.env.duke.edu/marinelab/about/dumlmap.pdf; accessed 4/22/07)



APPENDIX B: Questions For Environmental (Energy Audit) of the Marine Lab

My own questions:

- When were the renovations made at Beaufort (in 2001)? The bills for Bookhout and Dorm #5/Lab#5 are both exceptionally high.
- Is Dorm #5 a lab or a dorm?
- (Verify that the ML is powered by Progress energy) Is there a contact or name of someone over at Progress that I could get in touch with to ask questions regarding the TYPE of energy that fuels the ML?

Questions From UCLA's Campus Environmental Audit[51]:

Page 5: (these can be applied to any area that is being audited; they are more general)

SECTION A
1) Who is the responsible campus authority?
2) What is the magnitude of the problem?
3) What are the current policies and programs?
4) What, if any, alternatives have been implemented or suggested?
5) What are the costs associated with the current policies and the alternatives?
6) Which local and state agencies interface with the university on the issue?

Page 28-29: Specific Energy Audit Questions:

SECTION B
1) What conservation measures have been implemented at your school?
2) What measures are under consideration or planned? (Distinguish between "technical fixes" and solutions requiring changes in human behavior).
3) Are new buildings designed to maximize efficiency?
4) Have energy audits been conducted?
5) Is there a computerized energy management control system?
6) What happens on weekends, holidays and evenings? (research what measures are feasible).
7) What sources of alternative energy could be or are used?(solar energy might be used to warm buildings or for domestic hot water in residence halls. Explore the use of alternative fuels, photovoltaic energy, cogeneration, and wind, for example).
8) How are energy costs and conservation programs funded?
9) Where do budget dollars saved through conservation measures go?
10) Are public bond monies or grants available?
11) Is third party financing possible?
12) What pay-back criteria are used for conservation projects?

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[51] UCLA Environmental Study Group and Earth Day 1990. 1989. *Campus Environmental Audit: A Student Guide to Campus Environmental Change*. Los Angeles.

13) Have you noticed certain buildings that are over-heated in the winter or overcooled during warm months?
14) What was the campus' total energy bill for the past year?
15) How does your campus compare to other institutions?

Questions from April Smith's Campus Ecology[52]

Pages xvi -xvii: Getting Started: take a survey of the campus
Campus Geography and the Physical Plant

SECTION C: Look at maps of your campus and the surrounding area
1) Where is your campus located?
2) Is it in a large city, or a small city, or a rural area?
3) Is it a "campus town," serving as the area's principle economic base, or is it only one of many activities in a larger urban setting?
4) How much area does your campus cover?
5) How much natural open space and agricultural land does it include?
6) Who are your nearest neighbors?
7) Is your campus set apart from the surrounding community, or are its buildings interspersed with homes and businesses?
8) Does your school operate more than one campus within the larger community?
9) What transportation facilities exist near your campus, and how do the majority of students, faculty, and staff go to, from, and around the campus each day?

SECTION D: Gather facts on the natural history of the region
1) What is the climate range of your region: temperature range, average rainfall?
2) Is it subject to drought, flooding or natural disasters such as earthquakes or hurricanes?
3) What are the geographical features: forested land, rivers, larger bodies of water?
4) What type of wildlife exists in the region?
5) What is the air quality?
6) Do other environmental problems exist, such as polluted waterways, acid rain, threatened wetlands areas, depletion of old-growth forests?

SECTION E: Research the history of your school
1) When was it established?
2) What are the ages of its buildings?
3) What are their architectural styles?
4) What is the growth pattern of your school, in terms of population as well as building construction?

SECTION F: Review the range of facilities located on the campus

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[52] Smith, April A. 1993. *Campus Ecology: A Guide for Assessing Environmental Quality and Creating Strategies for Change.* Los Angeles: Living Planet Press.

1) How many and what kinds of food services, libraries, classrooms, offices, maintenance facilities, housing museums, sports facilities, research labs, art studios, trade shops, theaters, parking lots, garages, and off-campus buildings are affiliated with the campus , including its medical centers, if any?
2) Who administrates each type of facility?

SECTION G: Obtain development plans from your school's office of capital programs
1) Does your campus have a long-range development plan?
2) When was it adopted and who developed it?
3) Is it being followed and implemented?
4) Is it being updated and revised?
5) Has your school prepared an environmental impact report for a new or projected campus project?

Campus Organization and Human Resources

SECTION H: Contact your school's personnel and admissions offices for campus statistics.
1) How many faculty, staff, and students does your school now have, both full time and part time?
2) Is the campus population growing or stable? (Be sure to include estimates of the number of night students and visitors, as those present daily.)
3) What percent of students (and employees) live on campus?
4) Do students live nearby or are they dispersed throughout the region?

SECTION I: Obtain organization charts from the president's office
1) How is your university organized?
2) Is it a public or private school?
3) Is it part of a state university system?
4) What is the structure of the governing authority of your school (such as a board of trustees or regents)?
5) What authorities do the state and local governments have over campus operations vs. the school's governing board?
6) What are the educational, businesses and professional backgrounds of prominent individuals in the administration?
7) What faculty and staff organizations and unions are represented on campus?

SECTION J: Contact your student association for a list of student organizations
1) How is undergraduate and graduate student government structured? Are there additional student associations representing professional schools and particular student interest groups, such as a public health student association, African-American student association?
2) Do your student government have decision-making power on campus separate from the university administration?

SECTION K: Trace the origin and destinations of campus resource flow
1) Where do campus water, energy, materials, and food come from?
2) Where does garbage and wastewater go?

My Own Questions for Regis:

1) Do you have a contact name over at Progress Energy who I could be put in touch with (in order to ask questions regarding the TYPE of energy that fuels the ML)?

2) Has FMD ever considered purchasing green power from Progress Energy to power the Lab?

3) What are the specific buildings at the Marine Lab that already have meters on them, and why haven't all the buildings over at the lab been retrofitted to have meters?

4) The data that you gave me from FY 2006 lists that Bookhout lab's total utility costs was only $14,000. When I compare it to the previous years, this number seems very inconsistent (off an order of magnitude). Is there any way I can double check that one buildings' utility costs for FY2006?

5) Will the new Energy Management Plan that FDM is drafting include the ML?

Once I received the Meter Data from Bob Friedman on February 22, 2007, the data led to more questions:

1) What is Transfer A, B, C, etc?
2) What is the Cape Hatteras Meter?
3) Why does the data not show meters on the labs?
4) Is there a reason why the KWH data appears to be so “neat” or seemingly rounded?

APPENDIX C: Square Footage Information for Marine Lab Buildings
(source: Financial Service Office at Duke,
http://www.finsvc.duke.edu/finsvc/budget/CostAlloc/Cost_psf_details.html#79; accessed 4/22/07)

Building Number	Building Description	ASF	Avg. cost per Assigned Sqft.	Net Sqft	Avg. cost per Net Sqft
7902	ML-Dining Hall	2,961	28.82	3,696	23.09
7903	ML-Lab # 2	2,310	16.07	2,780	13.35
7904	ML-Dorm 5	1,916	25.46	3,978	12.26
7905	ML-Lab # 1	1,310	25.34	1,422	23.34
7906	ML-Ocngrph Storage/EPA	1,968	16.67	1,968	16.67
7909	ML-Boathouse	1,799	17.51	1,839	17.13
7910	ML-Dorm #1	962	24.23	1,128	20.66
7913	ML-Dorm 4	1,207	18.71	1,907	11.84
7914	ML-Garage	588	13.40	917	8.59
7915	ML-Administration Bldg	3,381	12.39	4,087	10.25
7916	ML-Seawater Tank Facility	2,100	10.28	2,100	10.28
7917	ML-Lab # 5	3,623	12.36	4,292	10.43
7918	ML-Caretaker Residence	2,200	9.36	2,200	9.36
7920	ML-Dorm #2	948	23.00	1,117	19.52
7921	ML-Dorm #3	910	25.59	1,017	22.90
7923	ML-Bookhout Lab	16,340	21.95	24,141	14.86
7924	ML-Maintenance & Storage Bldg # 2	5,072	7.78	6,329	6.23
7925	ML-Recreational Facility	1,750	15.05	1,750	15.05
7926	ML-Library / Auditorium	6,275	22.19	7,455	18.68
7928	ML-Lift Station	50	54.00	50	54.00
7944	ML-Transformer	187	40.89	187	40.89
7947	ML-Dorm #6	1,650	11.98	1,930	10.24
7950	Volatile Storage	389	15.70	389	15.70
7951	ML-Paint Storage	247	3.80	247	3.80
7952	ML-Bradley International House	5,399	1.09	5,399	1.09
7956	2912 Main Maintenance	10,622	6.04	11,350	5.65
7962	ML-Service Bldg	3,753	12.31	4,181	11.05
7970	Library Service Center	19,586	9.56	21,081	8.88
7971	3540 Kangaroo Drive	23,533	6.76	26,737	5.95
7972	Diet and Fitness Center	28,339	14.12	32,618	12.27
7973	2707 Edmund St	3,692	6.97	3,692	6.97

7982	Pres House Doug & Grace Knight	11,042	0.12	11,042	0.12
7984	AF: Kennel #3	9,035	3.47	9,748	3.21
7986	AF: Kennel #1	14,965	7.64	16,413	6.97
7988	AF: Bedstor	1,895	3.29	1,895	3.29
7989	AF: Barn #1	5,108	3.34	9,134	1.87
7990	AF: Barn #2	7,411	1.00	9,378	0.79
7991	Teer House	6,891	15.15	8,789	11.88
7995	AF: Butler	4,168	1.86	5,907	1.31
7996	AF: OB-GYN Clinic	1,489	1.81	1,547	1.74