USING HARD COST DATA ON RESOURCE CONSUMPTION TO MEASURE GREEN BUILDING PERFORMANCE

By

ERIC MEISTER

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN BUILDING CONSTRUCTION

UNIVERSITY OF FLORIDA

2005

TABLE OF CONTENTS

page

CHAPTER

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science in Building Construction

USING HARD COST DATA ON RESOURCE CONSUMPTION TO MEASURE GREEN BUILDING PERFORMANCE

By

Eric Meister

May 2005

Chair: Charles Kibert
Major Department: Building Construction

In the rapidly expanding built environment, designers, owners, and constructors alike are making strides to conserve natural elements and to plan with sustainable intent. Although efforts are increasing at an exponential rate, the overall thrust of sustainable design is still in its infancy. As with any innovative movement, sustainable design has many skeptics. Many developers require considerable justification before they are willing to spend between 2 and 5 percent in additional construction costs. The goal of those involved with sustainable ideals is to develop designs and structures that do the convincing by themselves, through ground-breaking increases in building efficiency and overall effectiveness.

This study evaluated one such effort at M.E. Rinker Sr. Hall on the University of Florida(UF) campus. Although numerous initiatives were carried out to earn a Leadership in Energy and Environmental Design (LEED) “Gold” Certification, this study will examine the steps taken to reduce resource consumption limited to chilled water, potable water, steam, and electricity. Our results provided feedback to the UF, and also provided concrete evidence for future initiatives at the UF and other educational institutions.

By collecting and analyzing resource-consumption data, this study analyzed the performance of M.E. Rinker Sr. Hall compared to two similar structures on the UF campus; James N. Anderson Hall, and Frazier Rogers Hall. After qualifying data through Gainesville, FL climate analysis, and building characteristics, we conducted a head-to-head comparison of consumption and associated costs to present the first look into resource usage. Next, a life-cycle cost analysis produced current dollar amounts for a 20-year projected life of the resource consumption of each building to evaluate cost savings and pay-back for the Rinker Hall Sustainable Initiative. Final results laid the foundation for a future, more comprehensive study analyzing tangible consumption and performance costs, and also intangible positive results of the sustainable design efforts for Rinker Hall.

CHAPTER 1
INTRODUCTION

The Green Building Movement is a relatively young phenomenon in the construction world. New methods and materials are making the idea of sustainable construction more believable every day. As more and more “green” buildings are constructed, builders and designers are beginning to develop more effective techniques for producing savings in both energy and materials usage. The push behind sustainable design and green building lies nested heavily in environmental concerns; however, pitching revolutionary ideas to owners and builders based only on environmental protection would have proven quite difficult. While effects such as resource conservation, pollutant reduction, and revitalization of nature are bragging rights for sustainable innovations, so too is the financial performance of green buildings.

Statement of Problem

At the design phase of sustainable construction, designers begin to make selections regarding materials, systems, processes and other major components. These choices are driven simultaneously by both conservation and financial factors. Designers must attempt to balance the added construction costs of implementing sustainable technologies with the assumed life-cycle cost savings from the improved performance of the building. Because of the relatively young nature of green construction, these design-phase estimates of cost vs. savings are merely predictions, and are not necessarily reliable.

As a perspective owner, it is difficult to decide whether to add costs to your project for sustainable design when there is no guarantee of building performance. Different projects use different systems and different levels of integration of these systems within their sustainable designs, making it difficult to compare two projects under like conditions. Therefore, designers can face difficulty in explaining the feasibility of proposed designs, and in convincing perspective developers. This poses an escalating problem as the population continues to grow, and resource consumption continues to increase drastically. Sustainable design is becoming essential to preserving the human environment, and measures must be taken to help push green thinking to a much higher priority level in the design-development process.

Objective of Study

Our objective was to validate the use of hard cost data on resource consumption evaluate green building performance. We did this by producing a life-cycle-cost based, direct-cost economic model comparing performance of a green building on the UF campus to the performance of two additional, code-compliant structures. Buildings used for comparison will be a fully functioning LEED certified building, (Rinker Hall), and two additional structures, (one code-compliant structure completed in 2001, Frazier Rogers Hall; and one older building re-furbished for 2002, Anderson Hall). All three buildings are very similar in total amount of conditioned space, type of use, years of use, and environmental exposure. These similarities account for the control of the experiment, allowing true representation of “green” building performance in the Gainesville, FL environment. The study examined consumption of the 4 highest-use utilities for the buildings: electricity, steam, water, and chilled water. Our aim was to evaluate the actual difference in building performance brought forth by the sustainable design efforts for Rinker Hall. These findings will then be presented along with hard-cost data for the buildings in an attempt to evaluate the current status of sustainable efforts in central Florida higher education facilities.

Hypothesis

The true performance of Rinker Hall is the item in question in the study. The

$7 million, 47,270-square-foot building was designed to use half the electricity and an even smaller fraction of the water of other buildings its size. While it would be difficult to measure the effects of all the sustainable-design efforts in Rinker Hall, this study tested whether a life-cycle costing analysis of hard-cost, resource consumption data can effectively demonstrate the greenness of the structure as compared to similar structures on the University of Florida Campus.

Overview

This study was intended to effectively model the annual financial impacts on resource usage of the sustainable design of Rinker Hall. Author Hal R. Varian details the steps used to explain the rational behind an effective model as follows: 1. the model must address who makes the choices involved. 2. What constraints do the decision makers face. 3. What interaction exists. 4. What information is being processed and what is being predicted. 5. What adjusts to assure consistency (Varien, 1997).

CHAPTER 2
LITERATURE REVIEW

Our literature review explored the growing momentum of sustainable design and green building in today's construction industry. Sustainable design is defined as "Design that seeks to create spaces where materials, energy and water are used efficiently and where the impact on the natural environment is minimized" (Means 2004). While sustainable design extends far beyond physical structures, the built environment is perhaps the largest component of sustainability. At its current state, sustainable design is a young phenomenon of which the defining parameters are constantly changing. Designers are learning with each sustainable undertaking, and through the occasional mishap that "one who accepts an opportunity to design a project without clearly understanding the concepts and costs involved places the owner—not to mention the A/E's reputation and economic stability— at risk" (Wyatt, 2004, p.33) Adding to the problem is the vast amount of information available on the topic of sustainability; some of which is useful, most of which is not (Wyatt, 2004). Despite what is believed by many professionals, sustainable design is not achieved by simply amassing green products under one roof, but is achieved through a much more systematic approach that deals with not only bricks and mortar, but the entire environment, life cycle, and performance of the project.

Once the designer has a grasp of the intent of the sustainable design at hand, he or she must look closely at several factors. These factors are common to any type of construction design, but have additional implications for green buildings. For example, in any type of project, the designer must choose the building service systems to be installed. In sustainable design numerous factors are added to the checklist that otherwise wouldn’t exist. The same is true for material selection, building orientation, and various other components. Another major component in the decision making process is the climate and environment in which the structure will be put into place. “Today’s green designers realize that any approach must improve quality, such as better control of temperature, humidity, lighting effectiveness and indoor air” (Macaluso,2002, p.199). For example, when designing for solar gain in a particular climate, measures must be taken to adequately design for avoidance of excessive overheating in the summer while still maximizing potential gains during the colder winter months.

Effective sustainable designs are unique to each individual project because the needs of each project are unique in themselves. Individual owner’s ideas, material availabilities, environmental impacts, and numerous other factors give each project an individual identity. With this identity comes different critical factors for design. When designing a particular structure for natural lighting, for example, numerous factors come to mind. Relative heating, cooling and lighting requirements and potential heat gains from people, equipment, lighting and the sun have to be examined in relation to building form, orientation, occupancy patterns, and environmental requirements in order to ensure that the full picture emerges prior to making major design decisions. Overall, designers must keep one simple fact in mind, a solution that produces one successful commercial building cannot automatically be applied to another (McElroy, 1999).

In order to help regulate the green building process, the United States Green Building Council has established the Leadership in Energy and Environmental Design

(LEED) green building rating system. Members of the U.S. Green Building Council representing all segments of the building industry developed LEED and continue to contribute to its evolution. Based on well-founded scientific standards, LEED emphasizes state of the art strategies for sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality (USGBC, 2005). The LEED system was created to

- Define "green building" by establishing a common standard of measurement
- Promote integrated, whole-building design practices
- Recognize environmental leadership in the building industry
- Stimulate green competition
- Raise consumer awareness of green building benefits
- Transform the building market

Before the LEED system, energy-consumption designs were guided by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHREA) Standard 90.1. The 90.1 code is a set of requirements for energy efficient design of commercial buildings intended to promote the application of cost effective design practices and technologies that minimize energy consumption without sacrificing either the comfort or the productivity of the occupants (US Dept. of Energy, 2004). While ASHREA guidelines promote the same ideas as LEED, they are less stringent, and center only on space conditioning.

As one might expect, analyzing these added considerations also included an element of added costs. In any case, the implementation of new technologies will add to price tag of a project. Perspective owners often shy away from new methods or ideas due to fear of unanticipated costs or problems, but recent history is beginning to show that such concerns are less of a reality with sustainable design. A common misconception in the construction field deals with the additional cost of the added design effort, time, and materials required to achieve sustainable results. Some common figures overestimate the cost increase to be as high as 30%. In actuality, a properly implemented design effort can achieve a certified or “silver” rating under the LEED system with as little as 2.5 to 4% increase in costs (Tuchman 2004). Some even believe that improvement to the point of little or no cost increase can be achievable in the near future.

A 2003 study of thirty-three green buildings from throughout the United States compared their up-front design costs with conventional design costs for identical structures. The average price increase was surprisingly slightly less than 2%,($3 to $5/sf).

“The majority of this cost is due to the increased architectural and engineering design time, modeling costs, and time necessary to integrate sustainable building practices into projects” (Kats 2003, p. 3). One must realize that no true standard exists for which factors are taken into account in this type of analysis. The 1.82% average cost premium for Gold certified structures is very likely an underestimate of the added design effort and materials costs required to achieve that level. It is at the discretion of the study as to which items and factors are included in the cost premium, making such comparisons simply ball-park figures rather than true evidence.

In any pre-construction situation, building costs should be analyzed including not only up-front costs, but also future costs that occur over the lifetime of the facility, system, or component (Macaluso, 2002). This is perhaps the most important point that a sustainable designer can stress to a perspective owner. Detailed analysis of projected life cycle costs are required to illustrate that the increases in efficiency of the building can eventually outweigh the up-front increase in construction costs. It is also important for the designer to carefully research each product or system before making this statement however, as it is true in some cases that a green product can have both a higher up-front cost and a higher operating cost. In this case, it is the job of the designer to show that the unique advantages of the product outweigh both levels of cost increase. In somewhat rare cases, products are available that not only run more efficiently, but also cost less during construction, such as demand heaters in place of central hot water heaters, or smaller, more efficient chillers. These situations are the designer's dream, and can effortlessly convince a prospective owner. According to the USGBC, high performance green buildings (USGBC, 2003)

- **Recover higher first costs, if any.** Using integrated design can reduce first costs and higher costs for technology and controls.
- **Are designed for cost-effectiveness.** Added building efficiency produces savings in the 20% to 50% range as well as savings in building maintenance, landscaping, water, and wastewater costs. Integrated planning including site orientation, technology implementation and materials selection are the factors behind these savings.
- **Boost employee productivity.** Employers can realize significant bottom line savings through increased worker productivity. Simple investments in increased daylight, pleasant views, better sound control, and other features can reduce absenteeism, improve health and increase worker concentration/efficiency.
- **Enhance health and well-being.** High performance buildings offer healthier and more pleasing surroundings for their inhabitants. As results are becoming quantifiable, the improved indoor environments offered within green buildings are being used as recruiting tools for employers.
- **Reduce liability.** Focusing on the elimination of sick buildings and specific problems such as mold can reduce claims and litigation. Insurance companies are rumored to be investigating implementation of lower premiums for high performance buildings.
- **Create value for tenants.** Improved building efficiency and lowered operating costs can lead to decreased tenant turnover. Savings averaging $.50/sf per year greatly increase the likelihood of increased rental periods.
- **Increase property value.** LEED and Energy Star buildings which operate more efficiently and maintain high tenant capacity are more desirable for purchase. Also, the more efficient building frees up additional cash flow for outside investment

during ownership. These features ass assumed value to a high performance building and increase demand.

- **Take advantage of incentive programs.** Many states and private organizations offer financial and regulatory incentives for the development of green buildings. Government tax credits and private loan funds are effectively assisting developers of high performance projects. The number of these programs is likely to grow and may include, among other possibilities, reduced approval times, reduced permit fees, and lower property taxes.

- **Benefit your community.** **"**Properties that take advantage of brownfield and other infill redevelopment, while offering proximity to mass transit, walking, biking and shopping/daycare services have an automatic advantage in the race to attract top talent." Though reducing congestion and pollution, and providing economic benefit to local transit, high performance buildings and their companies are being welcomed into community after community.

- **Achieve more predictable results.** Green building delivery use "best of class"in order to reduce uncertainty and risk and delivery the final project at the level promised. Through interactive design, life cycle analysis and energy modeling, designers are able to focus on the particular needs of an individual site and building. These practices help to minimize surprises and errors during construction, and to ensure the delivery of the high quality level promised to customers.

Despite the convincing nature of the current body of knowledge, owners may still be asking themselves, "why build green?" The industry has yet another answer other than long term cost savings. "Aside from the obvious hurdles and often higher initial costs, there are some compelling, albeit long term financial advantages to building green. For example, a "green" building shows that the owner will spend more to invest in nature, quality, and innovation" (Macaluso, 2002, p.199.) At the current stage of the sustainable world, any major green project is marquee, and is essentially free press for any owner.

Cost Analysis

Unknown to most; construction activity, including both new construction and renovation, accounts for the nation's largest manufacturing sector. With a contribution to the U.S. economy of approximately $1.009 trillion, Construction accounts for over 15% of the Gross Domestic Product. Costs of construction can be broken down into 3 major categories, investment related costs, operational costs, and personnel costs. Contrary to popular belief, when viewed over a 30 year period, initial building costs (investment) account for only two percent of the total cost, and operations and maintenance costs amount to six percent. The remaining 92 percent consists of personnel costs. While the names are quite self-explanatory, the methods by which they are calculated differ greatly. Investment related costs are incurred during the construction phase of the project, often with a large lump sum, and additional periodic payments. Operational costs are constant throughout the life of the building, and are incurred on a periodic basis as well. During the design phase, after materials and systems are selected and priced, projected values for operational costs are then estimated and inserted along side the investment related costs to develop the projected life cycle costs analysis for the project. Taken a step further, an analysis can be carried out using simply code compliant materials and systems and laid out along side the sustainable design. The two will then be analyzed, to determine the payback period for the additional investment costs of the sustainable design. If the payback period ends early enough within the lifecycle to produce profit during the building’s life, and the initial cost increase is a feasible undertaking for the owner, the designer should then push for the sustainable option. Other systems used to help justify costing are the Initial Rate of Return (IRR), the net savings, and the Savings to Investment Ratio (SIR) (Fuller, 2002).

There are of course some difficulties in justifying the cost of sustainability, a major example of which lies within the less tangible results of sustainable design. “How do you put a price on clean air and clean water? What ultimately is the price of human life, and how do we value the avoidance of its loss” (Lippiat, 2002, p.267)? An owner who is willing to invest in sustainable design should also have a vested interest in its cause. By owning a piece of the sustainable built environment, said owner is doing their part to help preserve the environment for future generations. Some have begun to investigate how this side of "green" building can be financially rewarding as well. Insurance companies as well as government agencies and utility companies have begun looking seriously into providing benefits to certified green buildings. Such moves could help to completely offset the added costs of sustainable design. Another difficulty lies in the reliability of the future cost estimates. It is estimated that a properly designed green building can produce a 20 year net benefit of between $50 and $70 per square foot. This equates to over ten times the additional cost associated with such efforts (Kats, 2003). Future energy and environmental costs simply cannot be predicted accurately due to unknown factors that are beyond a true measure of control. Also, standard periods of comparison between code-compliant construction and sustainable construction should ideally be lengthened by several years to better display the longevity of sustainable design in order to see the true financial gains (Pitts, 2004).

Additional Benefits of Sustainable Design

Aside from the financial implications previously mentioned, green buildings provide many additional potential benefits. These may include waste reduction, lowered maintenance needs, improved public perception, and high indoor environmental quality(IEQ).These types of gains are more difficult to quantify, yet still factor heavily into the overall effectiveness of building design.

Of all the intangible factors, IEQ provides perhaps the heaviest influence on the overall success of a design. Humans spend approximately 90% of their time indoors, exposing themselves to concentrations of toxins typically 10 to 100 times higher than in the outdoor environment. Health and productivity costs associated with poor indoor environment have been roughly estimated to be as high as hundreds of billions of dollars per year. (Kats, 2003) Thousands of studies, articles and reports have proven a correlation between high indoor environmental quality and reductions in occupant illness and employee absenteeism, as well as increases in general productivity.

Numerous characteristics of green buildings contribute greatly to improved IEQ. LEED certified buildings implement less toxic materials found in many high frequency-of-use items such as low-emitting adhesives & sealants, paints, carpets, and composite wood products. Also, improved thermal comfort, ventilation, and HVAC efficiency are staples of the sustainable design effort. These two efforts, combined with CO2 monitoring vastly improve breathable air quality and lessen the risk of airborne toxins or contaminates such as mold or fungi. In addition to lowered health risks from improved breathable air, IEQ also increases significantly through natural lighting efforts. LEED accredited buildings implement modern daylight harvesting techniques, natural shading, and glare control to reproduce a comfortable, natural environment. These efforts to reproduce natural environments are centered upon multiple goals, the most important being occupant productivity. “Green buildings are designed to be healthier and more enjoyable working environments. Workplace qualities that improve the environment of knowledge workers may also reduce stress and lead to longer lives for multi-disciplinary teams” (Kats, 2003, p.6).

The design initiatives mentioned above have been positively linked to increases in productivity by numerous sources. “Increases in occupant control of ventilation, lighting and temperature have provided measured benefit from 0.5% up to 34%, with average measured workforce productivity gains of 7.1% from lighting control, 1.8% with ventilation control, and 1.2% with thermal control” (Kats, 2003, p.6).

It is estimated, at the low end, that a 1% productivity and health gain can be awarded to LEED certified and Silver rated buildings, and a 1.5% gain added to Gold and Platinum rated structures. For each 1% increase in productivity, equal to approximately 5 minutes per work day, an increase of $600 to $700 per employee per year, or $3/SF per year can be realized. Taking this into account, and applying a 5% discount rate over a 20 year period, the present value of productivity benefits is about $35/SF for LEED certified and Silver rated buildings, and $55/SF for Gold and Platinum (Kats, 2003).

Justification

Recent literature shows that sustainable design and green buildings are rapidly gaining momentum in society. At its current state, the movement has now reached the maturity level to provide sufficient data to produce actual results in comparison to standard construction. For example, the U.S. Department of Energy’s Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory (NREL) compared the costs and related savings of sustainable efforts on 2 prototype buildings. “A base two-story, 20,000 square foot building with a cost of $2.4 million dollars and meeting the requirements of ASHRAE Standard 90.1-1999 was modeled using two energy simulation programs, DOE-2.1e and Energy-10, and compared to a high performance building that added $47,210 in construction costs, or about 2% for its energy saving features”(Kibert 2005, p.488). Results of this comparison, shown below in Table 2.1, are quite noteworthy as the realized annual performance gain nearly equals the additional up-front cost in the first year alone.

Table 2-1. Cost and Related Savings on Two Prototype Buildings

Feature	Added Cost	Annual Savings
Energy efficiency measures	$38,000	$4,300
Commissioning	$4,200	$1,300
Natural landscaping, storm-water management	$5,600	$3,600
Raised floors, movable walls	0	$35,000
Waterless urinals	($590)	$330
Total	$47,210	$44,530

(Kibert 2005)

The above case thoroughly illustrates the convincing nature of the emerging results of such comparisons. Again one must pay attention to the apparent bias in the data. For example, item #4, Raised floors and moveable walls carries a $0 cost premium, and a $35,000 annual savings. This is the driving factor behind the incredible result of the study. While the actual materials in the floors and walls may have not added additional cost, common sense would say that added design effort, increased deck heights to accommodate ceiling heights after raised floors, and mechanisms to allow for movable walls would indeed add cost to the structure. Regardless, results still show a realized annual savings due to sustainable design efforts.

Even though results should not be held as 100% accurate, perspective owners and builders typically will rely more heavily upon such recorded studies over theoretical design values. Such comparisons are vital tools in the push to expand sustainable efforts to all realms of construction. Even more important is the need to localize such data to prove to perspective owners and builders that similar efforts will be fruitful for their respective projects as well. Data can, and should be made available for sustainable design results based on particular location/climate, building type/size, and intended use.

CHAPTER 3
RESEARCH METHODOLOGY

The objective of this study is to evaluate the effectiveness of the sustainable design of Rinker Hall through life-cycle cost analysis of annual resource consumption hard cost data. The two-fold aim of the study was 1.To establish a methodology for measuring building “greenness” through use of hard cost data. and 2. To use a life-cycle cost analysis of collected building performance data from three similar structures on the campus to display improvements in building efficiency through sustainable design efforts. The steps taken to carry out the aforementioned tasks are as follows

- A literature review was carried out on the history of “green building” and the associated economics. This was done with a two fold purpose; to determine the authenticity of the proposed study, and to gain increased knowledge of the topic.
- The required parameters to be analyzed were determined.
- Proper sources were identified from which to gather data.
- Data were collected for Rinker Hall, Anderson Hall, and Frazier-Rogers Hall.
- A building Life-cycle cost analysis was run on each of the three building’s consumption of four major utilities; water, steam, chilled water and electricity.
- A final conclusion was reached based on the produced result.

Parameters

The characteristics which determine environmental attributes for the University of Florida were determined through collecting data on monthly average temperature, humidity, precipitation, and heating degree day calculations. This data helps to justify the building comparison for use in similar climates. This particular study centers upon the mechanical systems performance analysis and therefore took into account consumption data for four major resources; water, steam, chilled water, and electricity. Consumption data was acquired through assistance from the University Florida Energy Office. While these four utilities do not represent a truly complete building analysis, they provide an accurate representation of performance efficiency. The results were then qualified based on average hours of building operation, and total horsepower of each building’s mechanical systems.

Life-Cycle Cost Analysis

The life-cycle costing analysis is a quantifiable determination of true cost of ownership, calculated within a standard Microsoft Excel Spreadsheet. The purpose of life-cycle costing is to analyze costs over a realized life of a building, and translate those costs into current dollars. Contrary to simply averaging costs and realizing annual expenditures, a life-cycle costing system will adjust for inflation and escalation, and allow for more accurate decision making by taking future factors into account. This particular life-cycle costing system will directly compare Rinker Hall with each additional building through separate analysis for each. Either Anderson, or Frazier Rogers Hall will serve as the control portion of the comparison, while Rinker Hall will be presented as the variable. The added costs for the sustainable initiatives in the Rinker Hall mechanical systems will be carried in the up-front cost portion of the life-cycle spreadsheet for Rinker, while the other buildings will show zero up-front cost. The annual total for each individual utility is then entered for each respective building as the annual costs. The sum of these costs over a 20 year period is adjusted for such factors as price escalation, inflation, and discount rate, then presented in equivalent current dollars for comparison sake. This comparison will then give the present day total value of each mechanical system and allow for the realization of savings over the 20 year period.

CHAPTER 4
RESULTS

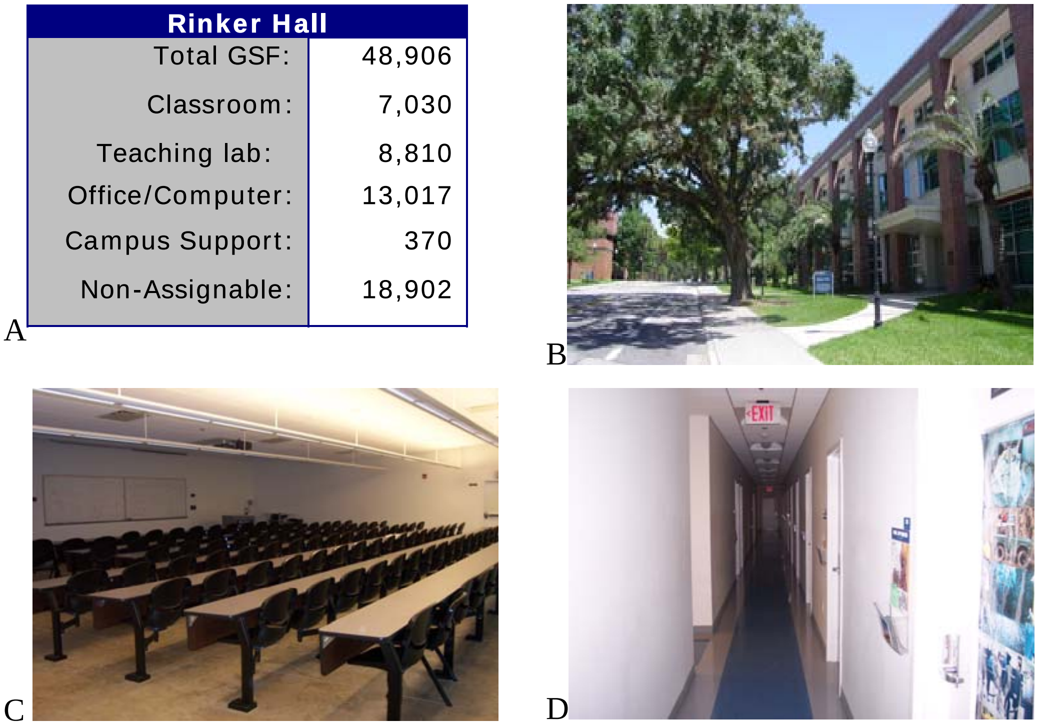
In order to accumulate the appropriate data for the life cycle comparison, three different classifications of construction were chosen within the same building genre; higher education classroom/administration. The three structures chosen are as follows:

Table 4-1. Building Properties

	Rinker Hall	Anderson Hall	Frazier Rogers Hall
Year Completed	2002	2002	2001
Building SF	48,906	47,757	53,543
Total Horsepower	*193	96.64	*165

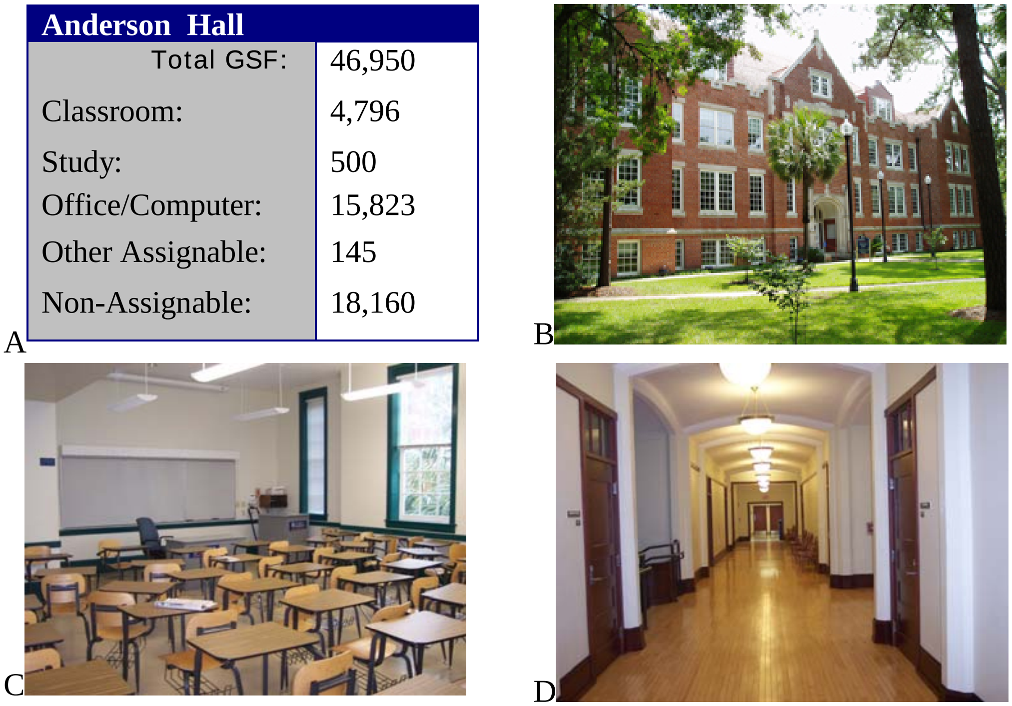
*Building horsepower for Rinker Hall and Frazier Rogers Hall is variable, ratings are for peak horsepower and actual operating power may be quite lower.

For this study, the term Building Horsepower refers to the total base horsepower associated with the mechanical systems housed within each structure. These systems include air handling units, fans, water pumps, and hot water heating units.



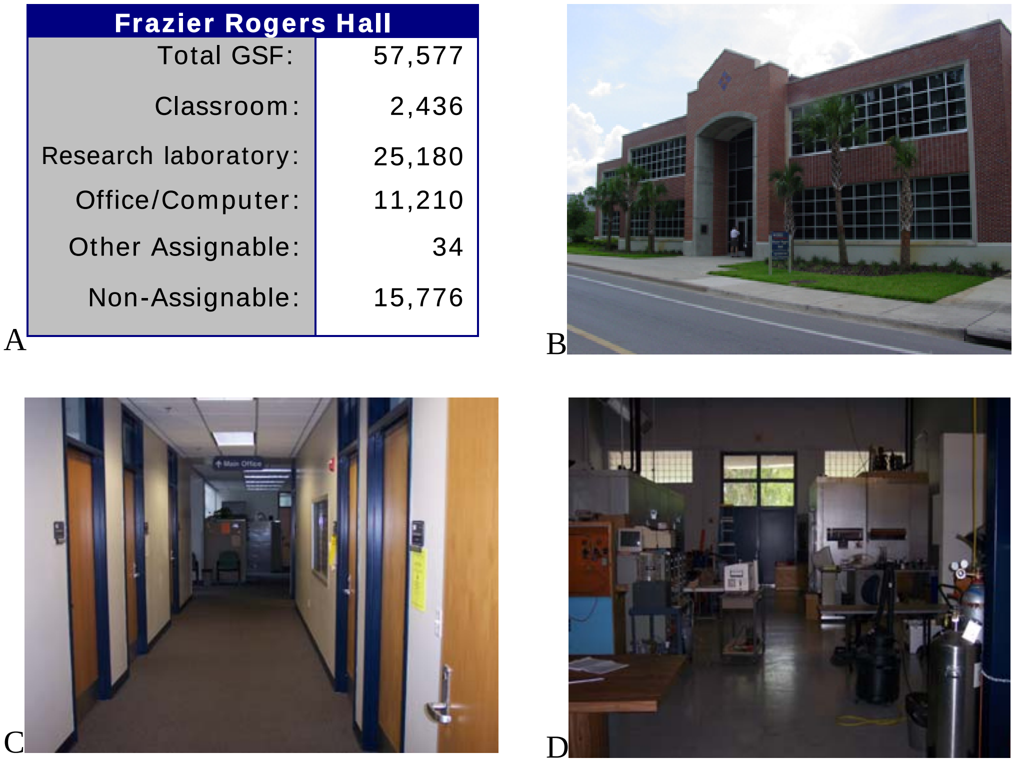
Rinker Hall	
Total GSF:	48,906
Classroom:	7,030
Teaching lab:	8,810
Office/Computer:	13,017
Campus Support:	370
Non-Assignable:	18,902

Figure 4-1. Rinker Hall Space Breakdown (clockwise from left) A Space breakdown table. B Building Front C Large Classroom D Faculty office corridor



Anderson Hall	
Total GSF:	46,950
Classroom:	4,796
Study:	500
Office/Computer:	15,823
Other Assignable:	145
Non-Assignable:	18,160

Figure 4-2. Anderson Hall Space Breakdown (clockwise from left) A. Space breakdown table. B. Building Front C. Typical Classroom D. Faculty office corridor



Frazier Rogers Hall	
Total GSF:	57,577
Classroom:	2,436
Research laboratory:	25,180
Office/Computer:	11,210
Other Assignable:	34
Non-Assignable:	15,776

Figure 4-3. Frazier Rogers Hall Space Breakdown. (clockwise from left) A.Space breakdown table B. Building Front C. Faculty office corridor D. Research laboratory

In order to effectively provide perspective owners/builders with an accurate prediction of how their project will perform, a true climate analysis should precede analyzed results in order to qualify such predictions. This study used buildings located on the University of Florida campus, located in Gainesville, FL. The National Climate Data Center(NCDC) produced the following climate description. “Gainesville lies in the north central part of the Florida peninsula, almost midway between the coasts of the Atlantic Ocean and the Gulf of Mexico. The terrain is fairly level with several nearby lakes to the east and south. Due to its centralized location, maritime influences are somewhat less than they would be along coastlines at the same latitude. Maximum temperatures in summer average slightly more than 90°F. From June to September, the number of days when temperatures exceed 89 °F is 84 on average. Record high temperatures are in excess of 100°F. Minimum temperatures in winter average a little more than 44°F. The average number of days per year when temperatures are freezing or below is 18. Record lows occur in the teens. Low temperatures are a consequence of cold winds from the north or nighttime radiational cooling of the ground in contact with rather calm air. Rainfall is appreciable in every month but is most abundant from showers and thunderstorms in summer. The average number of thunderstorm hours yearly is approximately 160. In winter, large-scale cyclone and frontal activity is responsible for some of the precipitation. Monthly average values range from about 2 inches in November to about 8 inches in August. Snowfall is practically unknown" (NCDC 2005).

Another indication of climatic factors on design is the calculation of degree days. Although used more-often for residential design, degree-day data can also be used to help qualify the impact of the Gainesville climate on the following study. Degree day calculations are quite simple to understand. The base idea is that any time the outside temperature is above or below a base-line temperature (in this case, 65 °F), the building must be heated or cooled to maintain a comfortable interior environment. Varying methods for calculating the total number of degree days exist, with some considering a 24 hour period above or below the baseline to be 1 degree day, and others counting that same period as 24. This study will consider 24 hours above or below the threshold to be 24 degree days. Gainesville FL averages 1081 degree days (heating) per year. This means that buildings may need to be heated for approximately 1081 hours in a given year depending on interior comfort needs of occupants. In comparison, cooler climates such as Washington DC average over 4,000 degree days annually, and mountain climates such as Colorado Springs average nearly 7,000. In the hot summer months in Gainesville Florida, temperatures are above a 65 degree baseline for approximately 3,600 hours in an average year. These figures are not taken directly into account in the following comparisons, however, should be taken into account as a measure of climatic impact on the structures, especially by readers unfamiliar with the Gainesville climate.

Rinker Hall Sustainable Design

The construction of Rinker Hall marked the first LEED Gold certified educational facility in the state of Florida. Numerous initiatives were taken in the design of the building to curb resource consumption, promote high levels of indoor air quality, and preserve the natural environment. The majority of building materials used in its construction were recycled or can someday be re-cycled for use in another building. As would hold true with any added design features, added costs were also realized. In total, the added cost to achieve "Gold" certification was approximately $655,500, which is equal to a cost premium of between 9 and 10%. Tables 4-2 to 4-4 show the added construction costs for Rinker Hall.

Table 4-2. Rinker Hall Day-lighting Premium

DAY-LIGHTING PREMIUM		
Div. 5	Atrium stairs, railings	$15,000
Div.9	Level 5 finish, reflective tile, atrium lightwells	$45,000
Div. 8	Skylights, max. window SF, drafstops, interior lites	$80,000
Div. 10	Daylighting Louvers	$150,000
Div. 15	Smoke exhaust fans, ductwork	$20,000
Div. 16	Pendant fixtures, conduit routing	$60,000
	Total Day-lighting Premium	$370,000

Table 4-3. Rinker Hall Energy Premium

ENERGY PREMIUM		
Div. 7	Energy Star TPO roof	No Effect
Div.8	Thermally-broken curtainwall, insulated/low-e glass, insulclad, operable windows	$75,000
Div. 7,9	High-performance wall (metal panels, insulation, wood strips)	$80,000
Div.15	Enthalpy wheel, fans, controls	$58,000
Div. 16	Dimming	$20,000
	Total Energy Premium	$233,000

Table 4-4. Rinker Hall Rainwater-Harvesting Premium

RAINWATER-HARVESTING PREMIUM		
Div. 3	Concrete (walls, slab)	$12,000
Div. 7	Waterproofing (bentonite, tank lining)	$2,500
Div 15	Plumbing (pumps, additional domestic piping)	$38,000
	Total Rainwater-Harvesting Premium	$52,500

In addition to the above, Rinker Hall incorporates low-flow fixtures, electronic faucets, and waterless urinals in the restrooms. Each waterless urinal alone saves an estimated 40,000 gallons of water per year. Dimming (table 4-3) above refers to the photo-cell and motion sensor regulation systems which provides artificial light within the structure only when it is needed, and at variable levels. The result of these efforts was a predicted savings of fifty percent over ASHRAE 90.1.

Rinker Hall also incorporated numerous other additions in order to achieve LEED certification. These included such measures as low e/low voc paints at a $5 per gallon premium, a radon protection system for $8,950, agriboard (strawboard) at $200 per sheet, and HPDE in lieu of PVC at a 20% cost increase. These measures were important in the design of Rinker Hall, and in achieving LEED Gold level, however, they have been ignored in this study due to the fact that they address soft cost concerns such as indoor environmental quality, and have little to no impact on the mechanical systems and the resource consumption levels addressed in this comparison.

Direct Resource Consumption Comparison

To evaluate the effectiveness of these unique features over the life cycle of Rinker Hall, building resource consumption data was collected in cooperation with the University of Florida Energy Office. The data is presented below in the form of direct building-to-building comparisons per resource between 1. Rinker Hall and Frazier-Rogers Hall, and 2. Rinker Hall and Anderson Hall. Data presented below was produced by the UF Energy Office for the complete calendar year of 2004.

Table 4-5. Chilled Water Consumption (Kth)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	18.8	20.5	13.8	17.1	16.0	21.1	18.0	24.1	21.9	19.5	18.3	23.3
Frazier	16.9	13.5	26.6	30.0	54.0	75.6	83.2	91.9	84.2	64.6	42.5	33.1
Difference	1.9	7.0	-12.8	-12.9	-37.9	-54.4	-65.1	-67.7	-62.3	-45.1	-24.2	-9.8

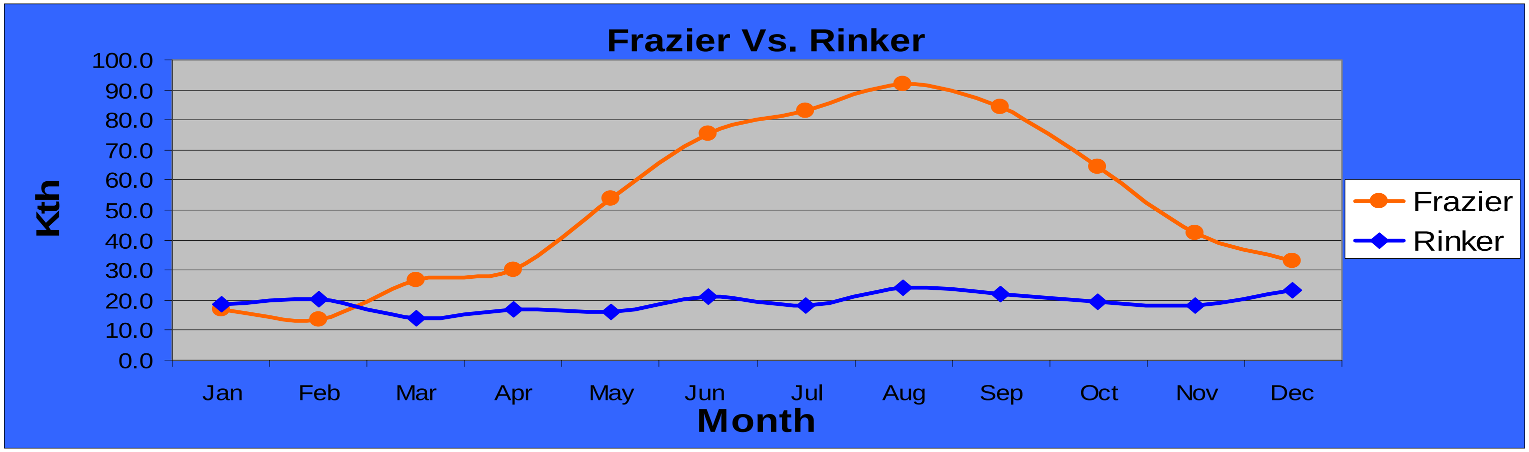


Figure 4-4. Chilled Water Consumption (Kth) For Frazier Hall vs. Rinker Hall

Table 4-6. Associated Costs for Chilled Water

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$1,535	$1,674	$1,125	$1,396	$1,309	$1,724	$1,613	$2,158	$1,962	$1,744	$1,641	$2,081
Frazier	$1,381	$1,104	$2,170	$2,450	$4,406	$6,169	$7,444	$8,221	$7,539	$5,780	$3,804	$2,959

Table 4-7. Electricity Usage (KWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	33,920	34,435	37,464	45,778	43,113	38,907	40,426	40,998	39,440	43,818	41,103	40,302
Frazier	70,342	71,920	75,059	79,640	79,094	79,156	74,793	81,059	75,231	81,254	77,133	69,440
Difference	36,422	37,485	37,595	33,862	35,981	40,249	34,368	40,062	35,791	37,436	36,030	29,138

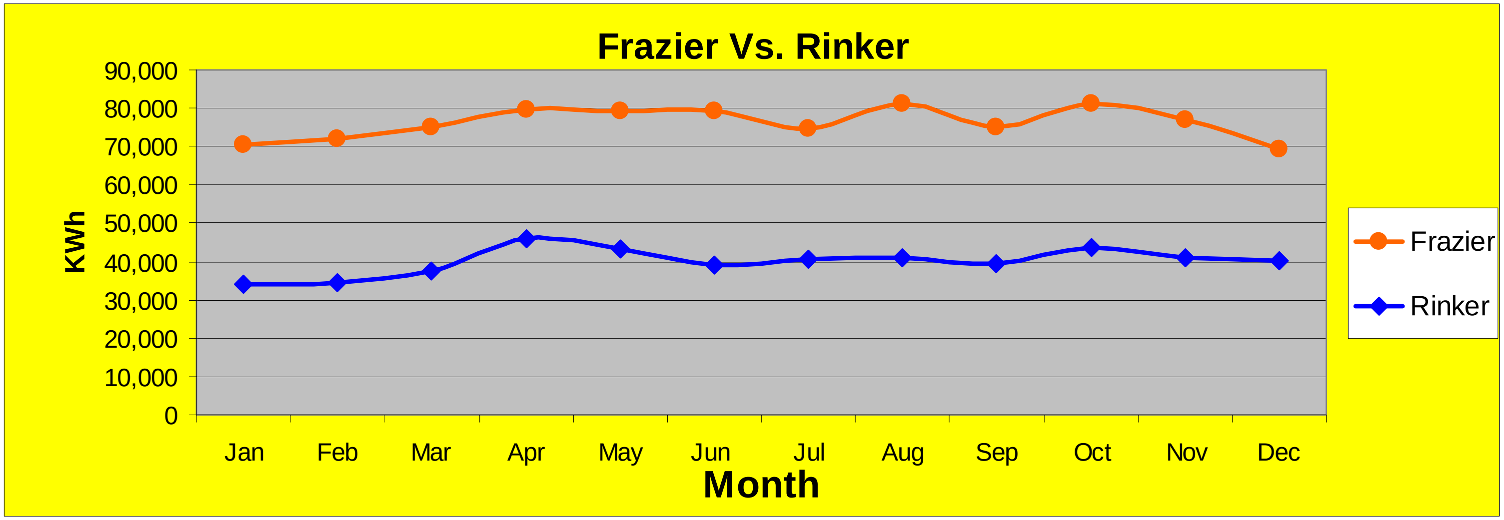


Figure 4-5. Electricity Consumption(KWh) for Frazier Hall vs. Rinker Hall

Table 4-8. Associated Costs for Electricity

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$2,083	$2,114	$2,300	$2,811	$2,647	$2,389	$2,862	$2,903	$2,792	$3,102	$2,910	$2,853
Frazier	$4,319	$4,416	$4,609	$4,890	$4,856	$4,860	$5,295	$5,739	$5,326	$5,753	$5,461	$4,916

Table 4-9. Steam Consumption (Klbs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	61.1	49.5	73.1	53.6	28.9	22.2	16.6	19.5	17.3	22.1	44.2	93.0
Frazier	75.2	58.9	58.7	51.0	41.3	36.7	40.8	48.2	43.8	46.5	54.2	80.6
Difference	-14	-9	14	3	-12	-14	-24	-29	-27	-24	-10	12

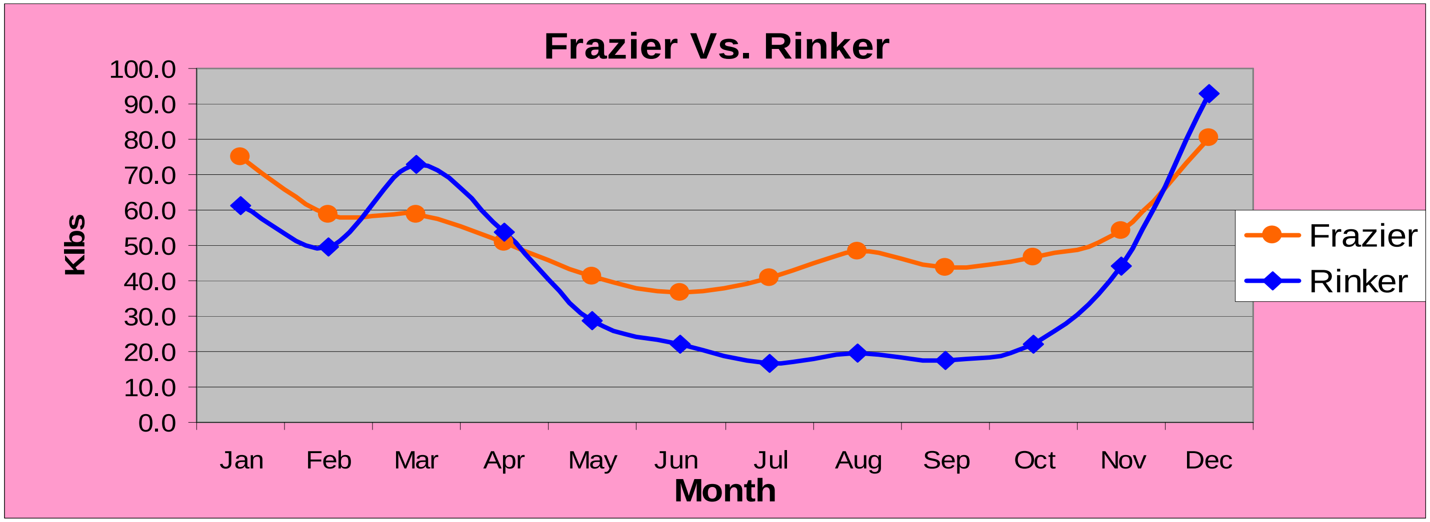


Figure 4-6. Steam Consumption (Klbs) for Frazier Hall vs. Rinker Hall

Table 4-10. Associated Costs for Steam Consumption

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$361	$293	$432	$317	$171	$131	$114	$134	$119	$152	$303	$639
Frazier	$444	$348	$347	$301	$244	$217	$280	$331	$301	$319	$372	$554

Table 4-11. Water Consumption (Kgal)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	7.4	13.2	7.9	14.2	6.1	5.1	5.3	5.0	4.7	2.7	8.3	1.9
Frazier	93.9	200.0	96.9	400.0	110.7	111.1	226.8	229.6	115.4	172.2	166.7	0.0
Difference	-87	-187	-89	-386	-105	-106	-221	-225	-111	-170	-158	2

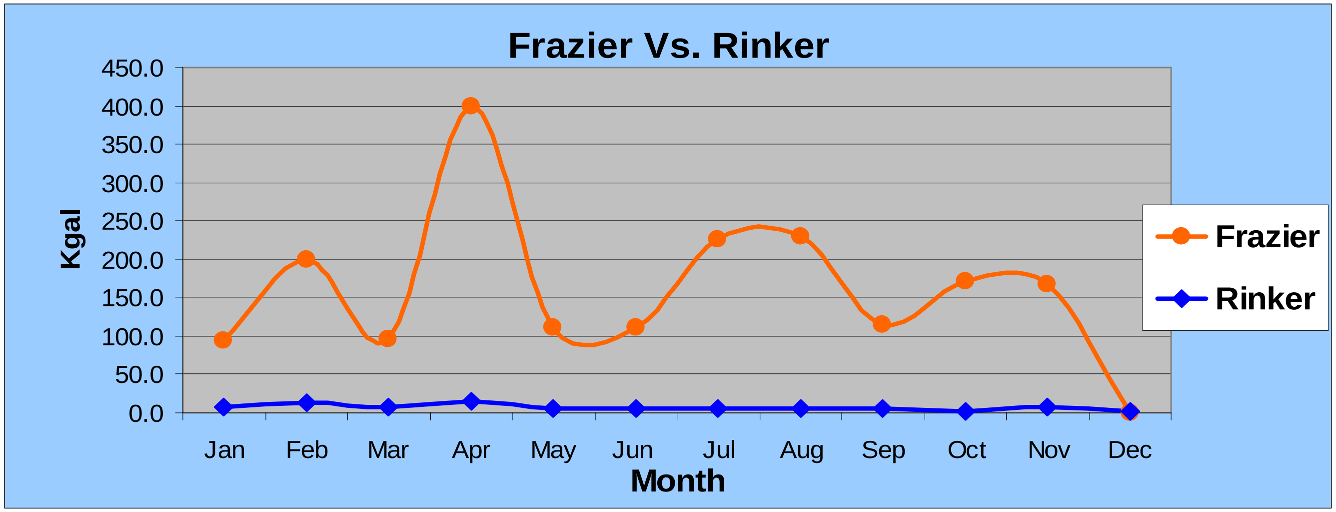


Figure 4-7. Water Consumption (Kgal) for Frazier Hall vs. Rinker Hall

Table 4-12. Associated Costs for Water Consumption

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$7	$13	$8	$14	$6	$5	$5	$5	$5	$3	$8	$2
Frazier	$93	$198	$96	$396	$110	$110	$227	$230	$115	$172	$167	$0*

*Due to meter malfunction, data not available

Table 4-13. Total Utility Consumption Costs

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$3,986	$4,094	$3,865	$4,538	$4,133	$4,249	$4,594	$5,200	$4,878	$5,001	$4,863	$5,575
Frazier	$6,237	$6,066	$7,221	$8,037	$9,616	$11,356	$13,246	$14,521	$13,282	$12,025	$9,804	$8,430
Difference	$2,251	$1,972	$3,356	$3,499	$5,483	$7,107	$8,652	$9,321	$8,404	$7,024	$4,941	$2,854

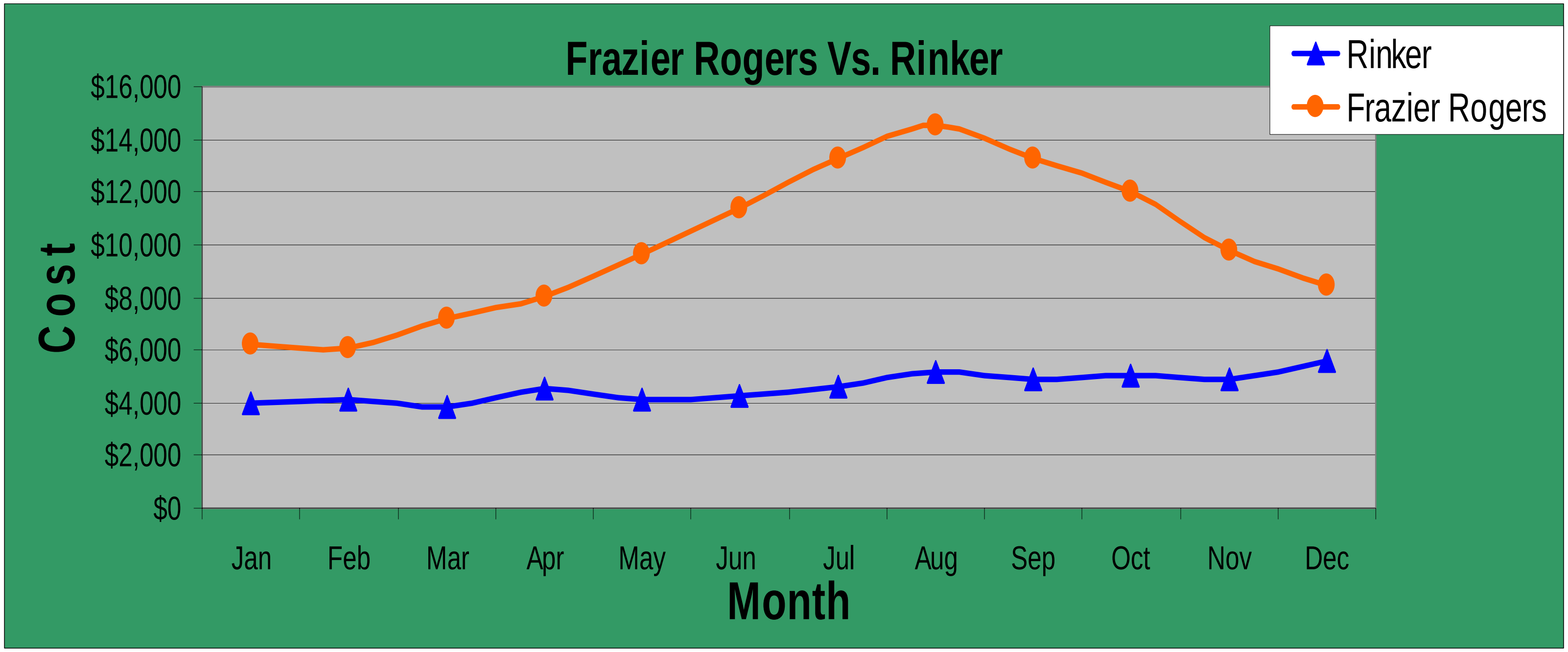


Figure 4-8. Total Utility Cost for Frazier Hall vs. Rinker Hall

Conclusion

As noted in table 4-1, both building size, usage, and horsepower are very similar between Rinker Hall and Frazier Rogers Hall. In fact, Rinker Hall's systems actually incorporate approximately twenty-eight horsepower more than Frazier Rogers Hall, a seventeen percent increase. Systems within each building function on schedules based on occupancy. The University Engineering and Performance Department regulates hours of operation to control comfort levels during the hours of the day in which the building is in use. For Rinker Hall, The HVAC system is operational from10:00 a.m. until 2:00 p.m. on weekends and holidays, and from 6:30 am until 11:00 pm on weekdays. Frazier Hall varies operation schedules by area, with administrative areas operating from 6:00 am to 6:00 pm on weekdays, and laboratory areas operating from 5:30am until 11:30pm. Both areas are operational from 10:00am until 2:00pm on weekends and holidays. Averaging hours of operation based on assigned square footage for Frazier Rogers Hall gives an approximate equivalent total of 82 hours of operation per week, approximately 10 percent lower than Rinker Hall's 90.5 hours per week.

Figure 4-5 details the overwhelming difference in utility costs in favor of Rinker Hall. Frazier Rogers Hall accrues $119,840 in utility charges over one calendar year, more than double the $54,975 for Rinker Hall. While Frazier Rogers Hall utility consumption varies drastically over the course of the year in question, it is clear that Rinker Hall maintains a steady consumption rate throughout even the brutal central Florida summer months. In particular, the drastic spike experienced by Frazier Rogers Hall in August, the month with highest heat and humidity index of the year, is almost non-existent for Rinker Hall. The presence of additional research laboratory space can be blamed for a portion of the added consumption for Frazier Rogers Hall, but the overall similarities in building size and systems lead to the high-performance design of Rinker Hall accounting for the majority of the difference.

Table 4-14. Chilled Water Consumption (Kth)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	18.8	20.5	13.8	17.1	16.0	21.1	18.0	24.1	21.9	19.5	18.3	23.3
Anderson	10.3	13.5	15.5	19.3	19.9	26.7	23.3	28.6	28.8	25.7	20.7	16.2
Difference	8.5	7.0	-1.7	-2.2	-3.9	-5.6	-5.2	-4.5	-6.8	-6.2	-2.4	7.1

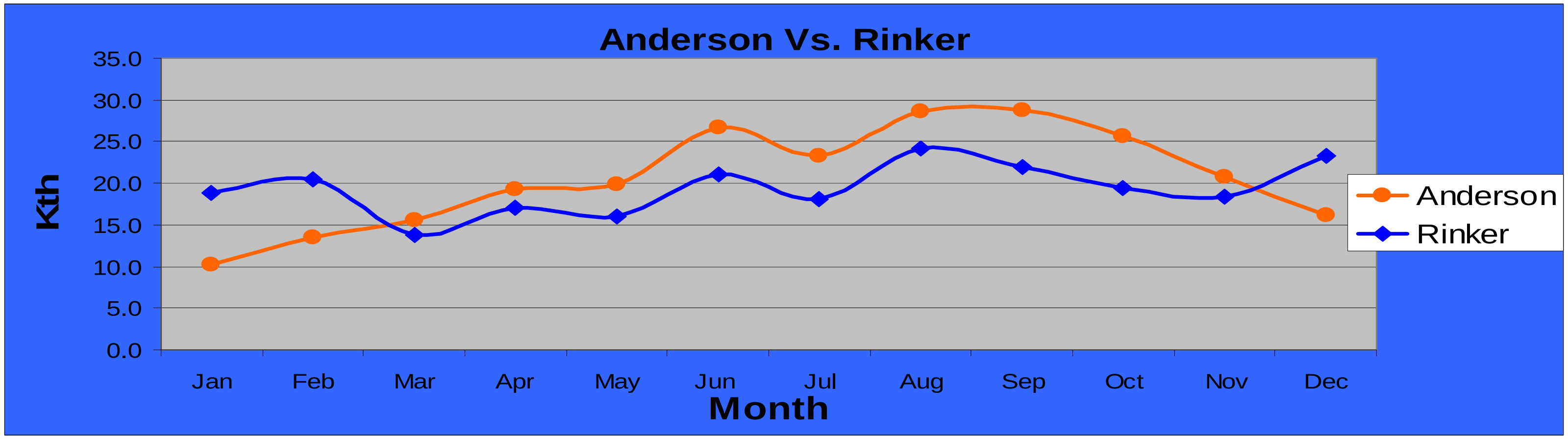


Figure 4-9. Chilled Water Consumption (Kth) for Anderson Hall vs. Rinker Hall

Table 4-15. Associated Costs for Chilled Water

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$1,535	$1,674	$1,125	$1,396	$1,309	$1,724	$1,613	$2,158	$1,962	$1,744	$1,641	$2,081
Anderson	$841	$1,102	$1,266	$1,576	$1,627	$2,177	$2,081	$2,561	$2,573	$2,302	$1,852	$1,448

Table 4-16. Electricity Consumption(Kwh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	33,920	34,435	37,464	45,778	43,113	38,907	40,426	40,998	39,440	43,818	41,103	40,302
Anderson	34,543	34,580	35,216	36,364	34,543	35,378	36,236	41,190	36,730	39,152	38,897	34,289
Difference	-623	-145	2,248	9,414	8,570	3,529	4,190	-192	2,709	4,666	2,207	6,013

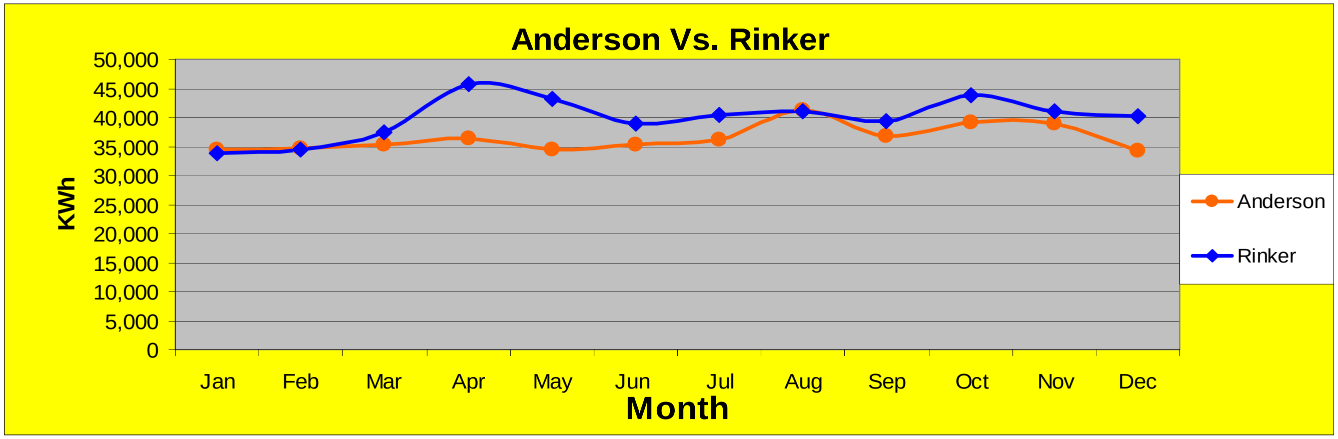


Figure 4-10. Electricity Consumption(KWh) for Anderson Hall vs. Rinker Hall

Table 4-17. Associated Costs for Electricity

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$2,083	$2,114	$2,300	$2,811	$2,647	$2,389	$2,862	$2,903	$2,792	$3,102	$2,910	$2,853
Anderson	$2,121	$2,123	$2,162	$2,233	$2,121	$2,172	$2,565	$2,916	$2,601	$2,772	$2,754	$2,428

Table 4-18. Steam Consumption (Klbs)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	61.1	49.5	73.1	53.6	28.9	22.2	16.6	19.5	17.3	22.1	44.2	93.0
Anderson	82.7	79.2	52.0	35.4	16.6	14.4	11.3	16.7	15.0	20.4	29.0	105.8
Difference	-22	-30	21	18	12	8	5	3	2	2	15	-13

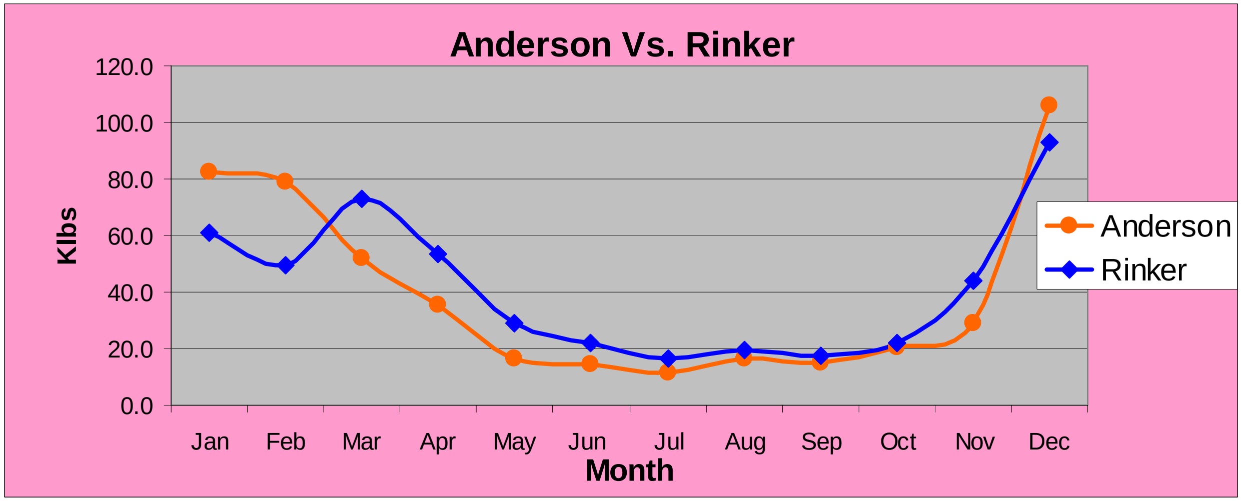


Figure 4-11. Steam Consumption (Klbs) for Anderson Hall vs. Rinker Hall

Table 4-19. Associated Costs for Steam Consumption

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$361	$293	$432	$317	$171	$131	$114	$134	$119	$152	$303	$639
Anderson	$489	$468	$308	$209	$98	$85	$77	$115	$103	$140	$199	$727

Table 4-20. Water Consumption (Kgal)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	7.4	13.2	7.9	14.2	6.1	5.1	5.3	5.0	4.7	2.7	8.3	1.9
Anderson	43.4	94.9	46.1	50.5	45.6	64.6	55.1	58.5	52.3	70.1	55.7	44.5
Difference	-36	-82	-38	-36	-40	-59	-50	-54	-48	-67	-47	-43

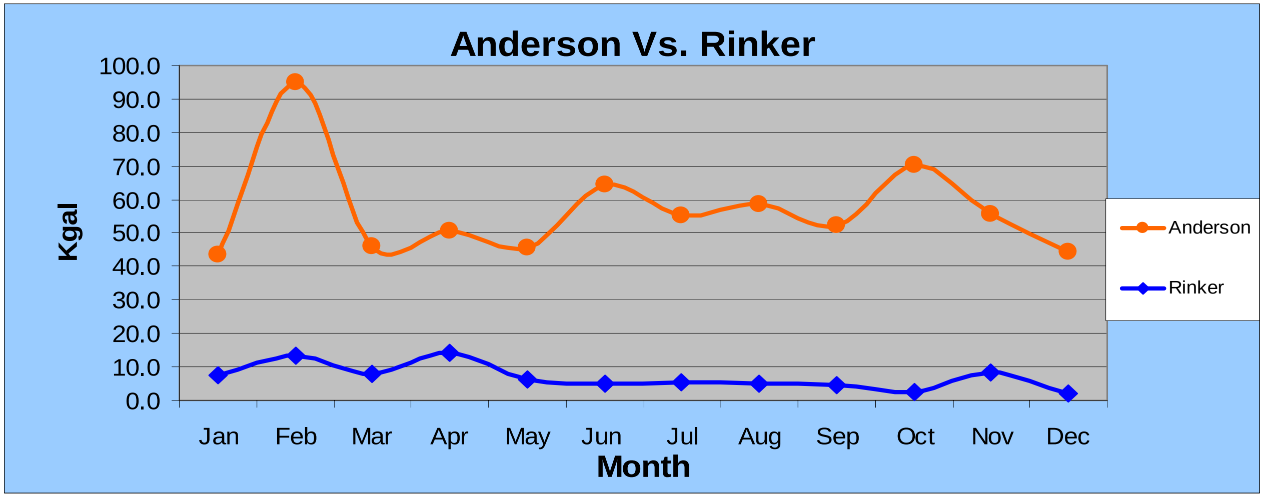


Figure 4-12. Water Consumption (Kgal) for Anderson Hall vs. Rinker Hall

Table 4-21. Associated Costs for Water Consumption

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$7	$13	$8	$14	$6	$5	$5	$5	$5	$3	$8	$2
Anderson	$43	$94	$46	$50	$45	$64	$55	$58	$52	$70	$56	$44

Table 4-22. Total Utility Consumption Costs for Rinker Hall and Anderson Hall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rinker	$3,986	$4,094	$3,865	$4,538	$4,133	$4,249	$4,594	$5,200	$4,878	$5,001	$4,863	$5,575
Anderson	$3,494	$3,788	$3,781	$4,068	$3,891	$4,499	$4,779	$5,650	$5,329	$5,285	$4,860	$4,646
Difference	$492	$306	$84	$470	$242	-$250	-$184	-$451	-$451	-$284	$2	$929

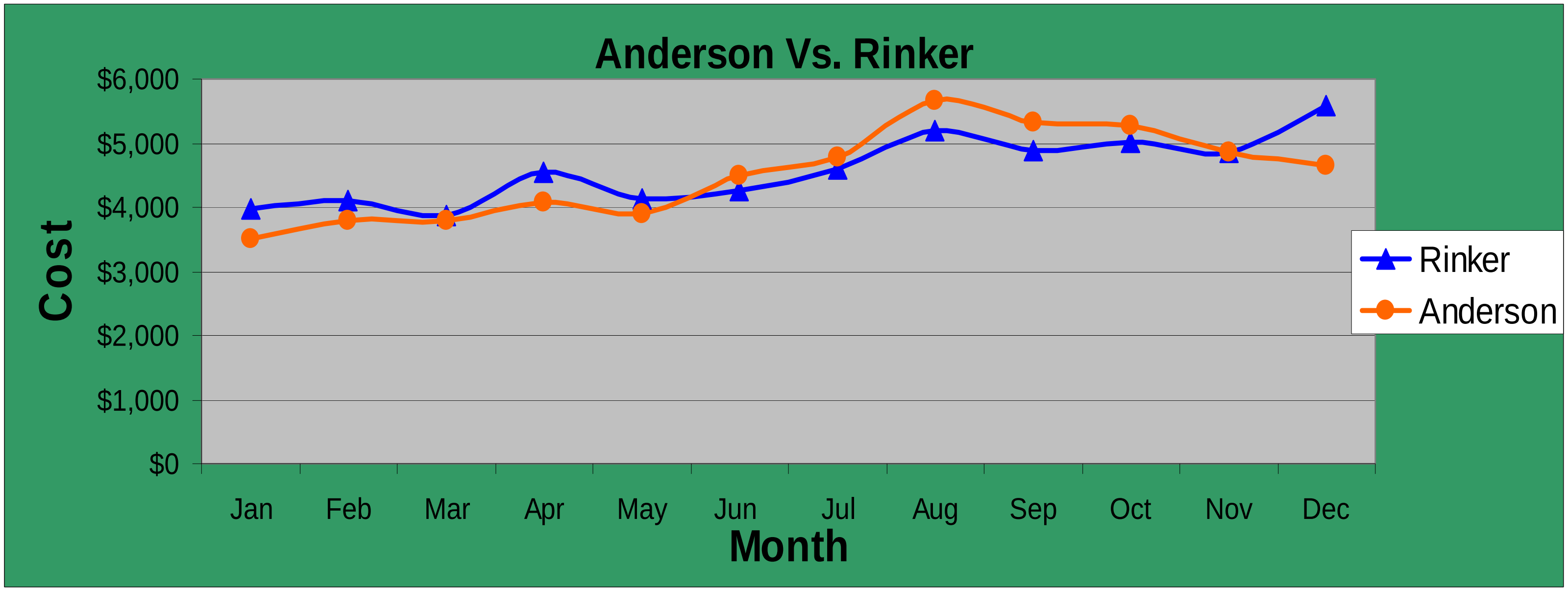


Figure 4-13. Total Annual Utility Cost for Anderson Hall vs. Rinker Hall

Conclusion

At first glance, one may be surprised to find that at $54,070 Anderson Hall's total cost of utilities was nearly two percent lower than Rinker Hall's $54,975 for the year 2004. However, several key determining factors must be taken into account in order to accurately qualify the numbers presented figure 4-13. First is total building horsepower. The two structures are within three percent of one another in total building square footage, while the building horsepower for Rinker Hall is double that of Anderson Hall. Similar to the above comparison with Frazier Hall, these results show that Rinker hall performs considerably more efficiently based on horsepower levels than does Anderson Hall. Second is total classroom area and student traffic. Anderson Hall houses eight general purpose classrooms, while Rinker Hall contains six classrooms, six student laboratories, and one large auditorium.

As noted above, Rinker Hall operates from 6:30am until 11:00pm, on weekdays while Anderson is operational 7:00am until 8:00pm. Both buildings are operational for four hours per day on weekends and holidays. Therefore, Anderson Hall's 73 hours of operation per week is nearly 25 percent lower than Rinker's 90.5 hours and should more than offset the two percent difference in annual utilities between the two buildings. One should also note that during the harsh Florida summer months of June-September, Rinker Hall ran more efficiently than Anderson despite the extensively larger systems at work within the structure.

Summary Analysis

The above data for each comparison was consolidated into “total energy values” and is presented in table 4-23

Table 4-23. Total Annual Values by Square Footage

	Cost	BTU (all)	Gal.	KWh. (elec.)
Rinker Hall	$1.19	80,761.8	1.1	8.0
Frazier Rogers	$2.93	148,689.8	28.6	13.0
Anderson Hall	$1.18	77,350.1	10.4	7.0

"Cost" represents the total cost for Utility consumption divided by total building square footage. "BTU" calculations take into account the total annual energy consumption in BTU's including Chilled Water, Steam, and Electricity. "Gal." represents total gallons of potable water consumed annually divided by building square footage. The "KWh" column represents the annual electrical consumption per square foot with electricity being the only resource taken into account. In consistency with earlier results, Frazier Rogers hall is highly inefficient in comparison to the other two structures, and Anderson Hall narrowly edges Rinker Hall by $.01 per square foot.

By modifying to take into account the hours of operation differences between the 3 structures, an approximation can be made on a theoretically more accurate level. However, results are merely theoretical as the added hours to Anderson Hall and Frazier Rogers Hall would not be during peak building load hours. Therefore, Table 4-24 is adjusted to the average hours of operation per week for Rinker Hall, 90.5.

Table 4-24. Total Annual Values by Square Footage Adjusted for Hours of Operation

	Cost	BTU (all)	Gal.	KWh. (elec.)
Rinker Hall	$1.19	80,761.8	1.1	8.0
Frazier Rogers	$3.07	156,124.3	30.3	13.7
Anderson Hall	$1.48	96,687.6	13	8.75

As is visible in figure 4-24, this theoretical comparison skews results heavily in Rinker Hall's favor. Anderson Hall operates on a uniform schedule and was adjusted directly by a 25% increase in consumption to match Rinker Hall's hours of operation. Frazier Rogers Hall was modified based on square footages of usage type, with an overall average increase in operation of approximately 5%. Although these values cannot be held as factual or completely accurate, they serve as an effective tool for displaying the added efficiency of Rinker Hall’s operations.

Life-Cycle Cost Analysis

In order to analyze the above data, a life-cycle costing system was used to document predicted future expenses over a twenty year projected life and value them in terms of current dollar amounts. In order to do so, recommendations were taken from the National Institute of Standards and Technology Handbook #135 “Life-Cycle Costing Manual for the Federal Energy Management Program.” An actual discount rate of 3% was applied based on Department Of Energy(DOE) recommendations, and adjusted for long-term inflation of 1.75%. The resulting nominal discount rate applied was equal to 4.8%. Individual resource prices were subjected to an averaged price escalation rate of two percent per year over the twenty year life cycle. For each of the two comparisons, Rinker Hall was presented as the alternative, with the sustainable design premiums shown as initial costs, while both Anderson and Frazier Rogers Hall carried zero initial cost due to their conventional code compliant designs. Presented in Microsoft Excel format, results are shown in figures 4-14 and 4-15 below.

Sustainable Design Comparison

Subject: Utility Consumption								
Description:								
Project Life Cycle =		**20**	**Years**		**Frazier-Rogers Hall**		**Rinker Hall**	
Discount Rate =		**4.80%**			Year Completed:	2001	Year Completed:	2002
Present Time =		**Jan-05**			Square Footage	53,543	Square Footage	46,530
INITIAL COSTS		**Quantity**	**UM**	**Unit Price**	**Est.**	**PW**	**Est.**	**PW**
Construction Costs								
A.	Daylighting Premium	1	LS	$0.00	0	0	370,000	370,000
B.	Energy Premium	1	LS	$0.00	0	0	233,000	233,000
C.	Water Conservation	1	LS	$0.00	0	0	52,500	52,500
D.				$0.00		0		0
Total Initial Cost						**0**		**655,500**
Initial Cost PW Savings (Compared to Alt. 1)								**(655,500)**
ANNUAL COSTS								
	Description		**Escl. %**	**PWA**				
A.	Chilled Water		2.000%	15.234	$53,425	$813,889	$19,692	$299,992
B.	Water		2.000%	15.234	$2,087	31,794	$81	1,234
C.	Steam		2.000%	15.234	$4,060	61,851	$3,166	48,232
D.	Electricity		2.000%	15.234	$60,441	920,772	$31,767	483,946
E.	Waste Water Fees		2.000%	15.234	$3,965	60,408	$154	2,345
Total Annual Costs (Present Worth)						**$1,888,714**		**$835,748**
Total Life Cycle Costs (Present Worth)						**$1,888,714**		**$1,491,248**
Life Cycle Savings (Compared to Alt. 1)								**$397,466**
Discounted Payback (Compared to Alt. 1)				**PP Factor**			**11.10**	**Years**
Total Life Cycle Costs (Annualized)				**0.0789**	**148,996**	**Per Year**	**117,641**	**Per Year**

**University Facilities Management does not charge Wastewater to buildings; however, UF Physical Plant division has established a wastwater processing fee of $1.90/kgal

Figure 4-14. Life-Cycle Cost Analysis for Rinker Hall vs. Frazier Rogers Hall

Figure 4-14 shows results leaning heavily in favor of Rinker Hall. With the present worth of annual costs of $835,748, Rinker operates at approximately forty-four percent of the total cost of Frazier Rogers Hall's $1,888,714 (in current dollars). As shown above, in direct comparison with Frazier Rogers Hall, the life cycle model predicts that by simply accounting for resource savings, a payback for the Rinker Hall sustainable design premium can be realized in just over eleven years. Over the twenty year projected life represented above, Rinker Hall will not only payback the additional up front expense, but will generate a "savings" of $397,466. Using the ratio of total (of annual) operations savings versus original cost, the Savings to Investment Ratio (S.I.R) for the above comparison is calculated at 1.606. In terms of costs per square footage over the 20 year life, utility costs for Rinker Hall are $17.96/sf, while Frazier Rogers Hall costs $35.27/sf. Although there is considerably more research laboratory space in Frazier Rogers Hall, its total energy consumption should be considered similar to that of an ASHREA 90.1 compliant version of Rinker Hall. Therefore, during the period between realized pay-back in year eleven and the end of the twenty year life, Rinker Hall will be operating at a profit in comparison to Frazier Rogers Hall.

Sustainable Design Comparison

Subject: Utility Consumption							
Description:							
Project Life Cycle =	**20**	**Years**		**Anderson Hall**		**Rinker Hall**	
Discount Rate =	**4.80%**			Year Completed	2002	Year Completed:	2002
Present Time =	**Jan-05**			Square Footage	47,757	Square Footage	46,530
INITIAL COSTS	**Quantity**	**UM**	**Unit Price**	**Est.**	**PW**	**Est.**	**PW**
Construction Costs							
A. Daylighting Premium	1	LS	$0.00	0	0	370,000	370,000
B. Energy Premium	1	LS	$0.00		0	233,000	233,000
C. Water Conservation	1	LS	$0.00		0	52,500	52,500
D.			$0.00		0		0
Total Initial Cost					**0**		**655,500**
Initial Cost PW Savings (Compared to Alt. 1)							**(655,500)**
ANNUAL COSTS							
Description		**Escl. %**	**PWA**				
A. Chilled Water		2.000%	15.234	$21,072	$321,016	$19,692	$299,992
B. Water		2.000%	15.234	$677	10,314	$81	1,234
C. Steam		2.000%	15.234	$2,603	39,655	$3,166	48,232
D. Electricity		2.000%	15.234	$28,019	426,848	$31,767	483,946
E. Waste Water**		2.000%	15.234	$1,286	19,596	$154	2,345
F.		0.000%	12.676		0		0
Total Annual Costs (Present Worth)					**$817,428**		**$835,748**
Total Life Cycle Costs (Present Worth)					**$817,428**		**$1,491,248**
Life Cycle Savings (Compared to Alt. 1)							**($673,821)**
Total Life Cycle Costs (Annualized)	**PP Factor**		**0.0789**	**64,485**	**Per Year**	**117,641**	**Per Year**

**University Facilities Management does not charge Wastewater to buildings; however, UF Physical Plant division has established a wastwater processing fee of $1.90/kgal

Figure 4-15. Life Cycle-Cost Analysis for Rinker Hall vs. Anderson Hall

Anderson Hall is predominately an administration building which caters to a smaller population traffic level than Rinker Hall, and contains no research or teaching laboratory space. As shown in Table 4-1, total building horsepower for Anderson hall is approximately half of the peak ratings for Rinker. These qualifications give insight into the results shown in Figure 4-15. Over the 20 year life-cycle presented above, Anderson Hall utility costs total out to $817,428, approximately 2.2% below Rinker Hall's $835,748. Due to this difference, expected payback period cannot be calculated as the model would never make up for the initial up-front costs and the gap would increase annually. The S.I.R. for the above comparison is -.028, showing a theoretical negative return on investment. When related to square footage, Anderson Hall costs are equal to $17.12/sf over the twenty year life span, $.84/sf lower than that of Rinker Hall. In following traditional LCC methods of thought, Anderson Hall would prove to be the more cost efficient building, however the above qualifications still lend credibility to the design efforts present in Rinker Hall. Results are still quite profound and in favor of Rinker when the complete facts behind the complexity of building systems are taken into account.

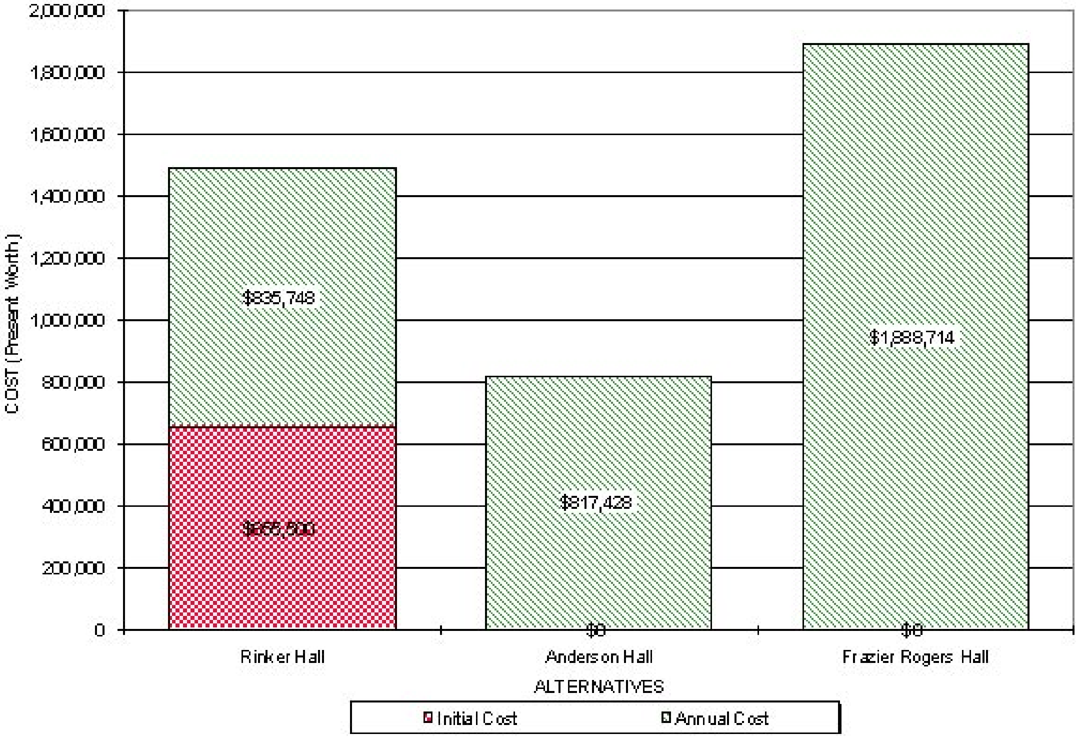


Figure 4-16. Graphical Display of Life-Cycle Cost Analysis

The total Life-Cycle cost for resources in Frazier Rogers Hall easily exceeds the combination of the cost premiums and the annual operational costs for Rinker Hall. When viewing the bar representation of Anderson Hall, resource costs appear to be almost equal to the graphical display for Rinker Hall.

CHAPTER 5
CONCLUSION

Sustainable design for Green building is without a doubt the way of the future. High performance structures and systems are gaining momentum with each successive implementation. This study showed an example of how clearly and easily the positive results of sustainable design efforts can be realized. The brief existence of the structures studied in the preceding pages allows for a larger than normal margin of error for the realized results due to “quirks” not having been completely worked out of the systems in question, especially in the more complex Rinker Hall.

At this point, outlying data cannot yet be determined due to lack of data population size; however, portions of the collected building consumption data show potential for outlying points, such as unexplained spikes in chilled water consumption during the coldest months of the year, or highly fluctuating steam consumption. These irregularities, as well as the cost similarities between Rinker Hall and Anderson Hall give rise to many assumptions; first and foremost being the existence of minor flaws in the design of Rinker Hall. As is often the case in commercial construction, despite the impressive performance of the building, the mechanical system in Rinker Hall may in fact be over designed. For example, why does Rinker Hall require a 50% increase in available building horsepower over the equally sized Anderson Hall? Perhaps a lesser powered structure could still produce the same efficient output at an even lower cost.

In Reference to Hal Varien’s criteria for an effective model, 1. *The model must address who makes the choices involved*: Perspective owners are making the decision as to whether or not they will assume the added construction costs to achieve a sustainable design. 2. *What constraints do the decision makers face?* Again, decision makers must determine if long-run cost savings will outweigh the initial up-front investment in sustainability. *3. What interaction exists?* Designers with a vested interest in sustainability should be on board from the beginning of the design phase in order to ensure the most efficient usage of green building technologies and strategies. 4. *What information is being processed and what is being predicted?* At the design phase, theoretical values are being processed to predict life-cycle savings. In the case of the Rinker Hall model above, actual annual costs are used to provide evidence that the savings do exist. *5. What adjusts to assure consistency?* Adjustments for building horsepower, and total hours of operation can be made in order to allow for even more consistency.

The stated hypothesis of the thesis poses the question of whether or not hard cost data on resource consumption can be used to accurately evaluate green building performance. Through taking into account all applicable costs and modification factors to establish a methodology for comparison, the previous study showed that hard cost data can in fact be a reliable predictor of building performance. The fact that hard cost data alone nearly pays back the up-front expenditures before taking into account other factors such as soft cost savings, community/environmental implications, and others proves that substantial improvement in resource consumption hard costs are an effective display of the greenness of a high performance building.

Through conducting the literature review, it became apparent that there is a lack of extensive data on actual performance for sustainable, high performance buildings. This is due not only to the lack of available data, but also to lack of known methods for both accumulation and analysis. The previous study merely took a conservative look into the financial gains of sustainable construction efforts for higher educational facilities under one particular set of conditions. By obtaining and evaluating resource consumption data and related costs, quantifiable evidence was produced to help justify the realized gain from sustainable design. These resource costs or “hard-costs” are easy to obtain, and provide for simple direct comparisons between sustainable and conventional structures. In order to create a true evaluation of the positive effects of sustainable design initiatives, less tangible, or “soft cost” data must also be included.

These costs include such items as indoor environmental quality, consumer satisfaction, student/faculty efficiency, and several others. These types of data are difficult to obtain, and even more difficult to assign direct costs/savings. Further research into methods of quantifying soft cost factors for sustainable construction will pave the way for production of substantially more comprehensive economic performance models. Hard cost data alone has proven to be very convincing when combined with theoretical values for soft cost data. True results for soft cost savings will prove once and for all the necessity of sustainable efforts in the built environment.

In order to carry out additional studies regarding similar data, or expanding upon the above data, several courses of action can be recommended. First, the organizer of the study should establish a list of contacts from the start. These contacts should cover every aspect of the study. In the above case it was necessary to have contacts at several departments within the University of Florida, as well as within the actual field of study. Secondly, upon collecting data, use digression as to which are relevant to the particular analysis. For example, any data relating to soft costs, or aesthetics for the structures in the preceding study was discounted from the results as it had no impact on the variables of the study. Finally, organizers of future studies must understand that historical data available on similar topics is not regulated, and may very well be skewed in favor of the intentions of the study. As shown by table 4-24, theoretical numbers can quickly sway results in either direction.

LIST OF REFERENCES

Building Energy Codes Program
US Department of Energy: Energy Efficiency and Renewable Energy
http://www.energycodes.gov/comcheck/89_compliance_manual.stm

Fuller PhD., Sieglinde K. "Economic Analysis and Green Building"
Green Building: Project Planning and Cost Estimating: A Practical Guide for Constructing Sustainable Buildings
Editors: Andrea Keenan and Danielle Georges
Published: Kingston, Mass. c2002

Fuller, Sieglinde K., Peterson, Stephen R.
National Institute of Standards and Technology Handbook #135 1995 Edition
Life-Cycle Costing Manual for the Federal Energy Management Program
United States Department of Commerce, February 1996

GETTING TO GREEN: How to Get LEED Certified
"Gold Level" M. E. Rinker, Sr. Hall
Rinker School of Building Construction, University of Florida

Gottfried, David "A Blueprint for Green Building Economics"
Found in Industry and Environment v26 n 2-3 April/September 2003 p 20-21

Kats, Gregory H. Green Building Costs and Financial Benefits
Editors: Andrea Keenan and Danielle Georges
Published: Kingston, Mass. c2002
Published for Massachusetts Technology Collaborative, 2003. Available online at the Capital E website, http://www.cap-e.com/

Kibert, Charles J. 2005. Sustainable Construction: Green Building Design and Delivery,
New York: John Wiley & Sons.

LEED: Building Green. Everyone Profits.
Copyright 2005. US Green Building Council
www.USGBC.org/displaypage.aspx?categoryID=19

Lippiat, Barbara C. "Evaluating Products Over their Life-Cycle"
Found in Green Building: Project Planning and Cost Estimating: A Practical Guide for Constructing Sustainable Buildings
Editors: Andrea Keenan and Danielle Georges
Published: Kingston, Mass. c2002

"Making the Business Case for High Performance Green Buildings",
U.S. Green Building Council(USGBC). 2003.
Available for download at http://www.usgbc.org/

Macaluso, Joseph CCC. "Economic Incentives and Funding Sources"
Found in Green Building: Project Planning and Cost Estimating: A Practical Guide for Constructing Sustainable Buildings
Editors: Andrea Keenan and Danielle Georges
Published: Kingston, Mass. c2002

McElroy, Lori "Technical Factors in the Design of Commercial Buildings"
Sustainable Architecture: Second Edition
Edwards, Brian
Published: Architectural Press, 1999

Pitts, Adrian Planning and Design for Sustainability and Profit
Published: Architectual Press 2004.

R.S.Means Online Construction Dictionary
http://rsmeans.com/dictionary/index.asp
2004 Reed Business Information

Shultz. Laura L, Rushing, Amy S., Fuller, Sieglinde K.
Annual Supplement to NIST Handbook #135
Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis April-2004
United States Department of Commerce, February 2004

Wyatt, David J. "Look Before Leaping into Green Design"
Found in Construction Specifier v57 n 6 June 2004 p32-34.

BIOGRAPHICAL SKETCH

Eric Meister received a Bachelor of Science in Business Administration (with a concentration in management) from the Warrington College of Business Administration at the University of Florida in Spring 2003. His interest in environmentally sustainable design was spawned through course work at the University of Florida taken in effort to earn his Master of Science in Building Construction.

.