

BEHAVIOR, COMFORT, AND ENERGY CONSUMPTION
IN STUDENT RESIDENCE HALLS

by

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Title: BEHAVIOR, COMFORT, AND ENERGY CONSUMPTION IN STUDENT
RESIDENCE HALLS

New residence halls differ from their predecessors because of sophisticated systems, concern for energy efficiency, and attention to student satisfaction. Nevertheless, older facilities represent the bulk of housing stock on many campuses. A literature review revealed few recent studies related to student housing. This thesis questions how residence hall age influences occupant perceptions and actions related to comfort and energy consumption. The study took place in two residence halls, built in 1963 and 2006, and entailed an occupant survey of 103 residents as well as the collection of thermal and utility data. Survey results did not show a significant difference in occupant behaviors between the older and newer buildings. Thermal measurements in both buildings fell inside and outside the ASHRAE Comfort Zone, which supported occupant perceptions. Findings indicate a lack of student awareness of energy conservation strategies. Furthermore, greater consistency in campus utility metering would enable more accurate building performance comparisons.

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CHAPTER I

INTRODUCTION

1.1. Introduction

According to the 2000 US Census, over 2 million students live in residence hall buildings in the United States¹ and this number is expected to increase substantially when the next census is released in 2010. In recent years many colleges and universities have constructed new residence halls that respond to growing student populations, increased student and parent expectations, rising fuel costs, energy consumption, environmental impact, and concern for student achievement and social interaction. These new buildings differ substantially from many of their predecessors due to their technical superiority, luxurious appointments, aesthetic appeal, spaciousness, energy efficiency, occupant control, and sustainable features.²

Understandably, the student demand for rooms in newer halls often exceeds the limited supply.³ The bulk of campus housing available to students dates from the 1950s and 1960s, a period of dramatic growth and expansion for institutions.⁴ Although students often describe the older residence halls as sterile, banal, uncomfortable, ugly, and institutional, college and university housing administrators struggle to renovate or replace the buildings amid growing student populations and cost constraints. The lack of amenities and automated controls in older, preexisting residence halls results in buildings

that do less of the work for the occupants and, therefore, simpler buildings seem to demand more interaction from the students who live in them. This increased interaction may be advantageous because studies have found that occupants of other building types, such as offices, appear less willing to take action to adjust their comfort in the presence of sophisticated systems that regulate environmental conditions.⁵

This thesis project seeks to expand upon the notion that building design and age have a significant impact on occupant perception and interaction with their living environments. Data was collected from two residence halls at the University of Oregon. The three components of the research methodology included: occupant surveys completed by 103 students, thermal measurements taken in ten locations, and utility data collected from the university. The results of this study provide data related to thermal comfort and energy consumption that may be valuable in the design, refurbishment, or renovation of other residence hall facilities on college and university campuses.

1.2. Thesis Objectives

The primary objective of this thesis is to address the gap that presently exists in the body of research related to occupant thermal comfort and energy consumption in residence halls. A large body of social science and environment-behavior research was conducted in residence halls in the 1960s and 1970s. However, very little research has addressed occupant perception and action with respect to thermal comfort and energy consumption conditions in student living environments. In addition, thermal comfort studies typically focus primarily on populations in offices and schools where groups of

occupants often share work or classroom space, which facilitates easier surveying by research investigators. Residence hall buildings, by contrast, are usually organized around small groups of two to three occupants sharing bedrooms. This compartmentalization into many small rooms presents challenges to investigators surveying building occupants.

Despite the procedural challenges inherent in conducting research in residence halls, information related to comfort and energy in these buildings could assist institutions in providing superior campus housing that improves student satisfaction, productivity, achievement, and health in addition to reducing energy costs, waste, and environmental impacts.

Research Questions

1. What are the ranges of perceptions and behaviors that residence hall occupants have in response to thermal comfort and energy consumption in their living environments?
2. What role does building age play in the occupant perceptions of thermal comfort and energy consumption in residence halls?
3. What role does building age play in the ways that occupants interact with thermal comfort conditions and energy consumption in residence halls?
4. What are the ranges of thermal conditions found in old and new residence hall buildings?
5. What is the aggregate electricity consumption in old and new residence hall buildings?

Hypotheses

The first hypothesis of this thesis is that occupants of student resident halls built during the 1950s and 1960s perceive⁶ thermal comfort conditions⁷ and energy conservation opportunities⁸ less favorably⁹ than students living in residence halls constructed within the past ten years.

The second hypothesis of this thesis is that the simplicity inherent in older residence halls demands and encourages greater occupant interaction and engagement¹⁰ with their living environments than do the newer, more technically complex and automated buildings.

A secondary hypothesis is that occupant actions to maintain or restore personal thermal comfort¹¹ in both older and newer residence halls are taken with little regard for energy consumption because students are unaware of their actual energy usage and do not pay utility bills.

1.3. Thesis Approach

This thesis utilizes two residence halls at the University of Oregon, one built in 1963 and the other built in 2006, to investigate the relationship between occupant thermal comfort and energy consumption in student housing of different vintages.

The research design follows a “combined strategy” approach in which several data collection methods are utilized to account for the inherent strengths and weaknesses of using one particular strategy alone. An occupant survey was the dominant data collection method. Physical measurement and utility data collection assume less-

dominant roles, and serve to support and balance the survey data and to add robustness to the research methodology.¹²

1.4. Thesis Organization

This thesis is subdivided into six chapters, four appendices, and a bibliography. Each chapter begins with a brief introduction and concludes with a summary and chapter endnote citations. Chapter 1 presents a general introduction to the research thesis project including the motivations for a study involving thermal comfort and energy consumption in residence hall buildings as well as a general overview of the research objectives, approach, and organization. Chapter 2 presents a summary of previous research relevant to issues of thermal comfort and energy consumption in buildings and research focused on the residence hall building type. Chapter 3 presents an overview of the residence hall building type and is subdivided into sections addressing the history of student housing at colleges and universities, current trends in student housing, and the evolution of the residence hall at the University of Oregon, the data collection location for this thesis. Chapter 4 presents the methodology used to collect data including occupant surveys, physical measurement of environmental conditions, and the collection of utility data from the university. The chapter ends with a description of the protocol undertaken to analyze the data using spreadsheets and statistical software. Chapter 5 presents the results and data analysis process. Chapter 6 presents a discussion focused on how the findings of this study relate to the initial research questions and objectives. Chapter 7 presents the conclusions of the study and suggests opportunities for future research. Appendix A

presents the occupant survey, Appendix B presents the graphic fliers used to recruit survey participants, Appendix C presents drawings of the residence hall buildings that were utilized in the data collection, Appendix D presents photographs of the residence hall buildings used in the data collection, Appendix E presents additional thermal measurement information, Appendix F presents the final presentation slides and a transcription of the question and answer session, and the bibliography presents a comprehensive list of sources used in this study.

1.5. Endnotes

- ¹ U.S. Census Bureau. *United States Census 2000 PHC-T-26*. Washington, DC: U.S. Census Bureau, 2000. Web. 2 Jun. 2009.
- ² Shimm, Jon. "Sustainable Campus Housing." *American School & University*. 73. 12 (2001): 142, 144. Print.
- ³ Herron, Deborah, and Beverly Mayhew. *UO University Housing – Residence Halls Survey*. Eugene, OR: The Ulum Group. (2007): 1-9. Print.
- ⁴ Wills, Eric. "Sins of the 60s." *The Chronicle of Higher Education*. 52. 8 (2005): A26. Print.
- ⁵ Leaman, Adrian., and Bill. Bordass. "Productivity in Buildings: the 'killer' Variables." *Building Research and Information*. 27. 1 (1999): 4-19. Print.
- ⁶ Awareness of the elements and conditions present in the environment as measured by a survey.
- ⁷ A condition that results when a building occupant finds the combination physical parameters (temperature, humidity, and air movement) and personal factors (clothing and activity) present in their environment to be satisfactory such that they would seek no change.
- ⁸ Opportunities within a building that encourage or facilitate occupant energy conservation behaviors or regimes.

- ⁹ Occupants of the older building find the thermal comfort conditions and the energy conservation opportunities to be more unsatisfactory than do the occupants of the newer building as measured by survey responses.
- ¹⁰ A larger number of deliberate actions taken by occupants to change and adapt to varying conditions present in the building as measured by survey responses and physical thermal and energy data collected.
- ¹¹ A basic premise of the adaptive thermal comfort model, which suggests that human's naturally and intuitively adapt to their thermal environments.
- ¹² Groat, Linda N., and David Wang. *Architectural Research Methods*. New York: J. Wiley, 2002. 203-47, 341-73. Print.

CHAPTER II

OVERVIEW OF PREVIOUS RESEARCH

2.1. Introduction

This chapter presents an overview of previous research related to thermal comfort, energy consumption in buildings, the relationship between thermal comfort and energy consumption, and the residence hall building type. In addition, the discussion addresses the lack of research pertaining to thermal comfort and energy consumption in residence halls.

2.2. Thermal Comfort

ASHRAE Standard 55-2004 defines thermal comfort as “that condition of mind which expresses satisfaction with the thermal environment.”¹ The human body exchanges heat with the environment to maintain a constant temperature. Heat balance or equilibrium is accomplished through a combination of convection, radiation, conduction, and evaporation. There are six factors that affect thermal comfort. The four physical environmental factors are: air temperature, humidity, air movement, and surface or radiant temperature. The two personal factors are: clothing insulation and activity level (metabolic rate).²

Thermal Comfort Standards

ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy (hereafter Standard 55) is used in the design, testing, and evaluation of indoor environments and their mechanical systems.³ Standard 55 and ISO-7730-2005, Ergonomics of the Thermal Environment—Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria (hereafter ISO 7730), were developed in parallel. Both describe a PMV (Predicted Mean Vote) method and an alternate adaptive approach for calculating acceptable thermal conditions in buildings.⁴ The PMV model developed by Fanger is based upon heat balance principles studied with subjects in laboratory climate chambers. The adaptive model relies on field studies of occupant comfort in relation to outdoor temperatures.⁵

Comfort Zone

Standard 55 describes combinations of thermal parameters that produce comfort conditions acceptable to 80% of people. These parameters are plotted on a modified psychrometric chart to produce comfort zones. Because the psychrometric chart relates only air or dry-bulb temperature and humidity, the other four factors are “fixed.” The comfort zone can be extended to the left with the addition of radiant temperature and to the right with the addition of greater air movement.⁶ The thermal comfort zone assumes that: radiant temperature is the same as air temperature, air movement is no greater than 40 feet per minute, metabolic rate is between 1.0 and 1.3 MET, and clothing insulation is

either 0.5 CLO for the summer zone or 1.0 for the winter zone. There is an upper limit of 0.12 lb water/lb dry air for the humidity ratio and there is no lower limit.⁷

Adaptive Thermal Comfort

The adaptive approach to thermal comfort is predicated on the notion that “people have a natural tendency to adapt to changing conditions in their environment.” The approach differs from the traditional PMV method because it relies on the simultaneous collection of thermal measurements and occupant “comfort votes” given in surveys rather than on indices based upon climate chamber studies.⁸

An important premise of the adaptive approach is the *adaptive principle*, which states that “if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort.”⁹ These changes are made possible by *adaptive opportunities*, which are “the real and perceived freedom to make adjustments to the local environment...or to one’s own status.” Humans are likely to accept a wider range of indoor conditions if they have the ability to adapt or make changes to their environments.¹⁰ There are three types of adaptation: behavioral adjustment (modifications to clothing for instance), physiological (acclimatization for instance), and psychological (perceptual changes to sensory experience or expectations for instance).¹¹

In 1998 De Dear and Brager compiled a database of thermal comfort field studies from 160 naturally ventilated and mechanically conditioned buildings around the world in an effort to develop and test an adaptive model. One of the key findings of their study

is that “occupants in naturally ventilated buildings were tolerant of a significantly wider range of temperatures” due to their ability to adapt to their environments.¹²

In a study of 11 office buildings, Leaman and Bordass found a strong relationship between occupant perception of control over their environment and productivity. As building performance improves, the relationship weakens because there is less need for control when conditions are comfortable.¹³ However, the presence of an adaptive opportunity does not guarantee that occupants are effectively utilizing it to achieve thermal comfort. Researchers have questioned the usefulness of a comprehensive list of adaptive opportunities within buildings, if such a list could even be compiled. A larger number of opportunities do not guarantee greater thermal comfort. A more nuanced relationship exists in the myriad of ways that adaptive opportunities allow occupants to interact with their environment.¹⁴

2.3. Energy Consumption in Buildings

Energy consumption in buildings is measured at a wide variety of scales from the national and international surveys to specific building systems and equipment within individual buildings.

The US Department of Energy estimated that buildings accounted for 40.2% of the primary energy consumption and 72% of electricity consumption in the United States in 2005. Of the primary energy and electricity consumption in buildings, roughly half is attributable to commercial buildings and half to residential buildings.¹⁵

In 2003 the US Energy Information Agency released the results of its Commercial Buildings Energy Consumption Survey (hereafter CBECS). The survey included approximately 4.9 million buildings totaling 71.6 billion square feet of space and 6,500 trillion BTUs of energy consumption. Of the energy used in commercial buildings, electricity accounted for 55% and natural gas accounted for 32% of the total consumption. Since the first CBECS in 1979, the number of buildings, square footage of space, and the total amount of energy used have increased dramatically.¹⁶

The Chartered Institution of Building Services Engineers (hereafter CIBSE) recommends that energy audits and surveys be conducted every three to five years in order to assess energy consumption and costs in specific buildings. Simple audits can focus on aggregate energy use and cost data gathered from utility bills. More comprehensive surveys involve breaking down aggregate energy use within buildings, for example heating, lighting, and air-conditioning loads. The objective of energy audits is to identify areas where energy can be conserved within buildings and to assist building designers, owners, and managers in creating plans or protocols to address energy use reductions.¹⁷

2.4. The Relationship Between Comfort and Energy

In describing the critical relationship between energy and comfort, Nicol writes that the “provision of comfort has a major bearing on energy consumption and carbon dioxide emissions. At the same time, energy efficiency without occupant comfort is not sustainable.”¹⁸ CIBSE notes that energy efficient buildings can provide the desired

environmental comfort conditions and use less energy.¹⁹ Fountain, Brager, and de Dear suggest that the relationship between “rigidly controlled indoor environments” and energy consumption of buildings could be improved by “relaxing” clothing conventions and occupant expectations.²⁰ Shove et al. point to a need for buildings that “engage” occupants rather than simply satisfying their comfort needs. In such a scenario, people assume a more active role in their thermal comfort and environmental impact.²¹

2.5. Residence Halls

A large number of studies using student residence halls exist. Sommer speculates that the use of college dormitories for research is attributable to the large population of study subjects in close proximity to academic researchers.²² Much of this body of research has focused on social science and environment-behavior studies related to issues of student social interaction, room layouts, study habits, supervision, and crowding. Several recent studies address the issue of energy consumption and conservation in residence halls, but very little research appears to exist related to thermal comfort in student housing.

Residence Hall Studies

A comprehensive summary of previous residence hall studies would be a complex and time consuming research project in its own right. However, several studies have been selected to illustrate the variety of research interests and approaches undertaken by investigators in the past.

One of the most popular topics in residence hall studies is student room types and arrangements: the suite versus corridor dilemma. Corbett suggests that the term “suite” be more clearly defined because of the wide variety of configurations that exist. The study investigated suites in residence halls at the University of California at Davis. Corbett recruited 128 questionnaire respondents “on a door-to-door basis.” The findings show that suites appear to allow a larger number of activities to occur simultaneously when compared with their double-room counterparts. Students also perceive the suites to be more spacious than double-rooms, even when the square footage of their space is actually less. However, roommate conflicts appear to be greater in suites due to the close proximity of students living together. The study concludes that suites have benefits, but that institutions should continue to offer other housing options.²³

More recent research by Devlin et al. also looked at the issue of suites and traditional rooms. The study surveyed approximately 600 students living in 24 different buildings, some with double-occupancy rooms along corridors and some with clusters of suite rooms, to determine whether the building architecture impacts students’ “sense of community” within their residence halls. Their findings suggest that the suite-type layout satisfies practical needs such as storage and thermal and acoustical comfort better than the double room layout. However, the traditional double rooms provide better “sense of community” because students are less isolated.²⁴

A study by Van Der Ryn and Silverstein evaluated four existing student housing towers at the University of California, Berkeley that were experiencing high vacancy rates. The team used a wide variety of methods to analyze the buildings: physical

observation of occupant behavior; group and individual interviews; questionnaires; “activity logs,” which enable building residents to record their own behaviors and observations over time in a journal; and a literature review. The research team then recommended design and programming improvements for residence halls.

The findings suggest that students spend large amounts of time in their rooms and that more design attention should be devoted to room configurations. Furthermore, the tower layout segregates students by floor, which contributes to the formation of cliques. In addition, students dislike the “institutional” feel of dormitories, which could be improved if there were more social activities occurring in the buildings and if there was less emphasis on security and supervision. Finally, the study concludes that dormitories that integrate living and learning are becoming more popular, and that the historic “residential college” model poses challenges for modern colleges and universities.²⁵

Sommer conducted a number of different studies focusing on particular aspects of student life and behavior. The first study looked at study habits of students living in residence halls on eight different campuses. Study findings indicate that desk chairs are underutilized because students do not study at their desks and rarely use the chairs when socializing. The second study looked at the differences between 72 women living on-campus and 72 women living off-campus. The results suggest very little difference between the subjects’ grades, class attendance, or illness. However, women living on-campus are engaged in more campus activities and feel less isolated than women living off-campus. A third study looked at study habits and the number of students living in a room. Sommer finds that the number of students studying decreases as the number of

people living in a room increases. Finally, a study was conducted to assess student privacy needs. The results indicate that both acoustical and visual privacy are problematic in residence halls, but that students seem more willing to tolerate less acoustical privacy if they possess greater visual privacy.²⁶

Energy Consumption in Residence Halls

A review of literature related to energy benchmarks in the United States reveals a lack of information pertaining to the residence hall building type. CBECS groups residence halls into a “lodging” category that includes hotels, motels, nursing homes, half-way houses, convents, and monasteries.²⁷ According to unpublished data, 5 billion kWh of electricity consumption were used in the 16,000 dormitory buildings surveyed totaling 513 million square feet.²⁸ Thus, the average electricity consumption in the residence halls surveyed is 9.7 kWh/SF/year.

CIBSE provides overall energy benchmarks for existing “halls of residence” in the United Kingdom. Typical fossil fuel consumption is 290 kWh/m²/year and electricity consumption is 100 kWh/m²/year [9.3 kWh/SF/year]. Good practice fossil fuel consumption is 240 kWh/m²/year and electricity consumption is 85 kWh/m²/year [7.9 kWh/SF/year]. Good practice recommendations are considered to be the upper limit of what would be acceptable for new buildings.²⁹

In recent years, many colleges and universities in the United States have begun programs or competitions to encourage students living in residence halls to conserve resources. Petersen et al. note that one of the challenges with raising awareness of

resource consumption in residence halls is that the students do not pay a monthly utility bill and, thus, there is no financial incentive. The research team studied the impact web-based feedback and incentives have on occupant electricity and water conservation. The results of the study show significant electricity savings during the feedback period and that occupants are motivated by the feedback to conserve resources. The study suggests that new buildings substitute occupant control with building automation and that “‘smarter’ buildings may lead to environmentally dumber people.”³⁰

Thermal Comfort in Residence Halls

One study was found that focused on occupant thermal comfort in residence halls, revealing a significant lack of research in this area. The investigation took the form of a field study of 1,219 students in two residence halls in Taiwan; one naturally-ventilated and one air-conditioned. Using a typical thermal comfort field study approach, researchers surveyed building occupants while taking simultaneous measurements of physical thermal conditions. The survey focused on three areas: thermal sensation in which respondents indicate their comfort on an ASHRAE 7-point scale; thermal preference, which asked respondents if they would rather be warmer or cooler; and thermal acceptability, which asked respondents to comment on actions taken during discomfort.

The results indicate different ranges of temperatures in the buildings. The air-conditioned building never exceeds 30°C (86°F) and 70% RH, but the conditions in the naturally ventilated building exceeds 28°C (82.4°F) and 80% RH in 34% of the

measurements. Analysis of survey responses indicate that, despite the differences in measured thermal conditions, both buildings share a similar neutral temperature of 25.4°C (77.7°F). In addition, respondents in both buildings prefer a temperature that is cooler than neutral, 24.8°C (76.6°F). However, students living in naturally ventilated residence halls appear to prefer air-conditioning as an adaptive action less than students living in buildings where air-conditioning is available. The study concludes that the lack of air-conditioning may actually reduce student dependence on it as a means of regulating comfort.³¹

2.6. Summary

This chapter describes previous research pertaining to thermal comfort, energy consumption in buildings, the relationship between thermal comfort and energy, and the residence hall building type. The lack of research related to thermal comfort and energy consumption in residence halls is addressed.

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CHAPTER III

RESIDENCE HALLS

3.1. Introduction

Student housing has existed, in some form or another, for the last 900 years, beginning with the venerable European colleges and universities of England, France, and Germany. In the centuries since, a large number of names have been given to housing accommodations for students: hostel, hall, college, cottage, halls of residence, and dormitory, to name a few.¹ In recent years, however, the term “residence hall” has come to symbolize student housing that satisfies student needs for affordable, comfortable, and safe accommodation, and contributes in a positive way to academic and personal development.² The following chapter traces the history of collegiate housing in America, the current trends in residence hall design and construction, and the evolution of housing at the University of Oregon, the field study location of this thesis.

3.2. A Brief History of Collegiate Housing in America

European Precedents

As early as the 12th century, colleges and universities in Europe were beginning to provide housing accommodations for students. Some of the earliest examples were in England and France where “hospices” or “hostels” were created in surplus space within

hospitals. The accommodations were primitive and barracks-style, yet provided institutions the opportunity to supervise student activities and behavior.³

In time, there evolved two distinct approaches to student housing. The Oxford and Cambridge model, in England, was based on the residential college in which “faculty and students share time and lodgings during out-of-class hours as well as [come] together during formal instruction.”⁴ At the same time, colleges and universities in mainland Europe, particularly in Germany, began to reject the idea that institutions should provide housing and supervision for students. This became known as the German model, which was predicated on the idea that students are adults and should provide their own accommodations.⁵ Both models were influential in the development of student housing at American colleges and universities.

Early America

The English model, as exemplified by the residential colleges of Oxford and Cambridge, was the most commonly used precedent for student housing from the founding of the first colonial colleges until the American Civil War. These early institutions did not have the means to recreate the sophisticated quadrangles prevalent at English universities, but they included student housing from the outset. “The aim was to foster among all students a common social, moral, and intellectual life.”⁶ This arrangement has been called “in loco parentis” (Latin for “in the place of a parent”) because institutional staff or faculty acted in place of students’ parents while they were away from home.⁷

Mid 19th Century

Around the time of the American Civil War, colleges and universities were increasingly rejecting the notion that they should provide student housing. One significant factor in this decision was that student rebellious activity had convinced administrators that dormitories were havens for disorderly conduct and that colleges and universities would do well to follow the German model where students live off-campus.⁸ Another factor was that land-grant colleges and universities made possible by the Morrill Act of 1862 found it challenging to take funds away from instruction materials, academic buildings, and faculty salaries to pay for student housing.⁹

Early 20th Century

By the turn of the 20th century, many institutions were finding the German model untenable. Off-campus rooming and boarding houses were increasingly unable to accommodate the growing student populations in many college towns. The emergence of the fraternity and sorority system responded directly to the housing shortage by providing rooms and beds to shelter students. Nonetheless a surge in residence hall construction was simultaneously initiated by university presidents at many large and prestigious institutions.¹⁰ Cost and efficiency appear to have been concerns for many schools, yet issues of building scale, design, room layouts, and spaces for social interaction were not altogether forsaken.¹¹ Thwing, himself a university president, described this situation in

1914 when he wrote:

*The student is apart from his home. The building he occupies is made for the college; he lives with other students. With them he spends happy days and happier nights. His talk, his fun, his tricks, his friendship, are all academic; he takes the academic bath. The worth of such absorption is great.*¹²

Post World War II

The Great Depression prior to World War II was the first time that the federal government provided financial assistance to institutions wishing to expand, renovate, or construct student housing. Colleges and universities experienced unprecedented enrollments and a lack of adequate housing in the aftermath of World War II as a result of the Serviceman's Readjustment Act of 1944, also known as the "G.I. Bill." Once again, the government assumed a role in residence hall construction. Surplus war-era buildings were given to schools as temporary accommodations. Then, the Housing Act of 1950 made low-interest federal loans available to schools enabling a massive dormitory construction effort on college and university campuses. These buildings were designed and constructed with issues of economy, maintenance, and capacity in mind rather than "livability," social interaction, or student academic achievement.¹³

The Development of Residence Life

During the 1970s, many colleges and universities began to recognize that the dormitories built during the 1950s and 1960s, in direct response to rising enrollments, were unable to support the educational missions of their institutions. Academic research on student housing, as discussed in Chapter 2, became more prevalent at this time.

Institutional housing administrators, once relegated to issues of enrollment and maintenance, saw their institutional roles expand to encompass a wider variety of issues associated with student life. “Living and learning” became a term widely used to describe the close relationship between student housing and the educational missions of colleges and universities.¹⁴

3.3. Trends in Residence Hall Design and Construction

Recent renovations, replacements, and construction of residence hall facilities at colleges and universities are more thoughtfully addressing the issues of aging and obsolete housing facilities, the needs of current students, the relationship between academic goals and student living, and increasing enrollment numbers. A number of trends in residence hall design and construction have been identified in annual surveys and by design professionals that bare mention.

Many colleges and universities are focused on strengthening the relationship between academics and student housing, often referred to as “living and learning” environments. As such, the historical precedent of the “residential college” where learning occurs inside and outside the classroom has become increasingly popular. This goal is being accomplished through increased attention to the physical relationship of housing facilities to the rest of the campus and, in some cases, by bringing classrooms, faculty offices, and event spaces to the residence halls themselves.¹⁵

The classic residence hall arrangement—double-loaded corridors, double rooms, and gang bathrooms—is no longer preferred by most college students. As a result, many

institutions are adopting the suite-style arrangements with private or semi-private bathrooms.¹⁶ Although air-conditioning is provided in 91% of new residence halls, this percentage seems to be on the decline over the past five years. Carpeting in student rooms also appears to be less popular¹⁷ in response to maintenance and allergy concerns.

Students living in residence halls have greater access to public amenities such as ATM machines, lounges, fitness centers, dining facilities, classroom spaces, and laundry facilities within their buildings. Interestingly, changing technologies, and student access to them, have resulted in a decline of TV rooms, study spaces, and computer labs.¹⁸ The average amount of space per student (often referred to as space per student bed) has increased to more than 300 square feet. The number of beds provided in residence hall buildings varies widely with an average of around 300. Public institutions tend to build larger facilities and private institutions tend to build smaller facilities.¹⁹

With more space, more amenities, and more variety of room types, it should come as no surprise that residence halls built today are more expensive than ever before. Over the past decade, the cost per bed has risen from \$25,000 to over \$69,000.²⁰ Many colleges and universities are exploring ways to pay for these more expensive projects through partnerships with organizations outside the institutions themselves. In addition, schools are attempting to increase occupancy in residence halls during the summer months.²¹ Amid pressures from the off-campus housing market, institutions have taken an interest in enticing students to stay in or return to campus housing by offering what students want²² and by treating them as paying tenants.²³

Sustainable design features are being incorporated into many residence hall facilities in response to institutional climate change commitments, utility consumption, and student comfort. Common green considerations include materials and finishes, energy saving lighting and climate control, water saving fixtures, less air-conditioning, and more natural ventilation.²⁴

3.4. The Evolution of Residence Halls at the University of Oregon

The Early Years

The University of Oregon was founded in 1876 on a 10 acre site about one half mile east of the center of Eugene City (later renamed Eugene). Deady Hall was the first and only building on campus during the early years of the university. Students lived off campus in boarding houses, with private families, or “batched” alone or with a roommate in very modest accommodations. It was not long before Eugene City, a community of about 2,000 people, was unable to provide accommodations for the growing number of students attending the university. Temporary accommodations were built in the basement of Villard Hall during the early 1890s.²⁵

The new Dormitory Building (later renamed Friendly Hall) was built in 1893. The three-story, brick structure was divided into a north wing for men and south wing for women. It contained 40 rooms for 90 students. Students paid for their board, but not for the room itself.²⁶ The building housed both men and women for only its first year after which time it became an all-male dormitory.²⁷ Later additions and renovations added reception rooms, a dining facility, library space, classrooms, and additional student



Figure 3.1: Friendly Hall, University of Oregon

rooms. In 1932 the building was converted from a dormitory to classroom and alumni activity space.²⁸ (See Figure 3.1)

The Mary Spiller House dormitory was built in 1908 to house 20 women and was razed in 1952.²⁹

Hendricks Hall and Susan Campbell Hall were completed in 1918 and 1921 respectively to house 112 women each. The buildings, designed by architects Lawrence and Holford, were built as part of a larger women's dormitory quadrangle that was never completed. Each brick, Georgian-style, dormitory was subdivided into four vertical row houses containing suites for four women.³⁰ Both dormitories were converted to office space in the 1960s and early 1970s.

The Men's Dormitory (later renamed Straub Hall) was built in 1928. The four-story, brick and stucco, Georgian-style building was also designed by architects Lawrence and Holford.³¹ It was located south of 13th Avenue, but east of University Street in an area that would later include many of the university's residence halls.

Similar to Hendricks and Susan Campbell before it, The Men's Dormitory was divided into six separate units, each with its own dining facility and common space, with a total capacity of 300 students. The building was renovated in 1975 to become the Psychology Department.³² (See Figure 3.2)



Figure 3.2: Men's Dormitory (later Straub Hall),
University of Oregon

All of the dormitories built prior to World War II, with the exception of Mary Spiller Hall, are still standing, but are no longer used for student housing on campus.

Post World War II

In the two decades following World War II, the University of Oregon constructed five new residence halls. These buildings differed dramatically from their predecessors on campus because of their modernist-style designs, larger student capacities, double occupancy rooms, and double-loaded corridor layouts.

Carson Hall, designed by the architecture firm Lawrence, Tucker, and Wallman, was completed in 1949. The five-story brick building has an attached dining facility. The Earl Hall Complex, designed by Church, Newberry, and Roehr, was completed in 1955. (See Figure 3.3) This four-story brick building is attached to the back of the existing Men's Dormitory and is subdivided into small groups of student rooms. The Walton Complex, designed by Church, Newberry, Roehr, and Schuette, followed in 1958. Ten three-story brick and curtain wall wings are arranged around central courtyard and common spaces.³³ The Hamilton Hall Complex, designed by Church, Newberry, Roehr, and Schuette, was



Figure 3.3: Carson Hall, University of Oregon

completed in 1962. Ten four-story brick and curtain wall wings are arranged around a series of dining facilities. The Bean Hall Complex, designed by Wilmsen, Endicott, and Unthank, was completed in 1963. The three-story, brick and concrete complex consists of two wings arranged around open courtyards.³⁴

During the 1970s and 1980s, the university purchased two off-campus buildings to be used as residence halls. Riley Hall was one of these buildings and serves as one of two field study locations in this thesis. (See Chapter 4 for a full description of the facility) Barnhard Hall (originally University Inn), designed by Pratt, Henderson, and Box, was completed in 1968 and purchased in 1975.³⁵ The eight-story, cast-in-place concrete tower includes a dining facility.³⁶

In 2006, the University of Oregon opened the first new residence hall constructed on campus in 43 years. The Living and Learning Center (LLC), designed by Zimmer Gunsul Frasca, is comprised of two four-story, brick buildings separated by an outdoor lawn. The buildings were designed to provide larger student rooms and aimed to support the university's educational mission to be a residential campus where living and learning are integrated. Classrooms, dining facilities, a performance space, meeting rooms, and offices are located within the buildings. The LLC South building is one of two field study locations in this thesis. (See Chapter 4 for a full description of the building)³⁷

Current Status of University Housing

The University of Oregon currently has 3,501 student beds in eight residence hall buildings. Approximately 85% of freshman and 5-6% of upperclassman undergraduate students live in campus residence halls. In addition, the university has 447 apartment units and 77 single-family houses serve as married student and family housing.³⁸

Campus residence halls total 990,542 gross square feet, 646,035 net assignable square feet, and have a net assignable to gross square footage ratio, or mean building

efficiency, of 0.65. Combined residence hall and family housing square footage totals 1,447,876 gross square feet, 996, 221 net assignable square feet, and have a net assignable to gross square footage ratio, or mean building efficiency, of 0.69. The total space owned (on and off-campus) by the University of Oregon is 6,132,208 gross square feet.³⁹ Thus, of the total square footage of building space at the university, housing facilities account for 24% and residence halls account for 16%. (See Figure 3.4)

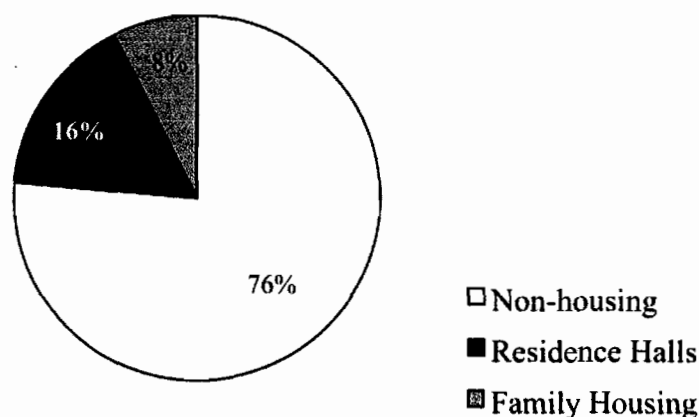


Figure 3.4: Gross square footage of campus buildings

In 2007 Anderson Strickler, LLC (a consultancy firm specializing in housing and campus real estate) completed the “Housing Strategic Plan Phase 2” for the University of Oregon. The plan consists of three components: a set of objectives and goals, an analysis of existing buildings and housing market conditions, and a plan to implement changes over a ten-year period.

The existing conditions and market analysis component of the plan identified several obstacles that the university faces with regard to student housing. First, all but one of the existing residence hall buildings is over 40 years old and in need of renovation

or replacement. Second, the university lacks diversity in housing options that other peer institutions offer. For example, most of the residence halls consist of double occupancy rooms with shared bathrooms on each floor. Suite and apartment style accommodations are needed. Third, there is a large “un-met” demand for university housing. However, many students willing to live on-campus are looking for more privacy, amenities, space, and layout options than are currently offered.

To address these issues, the strategic plan recommends the following: increasing available student bed capacity⁴⁰ by nearly 40%, renovating 1/3 of existing student beds, replacing 2/3 of existing student beds, and adding 1,600 new student beds. In addition, the plan recommends that the university entice sophomore, junior, and senior undergraduate students to live on campus by offering a wider variety of housing options. Increasing the number of students living on campus will allow the university to meet the Carnegie Classification for “Primarily Residential” status⁴¹, which requires that 25-49% undergraduates in degree programs live on campus⁴². Many of the university’s peer institutions currently hold this designation. The development cost of the implementation plan is estimated to be \$448 million.⁴³

A new residence hall is currently in the planning stages and is expected to be located east of Agate Street near the existing Bean Complex. This new residence hall facility will include nearly 500 student beds.⁴⁴

A post-occupancy evaluation (POE) of the LLC Complex was conducted in Spring 2009, two years after initial student occupancy, in an effort to better inform the planning of the new east campus residence hall. The study used an online survey and

focus groups to assess student, faculty, and staff satisfaction with the buildings. In addition, utility data was collected and analyzed. Of the 2,383 current and past users of the complex, 205 surveys were returned, resulting in an 8.6% response rate. Two gift card prizes were offered as an incentive for taking the survey. Results of the study reveal that the three most important building characteristics for the users are the size and flexibility of student rooms; the lounge and study spaces; and the DUX Bistro dining facility. The top three building characteristics that users would change are noisiness (sound transmission and hard materials); menu options and hours for the dining facility; and student restrooms (proximity to student rooms and the performance of fixtures). In addition, LLC resident respondents give high ratings to the natural daylighting, electric lighting, and room size. More than half of the resident respondents give favorable ratings to window shading devices, heating/cooling, and ventilation. In general, building users do not appear to be dissatisfied with the thermal comfort conditions in the complex. Energy usage over an 18 month period was calculated to be about 9% less than energy models developed during the design of the complex, but the survey did not ask students directly about energy use.⁴⁵

3.5. Summary

Over its long history, student housing at colleges and universities has changed dramatically from the primitive barracks of medieval Europe to luxury urban residence hall towers with panoramic views and long lists of amenities. Nevertheless, the age-old “residential college” concept appears alive and well at 21st century colleges and

universities. Institutions recognize that student housing serves both functional and educational needs and, as a result, the presence of student housing on campuses appears secure.

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CHAPTER IV

RESEARCH METHODS

4.1. Introduction

This chapter describes the research methods, study locations, equipment, and measurement protocol used to investigate thermal comfort and energy consumption in two student residence halls of different vintages at the University of Oregon. In addition, the data processing procedure is presented whereby survey, thermal, and utility data are sorted, cleaned, and, in some cases, coded in preparation for descriptive and inferential analyses using spreadsheets and statistical software.

The research methodology of this thesis relies heavily on the “dominant-less dominant design” as defined by Groat and Wang:

The insertion of one type of research design within the framework of a distinctly different research design. The advantage of this design is that the overall coherence of the study is easy to maintain, as it is vested in the dominant research design. The less dominant research design is then used to provide a particular aspect of the study with greater depth and/or validity.¹

Occupant surveys are employed as the *dominant* data collection method and focus on the building users’ perceptions and actions within their residence halls with respect to thermal comfort and energy consumption. The *less-dominant* data collection methods were physical measurement of thermal conditions within the residence halls and the collection of utility data from the university. The *less-dominant* methods seek to add

balance and richness to the occupant survey component of the study, but inherently occupy a secondary supporting role.

4.2. Eugene, Oregon

Eugene, Oregon is located in the Pacific Northwest region of the United States at approximately 44°02' N latitude and 123°06' W longitude (Figure 4.1). The city lies at the southern extreme of the Willamette River Valley approximately 400 feet above sea level, 65 miles east of the Pacific coastline, and 120 miles south of Portland, Oregon. Eugene falls within the temperate climate zone of the U.S.² Winter weather conditions are mild, wet, and overcast. Summer weather conditions are warm, dry, and sunny. Rainfall averages 30-40 inches annually.³ A diurnal temperature swing of 20-30° F between the early morning and the late afternoon occurs throughout the year.



Figure 4.1: Map of the United States showing the geographic location of Eugene, OR.

Eugene has 4,676 heating degree days (HDD) and 259 cooling degree days (CDD).⁴ Lechner notes that “areas with less than 500 CDDs per year are characterized by mild summers and little need for mechanical cooling.”⁵

4.3. Residence Hall Study Locations

Of the eight residence halls at the University of Oregon, Riley Hall and the Living and Learning Center South (henceforth LLC South) were selected as study locations for this thesis project. These buildings were chosen because of their difference in age, similar square footages and occupancy, and lack of dining facilities that consume large amounts of energy.

Riley Hall

Riley Hall is located at the southeast corner of 11th Avenue and Patterson Street approximately five blocks from the University of Oregon campus. Originally named Marian Hall, Riley Hall, designed by the Wilmsen, Endicott, and Unthank, was completed in 1963 by Sacred Heart General Hospital to house 150 nursing students.⁶



Figure 4.2: Riley Hall, University of Oregon

Marian Hall was purchased by Northwest Christian College in 1971 to house male students.⁷ In 1987, the University of Oregon purchased the building to satisfy a student

housing shortage on campus.⁸ (See Table 4.1 for information related to space allocations and efficiencies)

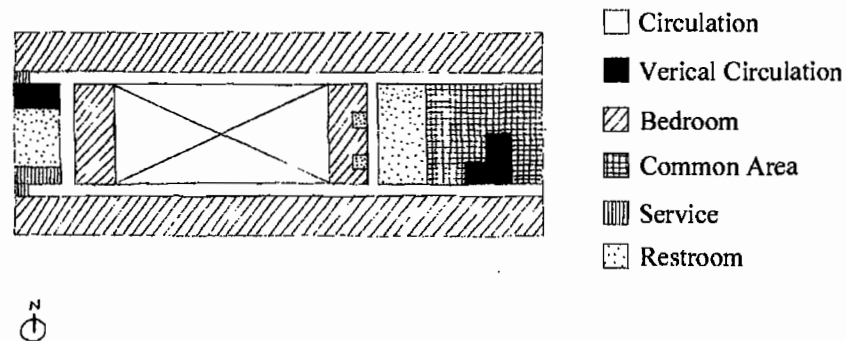


Figure 4.3: Riley Hall upper floor program diagram

The three-story facility is rectangular in plan with a central open courtyard toward the west end of the building. The first floor consists of lobby and lounge spaces as well as rooms for guests and visiting professors. The second and third floors are identical and include a large student lounge space. The majority of student rooms are arranged along two long and narrow (less than 4'-0" wide) east-west corridors (Figure 4.3). There are operable windows along the portions of the corridor adjacent the open courtyard space. The second and third floors of the long north and south facades have a concrete egg-crate design with horizontal and vertical fins protruding 32" from the plane of the windows. This egg-crate feature serves a solar shading function on the south façade. (See Appendices C and D)

The hydronic heating and domestic hot water systems at Riley Hall are powered by steam provided by the local utility company. All student rooms have simple thermostats to adjust the temperature according to numbered settings 1-5. The building

control system performs a minimal function within the building compared with the system in place at LLC South. There is no air-conditioning in Riley Hall.⁹

LLC South

LLC South is located on University of Oregon campus. The building faces E. 15th Street to the south, LLC North to the north, the Earl Hall Complex to the west, and the Walton Complex to the east.



Figure 4.4: LLC South, University of Oregon

The Living and Learning Center, designed by Zimmer Gunsul Frasca Partnership (ZGF), was completed in 2006 to house 387 students¹⁰ in two distinct buildings connected by an underground tunnel.¹¹ LLC South has a capacity of 164 students. See Table 4.1 for information related to space allocations and efficiencies.

The four-story facility is “C” shaped in plan with the short wings oriented north-south containing stair towers. The first floor consists of a series of public spaces

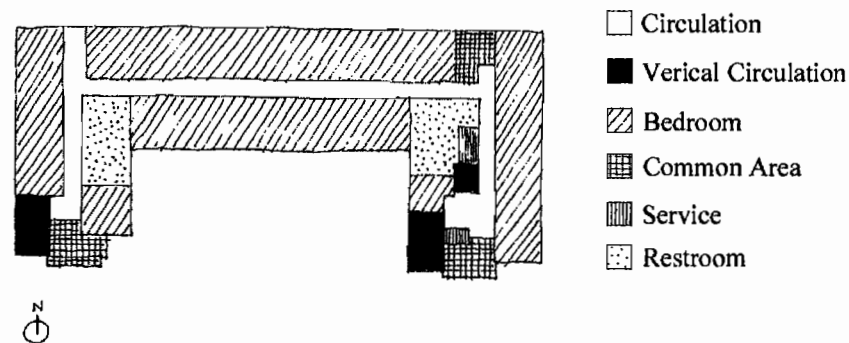


Figure 4.5: LLC South upper floor program diagram

accessible to the larger university community including a large performance room, a living room, and an unconditioned porch space. In addition there are seven student rooms and an apartment suite for the Housing Coordinator. The second, third, and fourth floors are identical and include student rooms along broad (5'-4" wide) double loaded corridors. There are two small student lounges and one laundry room per floor. (See Figure 4.5) The exterior of the building is brick with punched window and door openings and corrugated sheet metal at the fourth floor below the roof overhangs. The facility has a standing-seam metal hip roof. The south façade has fixed metal shading elements above windows. (See Appendices C and D)

The hydronic heating and domestic hot water systems at LLC South are powered by the campus steam system. All student rooms have thermostats that can be used to adjust the temperature set-points within a range of 70°F +/- 2°F. The building control system enables facilities managers to manually adjust temperature set-points in specific rooms. The system can operate in an economy mode if senses that it is taking too long for the space to heat-up, which might indicate an open window. There is no air-

conditioning in the building except for in the large Performance Room on the first floor. Temperature set-points in common spaces, corridors, and stairwells are set 2-8°F lower than in student rooms.¹² Plug loads for student bedrooms are separately metered on each floor. The design intent was to install a “dashboard” in the building lobbies to show real-time energy consumption and to facilitate student energy competitions. However, the system was never fully implemented. The submeters are not regularly read for building energy analysis purposes.

Table 4.1: Residence hall space allocation information.

Space Information		Riley Hall ¹³	LLC South ¹⁴
Gross Square Footage (GSF)		42,719	48,748
Net Assignable Square Footage (NASF)		22,355	26,280
Total Net Square Footage (NSF)		34,036	41,432
Student Bedroom Net Square Footage (SF)		11,636	18,075
Building Efficiency Ratio (NASF/GSF)		0.52	0.54
Space Factor (GSF/NASF)		1.91	1.85
Number of Students Housed		143	165
Number of Student Rooms	Double	70	77
	Single	10	11
Average Square Footage of Student Bedrooms (SF)	Double	163	215
	Single	88	139
Typical Ceiling Heights (Feet-Inches)	1 st Floor	8'-5"	15'-0"
	2 nd Floor	8'-5"	9'-10"
	3 rd Floor	8'-5"	9'-10"
	4 th Floor	NA	9'-10"

4.4. Survey Instrument

Survey Design

An occupant survey was the dominant research method used in this study because it facilitated the collection of data related to student perceptions, behaviors, and actions within residence hall living environments. Furthermore, surveys have been widely used as research instruments in thermal comfort, energy consumption, and residence hall studies as noted in Chapter 2.

The compartmentalized layout of residence hall buildings poses serious challenges to the accepted thermal comfort data collection methods, as described by Nicol and Humphreys, in which the researcher surveys occupants while thermal measurements are made simultaneously.¹⁵ It is impossible to survey a significant percentage of the occupants living in each building in an effective, efficient, and unintrusive manner if surveys are administered two at a time in standard double-occupancy rooms. For this reason, an online survey was utilized that enabled occupants to respond at their leisure over a two-week period. Online surveys have been used in many recent residence hall studies including research by Devlin et al.¹⁶ and Petersen et al.¹⁷ The online survey was created using the website [surveymonkey.com](https://www.surveymonkey.com). A monthly subscription account was purchased, which allowed for an expanded range of design and data collection options.

The survey was comprised of an introduction and consent page, instructions, 29 questions on 12 pages, an opportunity to be entered in an incentive prize drawing, and a concluding thank you page with contact information. Where possible, multiple questions

were located on a single page, which eliminated the problem of having to view more than 30 separate pages. (See Appendix A)

Questions were designed to be concise, specific, and brief to minimize respondent confusion and misunderstanding. The majority of questions were “closed-ended”: answer choices were exhaustive, mutually exclusive, and only one selection was possible. In many cases an “other” option was provided so that respondents could type-in their own answer as well. Respondents were generally asked about thoughts or behaviors within the past week to avoid unreliable answers that result from recalling experiences that are beyond recent memory. The question design and format was intended to produce data that could be statistically analyzed at a later date.¹⁸ In general, more important and complicated questions were placed at the beginning and basic demographics questions were placed at the end. The rationale for this question order is that respondents tire as they get further into the survey and demographic questions are often easier to answer than questions that use scales or require thinking.

Survey questions were divided into five parts that responded directly to thermal comfort and energy consumption issues within residence halls:

1. Your Thoughts or Opinions About Your Room
2. Your Routines and Behaviors in Your Residence Hall Room
3. Your Residence Hall Common Areas
4. Your Overall Residence Hall Experience
5. Demographics

The questions in Parts 1-4 primarily used a 5-point Likert Scale answer format that ranged from minimum to maximum (left to right respectively), for example: never, rarely, sometimes, often, always. The answers to these questions produce an ordinal level of measurement. The demographics questions in Part 5 primarily used a multiple-choice format that produced a nominal level of measurement.

Sample

Purposive or convenience sampling methods were used in the selection of survey subjects. Although purposive sampling methods place limits on the extent to which survey responses can be extended to a larger population, limited access to student populations and residence hall buildings made using random sampling methods unfeasible for this study. However, there is little reason to believe that the distribution of student occupants in Riley Hall and LLC South are significantly different than in other residence hall buildings on campus. A detailed summary of the sample demographics is provided in Chapter 5.

Survey Pretest

A pretest of the survey research instrument was conducted from October 24-30, 2009 after the Human Subjects Research Protocol Application had been approved, but before the official survey period began on November 2, 2009. The pretest participants were primarily undergraduate students living in University of Oregon housing who did not live in Riley Hall or LLC South. The occupant survey was edited slightly to remove

information related to the incentive prize drawing (no incentive was offered for the pretest), and to remove any information specific to Riley Hall or LLC South that may be confusing to students not living in those buildings. Three questions were added that allowed respondents to offer comments related to how long the survey took to complete, any confusing or unclear aspects of the survey, and any suggested improvements that could be made. A unique URL web-link that could be easily typed into a web browser was created and printed on small business cards. Approximately 30 students were approached on two separate days in the residence hall area of campus. Students were given a business card with the URL to the survey and asked if they could spare 5-10 minutes to assist with the pretest exercise. The majority of students agreed, but very few took the pretest right away. Two undergraduate architecture students were asked to assist with the recruitment effort. After six days, nine responses were received. Feedback from the pretest indicated that more than half of the respondents completed the survey in about 5 minutes, that the only confusion was related to the wording of several scale answer choices, and that one question referenced an incorrect question number. Revisions were made to the occupant survey based on the pretest feedback.

Recruitment Method

The methods used to recruit survey participants were intended to accomplish two objectives: to maximize the number of responses received from the students living in each residence hall, and to be as unintrusive as possible to occupants living in the

buildings. These stipulations meant that large numbers of participants had to be recruited without actually asking students to take the survey in person or through e-mail.

Printed fliers were used as the primary recruitment method. Color fliers with tear-away tabs were posted in corridors and common spaces and black and white fliers were placed underneath student room doors. In addition, the residence hall staff sent one e-mail to distribution lists for Riley Hall and LLC South announcing the survey period and incentive prize. (See Appendix B)

Survey Period

The online survey, which ran for two weeks, was launched on November 2, 2009. A customized online URL weblink was created to enable respondents to easily access the survey page. The online survey was closed on November 16, 2009.

4.5. Thermal Measurements

Data Collection Method

Six factors, or parameters, affect thermal comfort conditions in buildings: air temperature, relative humidity, air movement, radiant temperature, metabolic rate, and clothing insulation.¹⁹ Strict thermal comfort studies customarily measure the first three factors with instruments and calculate the later three factors from measurements and questionnaire data. The six parameters are then compared with occupant responses to questions related to their thermal comfort at the time the measurements were made. This

procedure is most effective when large numbers of occupants can be surveyed in a single space and at one or several distinct times.

As noted in section 4.4, residence hall buildings present unique challenges to thermal comfort research because of their compartmentalization into large numbers of bedrooms, which house one and two students each. Taking measurements in hundreds of separate student rooms would be prohibitively time consuming and intrusive to students' personal privacy. Therefore, this thesis did not follow a strict thermal comfort study measurement protocol. Instead of the more complex procedure, simple data logging devices were used to measure two thermal factors: air temperature and relative humidity. These measurements were taken in 10 locations over a three-week period.

Measurement Instruments

The measurement instrument chosen to log data was the Onset HOBO[®] U12-012 Data Logger. This device can log data on three internal channels (air temperature, relative humidity, and light intensity). It also has one external channel for accessory devices or sensors. For the purposes of this study, only the two internal channels for air temperature and relative humidity were utilized. The data loggers were set to record one air temperature and one relative humidity (RH) measurement every two minutes. The HOBO[®] U12 was selected because it is lightweight, small, simple to use, and cost effective. For consistency, the HOBO[®] U12 data loggers were used in both indoor and outdoor measurement locations even though the device is primarily intended for indoor use.

The air temperature channel has an accuracy of +/- 0.63°F from 32°F to 122°F and the relative humidity (RH) channel has an accuracy of 2.5% from 10% to 90% RH (typical) with a maximum of 3.5%. The air temperature channel has a resolution of 0.05°F at 77°F and the relative humidity (RH) channel has a resolution of 0.03% RH.

Mounting Locations

The data loggers were mounted in five locations in each building. In LLC South the locations were as follows: student rooms 234, 334, and 403 (all west facing rooms); lounge space 340 (south facing room); and on the exterior of the building at student room 403 (west facing).

Mounting Procedure

Each of the residence halls being investigated required card access to the interior spaces and key access to the student rooms. The housing staff provided access to the buildings on three separate dates and supervised the mounting, checking, and removal of the data logger devices.

One data logger was placed on the exterior of each residence hall. Because the HOBO® U12 data loggers are intended for indoor use, the devices were placed in a box that would protect them from solar radiation and precipitation over the three-week data logging period. A test was performed to determine whether the protective box would have an adverse effect on the accuracy of the temperature and relative humidity measurements. Two data loggers, one within a box and one without a box, were placed

side-by-side on the exterior of a building. They were left for 30 minutes to adjust to the outside temperature and then logged data for a one-hour period. The results showed that the difference in measurements between the two data loggers was 0.25°F and 2.43%RH, within the accuracy range specified by the manufacturer. For consistency, all data loggers were placed in the same box to account for any effect that the box might have on measurement readings.

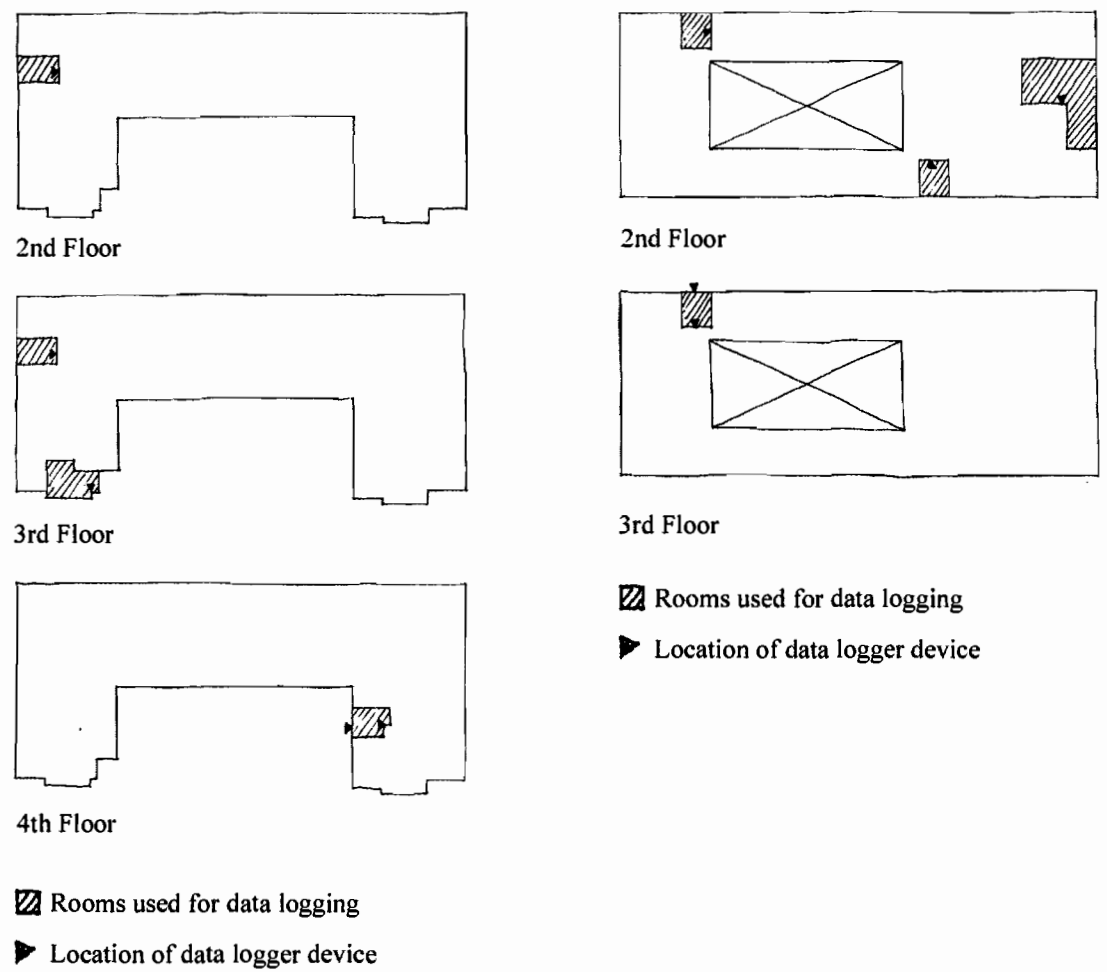


Figure 4.6: Data logger placement locations in LLC South (above left) and Riley Hall (above right)

Each protective box measured approximately 5" x 2.25" x 1". The boxes were unused, cardstock obtained from a fast food restaurant chain that were modified for use in this study. Additional holes were cut to facilitate air movement around the data logger. Each box was coated with clear, adhesive Contact[®] paper to make them more resistant to moisture. Labels were placed on each box that read: "Temperature Experiment in Progress. Please Do Not Disturb." Contact information and the data logger number and placement location were also included on the labels. (See Figure 4.7)

The interior data loggers were mounted inside each box with 3M Command[™] adhesive strips and each box was mounted to the wall surface using 3M Command[™] hook and loop strips. The adhesive strips were easy to use, remained completely adhered to

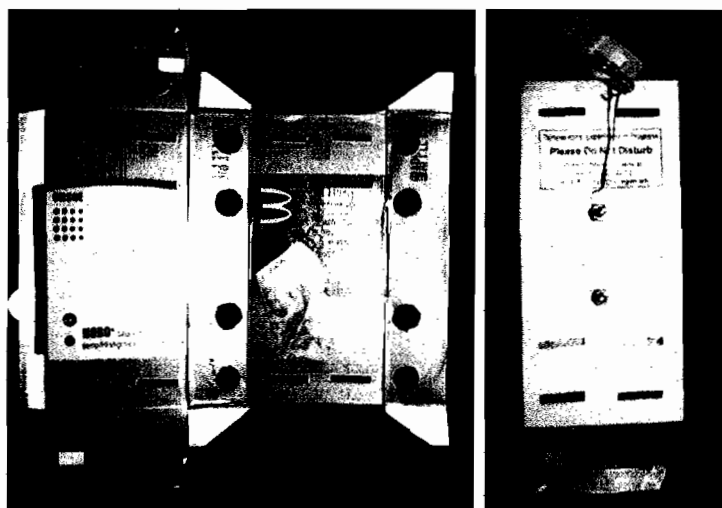


Figure 4.7: Protective boxes for data loggers

walls during data logging, and did not disturb paint finishes when removed. The exterior data loggers used a more robust mounting method. Screws were inserted into the mounting holes on the back of the data loggers. The protective box was then placed over

the screws, and the box and device were secured using nut fasteners. Metal wire was wound around the screws and nuts and then securely attached to a 3M Command™ hook. After the exterior glass window surface was cleaned with isopropyl alcohol swabs to remove dirt that might interfere with adhesion, the assembly was mounted with a 3M Command™ adhesive strip. It should be noted that even in damp and extremely windy conditions, the adhesive strips used for mounting performed exceptionally well. (See Figure 4.7)

The interior data loggers were mounted to walls at least 3.3 feet from the windows and 1.1 meter (43”) above the floor surface in accordance with the ASHRAE Standard 55-2004 specifications for spaces with “sedentary occupants.”²⁰ The exterior data loggers were mounted on window surfaces to ensure adequate protection from wind and precipitation under the eaves and overhangs.

Retrieving Logged Data

Data from each of the 10 data loggers was retrieved once midway through the three-week data collection period to verify that the devices were working properly and had not been moved, vandalized, or stolen. Data was downloaded onto a laptop computer using HOBOWare Pro software without interrupting the ongoing data collection process. All devices were working properly and appear to have been untouched by building occupants.

At the conclusion of the three-week data collection period, the ten data loggers were taken down, the data collection process was stopped, and the data was downloaded

onto a laptop computer using HOBOWare Pro software. The data from each device was then saved in Onset HOBOWare Datafile and Excel spreadsheet formats.

4.6. Utility Data Collection

Utility data was collected from the University of Oregon Department of Utilities and Energy Management^{21 22}. Spreadsheets were provided for monthly steam and electricity consumption for Riley Hall and LLC South since September 2006, the month that the LLC complex was opened. Initial discussions with university utilities personnel revealed that the LLC complex is not submetered for steam usage, but that the north and south buildings are submetered for electricity usage.

Because the LLC North building includes a dining facility and Riley Hall does not, only the submetered electricity data was used rather than the steam data. However, obtaining the submetered electricity data for the south building, independent of the north building, took several months. Furthermore, the consumption figures in the data obtained appeared inaccurate for the size and use of the building. Ultimately, it was determined that the LLC complex is not, in fact, completely submetered for electricity consumption, as was initially assumed, due to complex building metering as well as shared equipment between the north and south halves of the building.

In addition, shortly before the completion of this thesis it became apparent that student room plug loads are submetered for each floor of LLC South. These meters were intended to be used in student energy competitions and to be connected to a “dashboard” in the lobby. The system was never fully implemented and the submeters in place are not

read on a regular basis. Data from these meters indicates only the usage to-date since the building was opened. Nevertheless, because Riley Hall does not meter student room plug loads, a true comparison would not have been possible. However, knowledge of the true metering capabilities would have been a great benefit to this project in the early planning stages.

In short, a true comparison between two buildings of similar size, occupancy, and use was not possible. Nevertheless, the aggregate data for the entire LLC complex is presented in Chapter 5, which describes the relationships between monthly electricity consumption figures and trends in LLC and Riley Hall.

4.7. Data Collection Protocol

The measurement protocol was carefully designed to work within the constraints of a ten-week Fall academic term at the University of Oregon, to be unintrusive to residence hall occupants, and to limit the impact of the study on the busy schedules of housing staff members. As a result of these limitations, the bulk of the data collection was consolidated into a three-week period in late October and early November. The protocol devised for this study is as follows:

1. **Human Subjects Protocol Approval:** The Human Subjects Research Protocol Application was submitted to the Office for the Protection of Human Subjects on September 24, 2009. Several minor changes were requested and the revised protocol was approved on October 19, 2009.

2. **Survey Pretest:** Students living in University Housing other than the LLC South and Riley Hall residence halls were recruited to take a survey pretest. The pretest period was from October 24-30, 2009.
3. **Human Subjects Protocol Modification:** The results of the survey pretest necessitated several minor revisions to the human subjects protocol. The Modifications were submitted and approved on October 30, 2009.
4. **Data Logging:** Data logging devices were mounted in the buildings on October 26, 2009 and logged thermal measurements over a three week period.
5. **Survey Conducted:** The online survey was launched on November 2, 2009 and continued for a two-week period. Students were notified of the survey via e-mail from housing staff and printed fliers.
6. **Data Logger Check:** Data loggers were checked during the second week of the three week thermal measurement period (November 2nd for LLC South and November 5th for Riley Hall) to verify that the devices were operating correctly.
7. **Survey Period Concludes:** The survey period concluded on November 16, 2009. The URL web link to the online survey was disabled and the data was saved in spreadsheet format.
8. **Retrieving Data Loggers:** Data loggers were collected from each residence hall in the days following the end of the survey period. During this third and final visit to each building photographs and several dimensional measurements were taken. The thermal data was saved in spreadsheet format.

9. **Incentive Prizes:** Survey participants who submitted e-mail addresses at the conclusion of the survey were entered in an incentive prize drawing. Four prize winners were chosen from a random drawing. The gift card prizes were given to the housing staff to distribute to the student winners.
10. **Utility data:** Utility data was obtained from the university at the beginning of December.

4.8. Data Processing Procedure

Sorting and Cleaning

This thesis project uses survey data, thermal measurement data, and utility data. The raw, unedited data for these three data sets was accessed through Excel spreadsheet software. The spreadsheets were reformatted to better organize the large quantities of raw data: columns and rows were resized and labeled to better show the information. The data was then cleaned by checking the spreadsheet cells for any mistakes or missing information that may result in errors during the analysis process.²³

The survey data was organized such that each column represents a question and each row represents one respondent's answers to those questions, which results in 103 rows and 27 columns. For ease of use, the questions were entered at the top of each column and the unique identification number for each respondent was shown at the beginning of each row. Next, a new column was created to the right of each question column for data coding purposes. (See Figure 4.8)

Figure 4.8: Survey data spreadsheet.

The thermal measurement data from ten separate spreadsheets were compiled into one master file with each data set organized in a column and each row representing a measurement interval, in this case, two minutes. Similarly, the utility data from three separate files were compiled into one master file with columns representing the consumption by residence hall and year, and each row representing the months.

Coding

Spreadsheet and more advanced statistical software are unable to analyze non-numeric answers to questions. For this reason, the data for each response to each

question must be coded. The process is time-consuming, but relatively simple. A codebook is created whereby each close-ended question choice is given a numeric equivalent. For example, "Male" may be given a "0" and "Female" may be given a "1." Likewise, for questions where answer choices are in a scale, for instance "least important", "important", "most important," each choice would also receive a number, beginning with 1. The codebook serves as a reference for the coding process. The coded data is then meticulously checked for mistakes.²⁴ Answers to open-ended questions, such as the location where respondents have lived for most of their lives, is categorized and coded for further analysis. Other open-ended questions are summarized instead of being coded.

Descriptive Analysis

Spreadsheets are used to perform descriptive analysis on the three data sets. However, the analysis methods vary depending on the characteristics of the data.

Many of the survey questions are in the form of Likert scales, which categorize and rank choices but do not specify an exact distance between the choices. Appropriate descriptive statistics for ordinal measurements were performed on the survey data. These include measures of central tendency, such as mode and medians, and measures of variability, such as range. Frequency distribution tables which provide percentage breakdowns for answer choices, are used to compare percentages of groups, and may be collapsed by simplifying the number of answer choices into larger categories.²⁵

Descriptive statistical analyses of the survey data focuses on describing the

characteristics of the sample and comparing responses to dependent comfort and energy consumption variables with independent variables such as residence hall building. The expectation is that these analysis techniques will enable a large amount of data to be more easily understood in terms of frequencies and trends prior to being analyzed further using more complicated statistical tests.

Thermal measurement and utility data, by contrast, are measured at the interval or higher level where the distance between the numbers is more precise. For this data, additional descriptive statistical methods are available such as means (averages) and standard deviations (distribution of scores around the mean).²⁶ Mean temperatures and relative humidities were calculated using spreadsheets to distill the 150,000 data measurements into a format that can be easily described in tables and plotted on ASHRAE Comfort Zone charts. The objective of this analysis is to describe the range of thermal conditions that exist in residence hall spaces and to assess whether these conditions satisfy recognized standards for indoor comfort. Spreadsheets were also used to perform calculations on utility data, such as using electricity measurements to describe other energy metrics such as kWh/SF/year. The goal of this analysis is to be able to compare the electricity consumption in two residence hall buildings with benchmarks for the building-type.

Inferential Analysis

Survey data was entered into SPSS 13.0 Student Version, a statistical software package, for further analysis. Data measured at an ordinal level of measurement was

limited to non-parametric statistical testing methods. These are recognized to be less robust than parametric tests, but they are also considered “distribution-free” tests because they do not require that the data approach a normal distribution curve, such as if the distribution of data is positively or negatively skewed from the mean.²⁷ This thesis used a non-parametric analysis technique: group comparisons using the Mann Whitney U test.

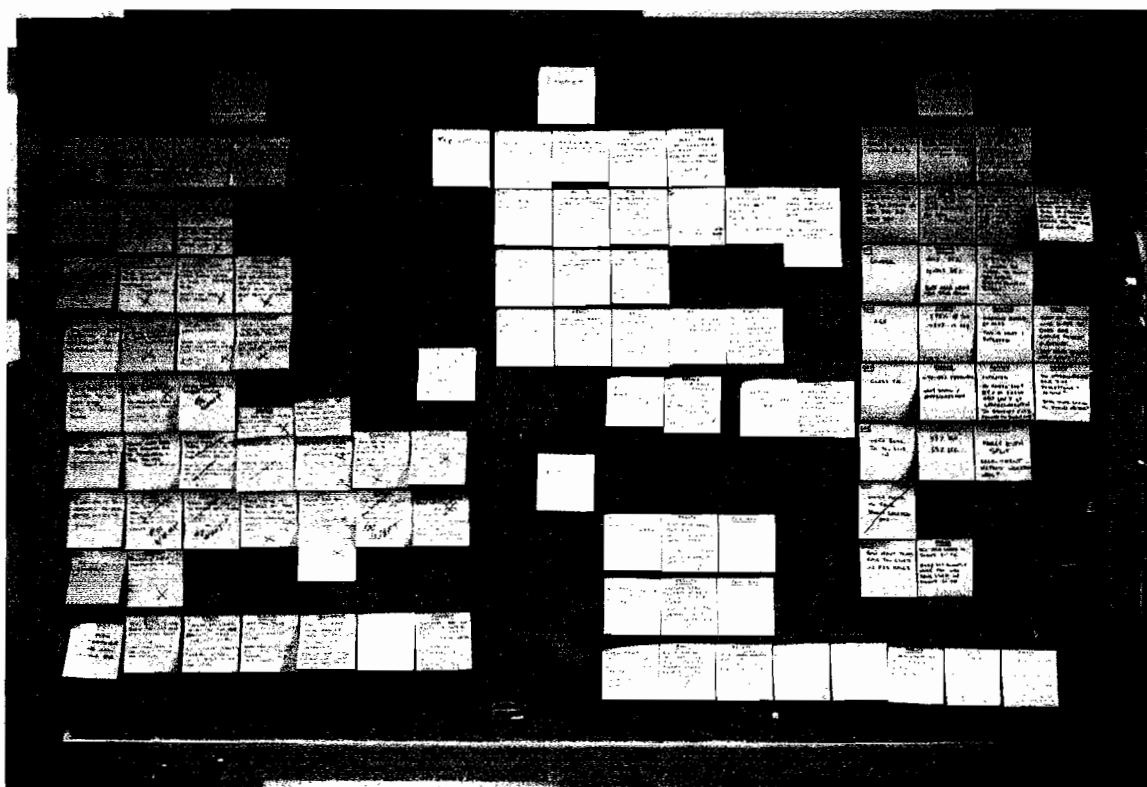


Figure 4.9: Survey data and results were organized using colored Post-it Notes on a blackboard.

Group comparisons were performed using the Mann Whitney U test to determine if significant differences exist between two groups, the independent variables, and each dependent variable. Mann Whitney U is the non-parametric version of the Independent t-

Test. Because means are not used with ordinal data, the test ranks scores and then compares the ranks. The results are reported as a z-score (the distance from the mean beyond which the significant population lies) and a p value (statistical significance). One tailed hypotheses (where the direction of the relationship is predicted) and two-tailed hypotheses can be tested using Mann Whitney U. This thesis uses one-tailed hypotheses.²⁸ Finally, a confidence level is set prior to running the test, which is the risk that the researcher is willing to take that he or she will be wrong. In this case the confidence level, also called alpha, is set at 0.05, a 5% chance of being wrong. If the p -value of less than or equal to 0.05, then the null hypothesis (N_0), which states that no significant difference exists between the groups, can be rejected. In essence, this is the validation of a hypotheses statement.²⁹ The Mann Whitney U test analysis method allows the thesis hypotheses to be tested: that building age has significant impacts on comfort and energy consumption in residence halls.

4.9. Summary

This chapter described the research methodology used in a study of thermal comfort and energy consumption in residence halls. The geographic location and buildings being investigated was presented. Three data collection methods, the research instruments, and the equipment used were described. Finally, the data collection protocol was outlined and the data analysis method was introduced.

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CHAPTER V

RESULTS AND ANALYSIS

5.1. Introduction

This chapter describes the results and analysis of three sets of data collected through surveys, thermal measurements, and utility information. First, the survey sample demographics are presented, which includes information related to gender, age, class standing, years that students have lived in residence halls, and locations where respondents have lived for most of their lives. Then, the results of descriptive and inferential statistical analysis related to comfort and energy perceptions and actions are presented. Lastly, the results and analysis of thermal measurement and utility data are presented.

5.2. Demographic Information

This section describes the general characteristics of the survey sample in the two residence halls under investigation. Table 5.1 summarizes the sample demographics. In addition, a brief synopsis of this information is provided below.

Sample Size and Response Rate

There were 143 students living in Riley Hall and 165 students living in LLC South at the time of this study. There were 47 survey responses in Riley Hall resulting in a 33% response rate. There were 54 survey responses in LLC South resulting in a 33% response rate. Two survey respondents did not specify their residence hall building. The sample size was 103 respondents out of a possible 308 occupants, which results in an overall response rate of over 33%. Given the limited opportunities for subject recruitment mentioned in Chapter 4, the sample size and response rate were better than expected.

Table 5.1: Summary of respondent demographic information.

Number of Responses (n=)		All	Riley Hall	LLC South
Gender	Male	35	16	19
	Female	66	31	35
Age (years)	Under 18	2	1	1
	18	75	34	41
	19	22	10	12
	20	2	2	0
Class Standing	Freshman	95	42	53
	Sophomore	3	2	1
	Junior	2	2	0
	Senior	1	1	0
Years Living in Residence Halls (years)	0-1	96	43	53
	1-2	3	2	1
	2-3	2	2	0
	3-4	0	0	0
	4+	0	0	0

Gender

The gender distribution of residents within the buildings was as follows: Riley Hall, 56.4% male/43.6% female; LLC South, 40.6% male/59.4% female. Of the 101 responses to the survey question regarding gender, 65% were Female and 35% were Male. The breakdown of male and female responses by gender in both buildings were nearly identical, even though greater numbers of male students live in Riley Hall and greater numbers of female students live in LLC South. Nevertheless, the survey results clearly show that more women responded than men. Several questions arose from these gender distribution results. Are women more likely to respond to surveys than men? Why did greater percentages of women respond in Riley Hall despite more males living in the building? The answers to these questions are difficult to answer. A brief literature search was conducted for research related to the role of gender in survey response rates. Few studies were found, and the extent to which gender plays a role in survey response appears inconclusive. One study looked specifically at gender and online survey response rates in an academic setting with faculty rather than student respondents. The results revealed that gender did not play a critical role in response rates and that other sample demographics appear to have a greater influence.¹

Age and Class Standing

Information related to age and class standing is necessary for an accurate description of student respondents in residence halls. Of the 101 responses to the survey question regarding age, 74% were 18 years old, 22% were 19 years old, 2% were under

18 years old, and 2% were 20 years old. There were no responses for students over 20 years old. Riley Hall has slightly higher percentages of students age 19 or 20, however the difference between the two buildings is minimal. Of the 101 responses to the survey question regarding class standing, 94% were Freshman, 3% were Sophomores, 2% were Juniors, and 1% were Seniors. Approximately 10% of respondents in Riley Hall are Sophomore class standing or higher compared with 2% in LLC South. The results indicate that the respondents in Riley Hall and LLC South are young and predominantly of Freshman class standing, which was expected given that approximately 85% of students living in University of Oregon student housing are first-year Freshmen.

Years Respondents Have Lived in Residence Halls

Of the 101 responses to the survey question related to the number of years students have lived in residence halls, 95% say one year or less, 3% say 1-2 years, and 2% say 2-3 years. There were no responses for 3-4 years or 4+ years. Riley Hall has a slightly higher percentage of respondents who have lived in residence halls for more than one year. The results indicate that most of the students living in Riley Hall and LLC South have lived in residence hall environments for a short period of time, which was expected given the small percentage of students that remain living on campus after their first year in residence halls.

It should be noted that the survey was conducted approximately one month after the beginning of the academic year and that the majority of the respondents had lived in residence hall buildings for a very short period of time. Surveying Freshmen students

later in the school year, for instance during Spring Term, may have given respondents more time to acclimate to their living environments. Thus, respondent perceptions and actions may have been different.

Where Respondents Have Lived for Most of Their Lives

An open-ended question asked respondents to provide the city, state, and country where they have lived for most of their lives. The specific locations were then grouped into five geographic regions of the United States: West/Pacific, West/Mountain, Mid-West, Northeast, and South.

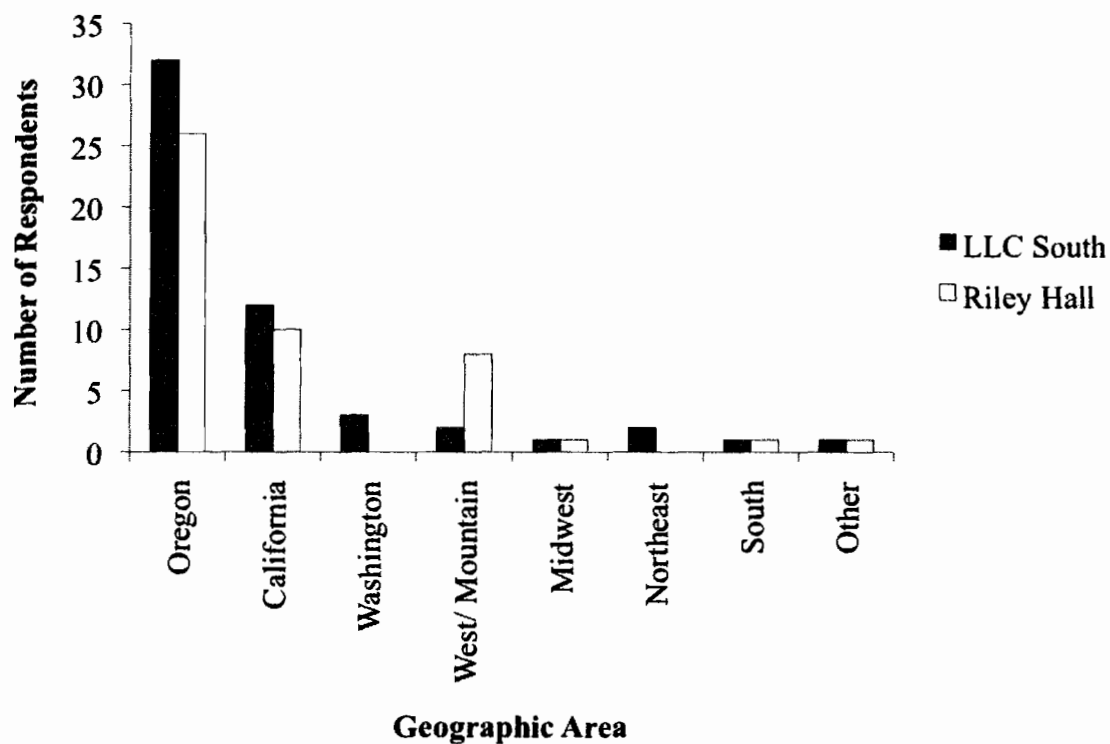


Figure 5.1: Locations where respondents have lived for most of their lives.

Due to the large number of responses in the West/Pacific region, this group was further subdivided into states (California, Oregon, and Washington). An “Other” category was created for two responses that listed Hawaii and France, areas outside of the continental United States.

Responses by geographic region and residence hall are shown in Figure 5.1. The 101 responses resulted in the following overall percentage distribution: 57% Oregon, 22% California, 10% West/Mountain, 3% Washington, 2% Mid-west, 2% Northeast, 2% South, and 2% “Other.” These findings indicate that over 80% of respondents have spent most of their lives in the West/Pacific region of the United States, which is not surprising for a state university in Oregon. It is likely that respondent perceptions and actions were influenced, at least to some degree, by their familiarity with the climate conditions in the Pacific Northwest region of the United States.

5.3. Occupant Behavior

Perceptions of Comfort

Survey results indicate positive perceptions of comfort overall, yet also highlight specific conditions that appear to interfere with occupant satisfaction. Respondents appear to perceive temperature to more frequently impact comfort than air movement or humidity. The only significant differences between LLC South and Riley Hall relate to two specific thermal parameters, hot and humid, and one use of their living space, sleeping.

When asked about control of temperature in their environment, 75% of respondents say they have “some” control or better. (See Figure 5.2) Respondents in LLC South indicate greater perceived control than respondents in Riley Hall. When asked how often roommates agree on comfort conditions, more than 95% say “often” or better. Again, respondents in LLC South indicate greater frequency than respondents in Riley Hall.

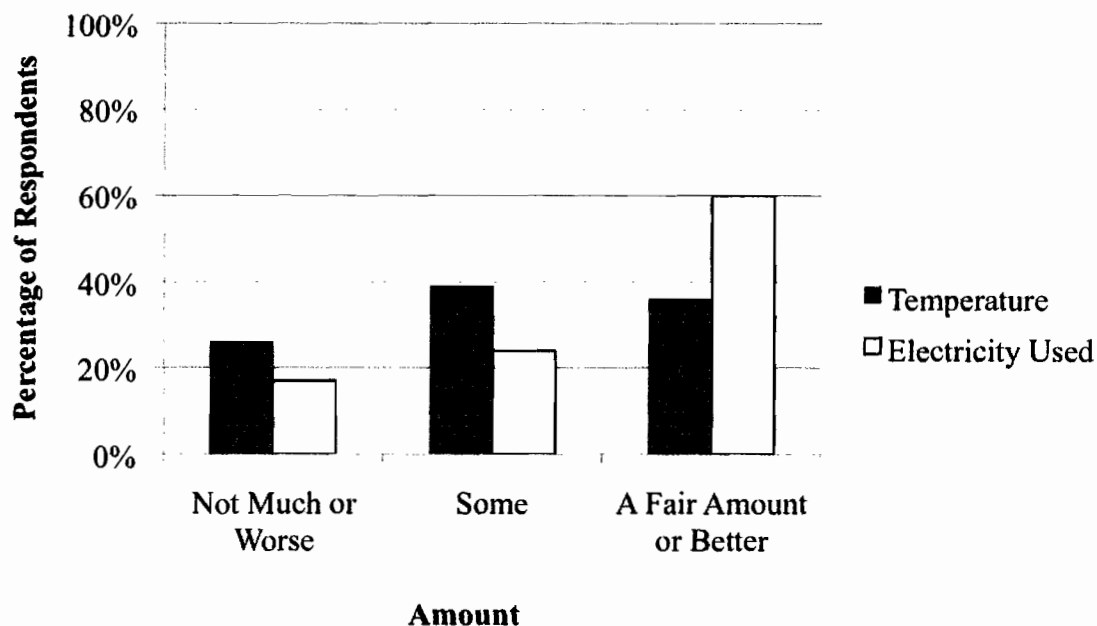


Figure 5.2: Respondent perceptions of control over the temperature and the electricity used in their living environments.

When asked to rate comfort in residence halls with comfort in other places respondents have lived, the results are less positive. More than 80% say “the same” or worse with the distribution skewed toward the more negative choices for both LLC South and Riley Hall. Respondents in LLC South seem to perceive slightly better comfort conditions than respondents in Riley Hall.

It appears that common spaces in both residence halls are well used with 66% of the respondents saying they spend “some” time or more. The distribution of responses is similar for LLC South and Riley Hall. When asked to compare thermal comfort in common spaces with their bedrooms, the distribution of responses resembles a normal curve with only slightly more responses falling to the negative side of the scale and with few responses at the extremes. Riley Hall respondents appear to have more positive perceptions of comfort in common areas, which is supported by physical thermal measurements that show a range of thermal conditions within the lounge space (L 208) that falls completely within the ASHRAE Comfort Zone. (See Appendix E)

The results of group comparisons using Mann Whitney U tests did not indicate significant differences between LLC South and Riley Hall on dependent variables related to perception of comfort. There are, however, three exceptions. When asked how often environmental conditions are hot, cold, stuffy, drafty, damp/humid, and dry, LLC South respondents perceive “hot” and “damp/humid” significantly less often. Thermal measurements support the perception of less frequent “hot” conditions, but do not support the perception of less frequent “damp/humid” conditions. Also, when asked how often temperature prevents respondents from completing school work, sleeping, relaxing, and socializing, LLC South respondents perceive less frequent disruption of “sleeping” as a result of temperature. These limited findings support the hypothesis that LLC residents perceive their conditions to be more comfortable. (See Table 5.2 for the details of the Mann Whitney U tests)

Table 5.2: Results from group comparisons of comfort perceptions.
* indicates a significant p -value.

Dependent Variable		Independent Variables					Test Statistics	
		n=	Riley Hall		LLC South		Z-score	p-value
			n	Mean Rank	n	Mean Rank		
Frequency of environmental conditions	Hot	100	47	42.97	54	57.18	-2.581	0.005*
	Damp/Humid	99	47	44.15	52	55.29	-2.171	0.015*
Frequency of temperature preventing activities	Sleeping	101	47	44.80	54	56.40	-2.080	0.019*

Comfort Actions

Survey results indicate that respondents frequently perceive that their adaptive actions within their residence hall rooms improve comfort conditions. The percentage of respondents answering “rarely” or “never” is 2% in both LLC South and Riley Hall. By contrast, the percentage of respondents answering “often” or “always” is 77% for LLC South and 73% for Riley Hall.

Weather appears to have a strong impact on occupant comfort. Results show that 55% of the respondents perceive weather to “often” or “always” influence comfort actions. These results suggest that future studies further investigate the relationship between weather and occupant comfort by asking additional survey questions related to this issue. For instance, investigators may ask respondents: How often do you obtain information about weather conditions? How do you obtain it?

When asked to comment on the frequency of taking specific adaptive actions when temperatures are too hot or cold, results vary widely. The most frequent action is opening or closing windows, to which 87% of respondents choose “often” or “always.” Riley Hall appears to employ this action more frequently than LLC South, however there is not a statistically significant difference between the groups. This finding is supported by thermal measurements that indicate rooms with operable windows in Riley Hall have cooler mean temperatures than the lounge space that does not have operable windows. Other frequent actions include: opening or closing doors, changing clothing, and eating or drinking something cold. The least frequent action is complaining to a Resident Assistant or the housing office, although there is a significant difference between LLC South and Riley Hall with this variable. This finding was surprising given the fact that University

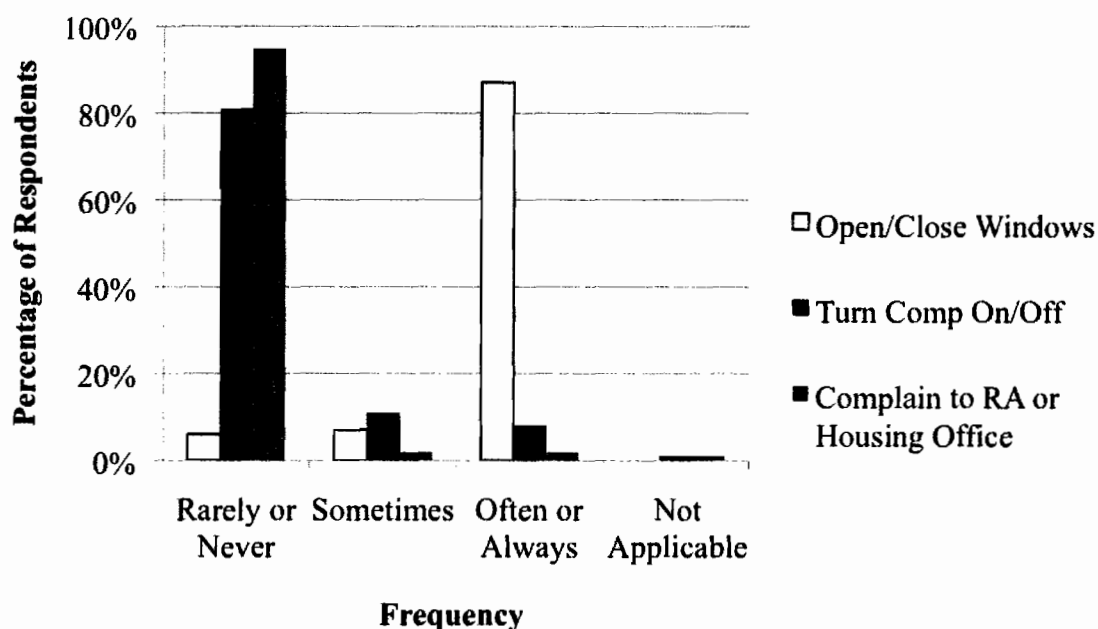


Figure 5.3: Frequency of respondent actions when conditions are uncomfortable.

Housing staff are able to adjust specific temperature set-points in LLC South student rooms based on student feedback. (See Figure 5.3) Respondents in LLC South appear to be unaware of this opportunity and, instead, open windows to lower indoor temperatures in their rooms. Other less frequent actions include: adjusting heater thermostat; turning off the lights, electronic equipment, and computers; or leaving the residence hall room. Taking no action is a strategy that respondents appear to take less frequently in Riley Hall than in LLC South, which lends validity to the hypothesis that residents in newer buildings interact with their environment less than residents of older buildings. However, a statistically significant difference between the groups was not found.

Results of group comparisons using Mann Whitney U tests indicate that the only significant difference between LLC South and Riley Hall on the 15 adaptive action dependent variables tested was complaining to an RA. (See Table 5.3) The least significant difference between groups is related to turning off lights, indicating that both LLC South and Riley Hall share similar perceptions that this action does not improve comfort.

When other independent variables are used for group comparisons with the adaptive action dependent variables, the results are more statistically significant. For example, older students who have lived in residence halls for more than one year appear to take significantly more frequent adaptive actions to regulate comfort, particularly with respect to complaining. Similarly, gender appears to have a statistically significant effect on actions. For example, men open windows more often than women, but women close windows, turn off equipment, turn off lights, and adjust the thermostats more often than

men. These findings indicate that factors other than building age have an influence on actions that occupants take to maintain comfort.

Table 5.3: Results from group comparisons of comfort actions.
* indicates a significant *p*-value.

Dependent Variable		Independent Variables					Test Statistics	
		n=	Riley Hall		LLC South		Z-score	<i>p</i> -value
			n	Mean Rank	n	Mean Rank		
Actions when temperatures are too hot or cold	Complain	101	47	46.49	54	56.18	-2.391	0.009*
	Turn Lights On/Off	101	47	51.45	54	50.61	-.150	0.441

Energy Consumption

Survey findings describe a wide variety and a large number of electronic devices being used in residence hall rooms. Respondents in Riley Hall appear to have slightly fewer electronic devices than in LLC South, perhaps as a result of the fact that the average double room size in LLC South is about 32% larger than in Riley Hall. (See Figure 5.4)

Refrigerators appear to be quite prevalent with 95% of respondents having either a small or large device. University Housing requires that mini-refrigerators be a maximum of 4 cubic feet.² Energy Star estimates that Energy Star-rated mini refrigerators less than 4 cubic feet use approximately 250-340 kWh of electricity per year.³ Thus, a double-occupancy student room with two larger-size mini refrigerators could use more than 500 kWh of power during the 8-9 month school year. Institutions

may see significant energy savings in residence halls simply by limiting the number of refrigerators per room to one and having students unplug the devices over winter and spring breaks. Institutions, such as Tulane University, have evaluated excessive electricity consumption from student room appliances, which may provide valuable lessons for other schools.⁴

Lamps also appear to be popular with 66% of respondents having two or more devices. However, Riley Hall has significantly fewer lamps than LLC South. (See Table 5.4) This finding is surprising given that LLC South is a newer building and considering the

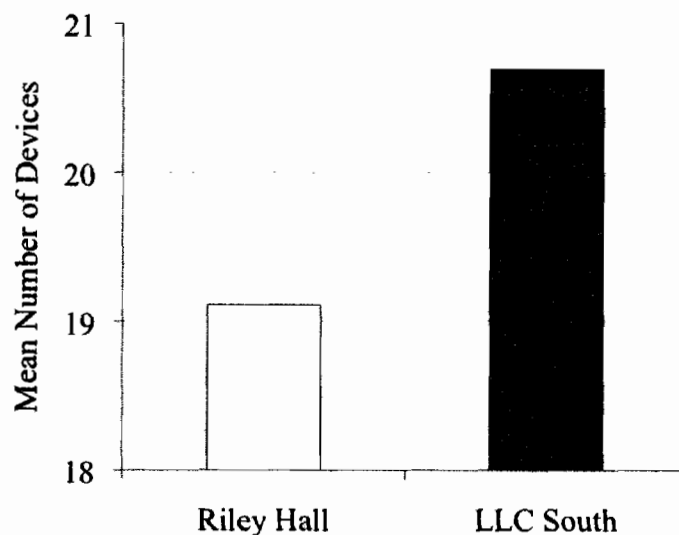


Figure 5.4: Electronic equipment in student rooms.

survey data from the 2009 POE in which occupants gave high ratings to natural daylighting and the building electric lighting. The larger sizes of the rooms in LLC South coupled with the fact that many rooms face the north orientation may necessitate

additional occupant-provided lighting devices. Findings suggest that institutions should recommend the appropriate types and numbers of plug-in lamps that students bring to their residence halls.

Riley Hall respondents have significantly fewer laptop computers when compared with LLC South. (See Table 5.4) However, very few desktop computers were reported. This finding was not surprising given the affordability of laptop computers coupled with their convenience. However, it is also widely recognized that laptop computers use less electricity and generate less heat than their desktop counterparts. Energy Star estimates that a 30 watt notebook computer uses 50-80% less electricity than a 120 watt desktop computer.⁵ The shift from desktop to laptop computer use on campuses may actually have had a positive impact on student energy consumption, despite the fact that occupants seem to rarely turn these devices off to save electricity.

Table 5.4: Results from group comparisons of electronic devices in student rooms. * indicates a significant *p*-value.

Dependent Variable		Independent Variables					Test Statistics	
		n=	Riley Hall		LLC South		Z-score	<i>p</i> -value
			n	Mean Rank	n	Mean Rank		
Number of electronic devices in student rooms	Lamps	100	47	34.10	53	65.05	-5.718	0.000*
	Laptop Computers	101	47	45.21	54	56.04	-2.788	0.003*
	Printers	101	47	46.12	54	55.25	-1.758	0.040*

Perceptions of Energy Consumption

Survey results indicate that respondents perceive opportunities to control electricity consumption in their residence hall rooms. (See Figure 5.2) Riley Hall residents appear to perceive slightly better control over electricity usage than LLC South residents, although the difference between the groups is not statistically significant. Nevertheless, the finding appears to refute the hypothesis that students in older buildings perceive fewer opportunities for energy conservation.

When students were asked about the importance of saving electricity within their living space, the distribution approaches a normal curve that is skewed slightly toward greater importance, with the highest percentage of responses stating “important” and the lowest percentage of responses at the positive and negative extremes. Respondents in Riley Hall seem to perceive saving electricity as less important when compared with LLC South, which contradicts the hypothesis that residents in older buildings interact with their living environments to a greater degree than residents in newer buildings.

Respondents appear to perceive fewer opportunities to control electricity consumption in common spaces with 73% choosing “not much” or “none at all.” The distribution of responses is similar for LLC South and Riley Hall, although LLC South appears to perceive slightly better control than Riley Hall. This finding supports the hypothesis that students in older buildings perceive less control over their environment, particularly because the lounges in Riley Hall do not have operable windows. Students in both Riley Hall and LLC South are unable to adjust thermostats in the lounge spaces, but

other survey results reveal that adjusting thermostats in student rooms is less favored as a means of environmental control than simply opening or closing the windows.

Energy Actions

Survey results indicate that 84% of survey respondents take actions to conserve electricity in their rooms “sometimes” or more frequently. The distribution of responses resembles a normal curve that is skewed slightly toward greater frequency with the largest percentage of responses for “sometimes” and with the smallest percentage of response occurring at the positive and negative extremes. A significant difference was not found between the Riley Hall and LLC South groups.

The frequency of actions taken by respondents when leaving their rooms varies widely. Turning off the lights is the most common action and is taken by 75% of respondents. There is little difference between responses in LLC South and Riley Hall for this variable. This finding suggests that the habit of turning lights off is well ingrained in young colleges student, perhaps as a result of their experiences living with their families while growing-up. Adjusting the thermostat is, by contrast, the least common action with 78% of respondents choosing “rarely” or “never.” By contrast, it seems that fewer students are accustomed to using a thermostat and that they do not fully comprehend the relationship between thermostat temperatures and energy consumption. (See Figure 5.5) Greater percentages of respondents appear to close rather than open windows when leaving the room. However, over 60% of respondents rarely or never leave a fan running.

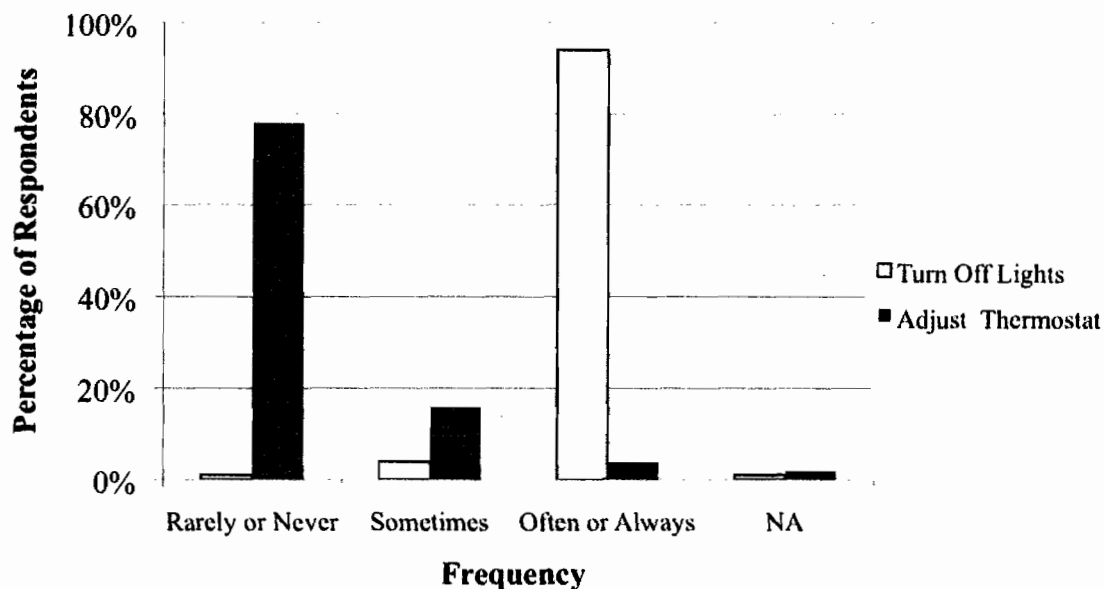


Figure 5.5: Frequency of respondent actions to conserve electricity when leaving the room.

Survey data also shows that only 42% of respondents often or always turn their computers off when leaving the room and that 58% of respondents often or always charge their computer batteries. These findings indicate that, although respondents appear to care about conserving electricity, there are certain actions that they are unwilling to take. Setting computers to go into sleep mode may help to conserve energy, but devices will still draw several watts of power unless they are turned-off or, in some cases, unplugged.

A group comparison of energy actions between the two residence halls did not yield statistically significant differences. However, group comparisons using respondent gender, rather than the buildings that they live in, shows that women close windows, turn off lights, and turn off computers significantly more often than men. Men open windows significantly more often than women. (See Table 5.5) These findings indicate that the

gender of occupants may influence actions to save electricity in ways that the building age does not.

Table 5.5: Results from group comparisons of actions when leaving residence hall room. * indicates a significant p -value.

Dependent Variable		Independent Variables					Test Statistics	
		n=	Male		Female		Z-score	p-value
			n	Mean Rank	n	Mean Rank		
Frequency of actions taken when leaving residence hall room	Open Windows	101	35	61.64	66	45.36	-2.728	0.006*
	Close Windows	99	33	38.58	66	55.71	-2.904	0.004*
	Turn Off Lights	101	35	42.51	66	55.50	-2.814	0.005*
	Turn Off Computer	101	35	40.54	66	56.55	-2.695	0.007*

When asked how important learning new resource conservation strategies would be in helping to save energy, 43% of respondents choose “slightly important” or “not important.” The distribution of responses resembles a normal curve that is skewed toward less important. LLC South appears to find learning new strategies slightly more important than Riley Hall, but the difference between the groups is not statistically significant. These findings, when viewed in light of the general perception that saving energy is important, suggest that students think that they know how to save energy already, and that learning new methods would not significantly impact their current energy-use practices.

Other Survey Findings

Survey results show clearly that respondents in LLC South and Riley Hall have little awareness of campus programs, campaigns, or initiatives that promote resource conservation in student housing. This finding is surprising given the University of Oregon's reputation for environmental consciousness. Of the eight groups listed, 60-90% of respondents chose "not at all aware." (See Figure 5.6) Riley Hall appears to have slightly better awareness than LLC South, although the difference between groups is not

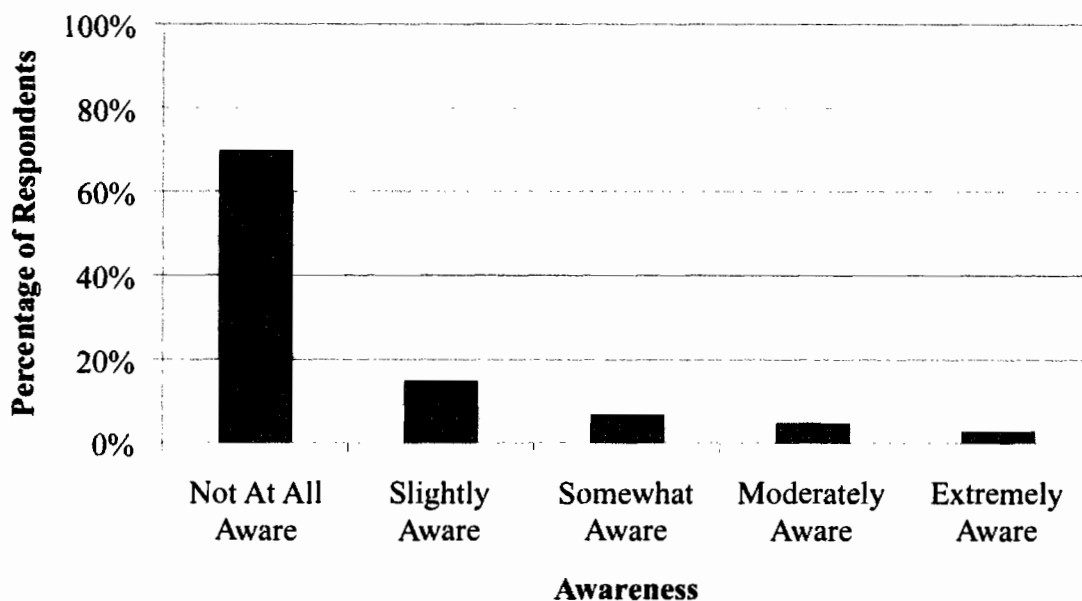


Figure 5.6: Respondent awareness of campus programs, campaigns, or initiatives that promote resource conservation in student housing.

statistically significant. In a follow-up question, nearly 90% of respondents claim to not participate in any of the campus groups listed.

A group comparison using the number of years that students have lived in residence halls as the independent variable yields better results. Respondents that have

lived in student housing for over one year have significantly greater awareness of resource conservation groups. Since the majority of students at the University of Oregon only live in student housing for one year, generally freshman year, these findings indicate that greater emphasis must be given to promoting awareness early-on, perhaps during student summer orientation sessions, if students are to take advantage of conservation strategies while living in student housing.

In addition, survey data shows that Riley Hall respondents spend a significantly greater amount of time in their residence hall during the late evening when compared with LLC South. This finding suggests that students living in residence halls off-campus may be less likely to leave their building at certain times of day due to the lack of other campus buildings in close proximity. Leaving the residence hall building in response to thermal discomfort appears to be an adaptive opportunity that students living in on-campus residence halls take greater advantage of, which is supported by the comfort action survey data described above.

5.4. Physical Measurements

Thermal Measurements

The three week temperature and relative humidity data logging period generated 30,240 data points for each of the ten measurement locations. A statistical summary of the thermal measurements is provided in Table 5.6. Findings indicate lower mean indoor temperatures and higher mean indoor relative humidities in LLC South when compared with Riley Hall. The mean temperature for the four spaces measured in each building

indicate a 5.66°F difference between LLC South and Riley Hall. This thermal data is supported by survey data, which indicates that uncomfortably “cold” conditions are more prevalent than discomfort caused by other thermal factors in LLC South. In addition, the mean relative humidity for the four spaces measured in each building indicates a 3.46% difference between LLC South and Riley Hall. This thermal data is also supported by the survey data, which indicates that “dry” environmental conditions are more prevalent in Riley Hall.

The mean minimum and maximum temperatures for the four spaces measured in each building indicate that Riley Hall has a range of 9.9°F and LLC South has a range of 11.8°F. It is surprising that the older building maintains a narrower range of temperatures than the newer building, which is better insulated and has more sophisticated mechanical systems and controls.

The range of temperatures found in the Riley Hall lounge space, SR 208, is 4.1°F, which suggests that the building systems are, indeed, maintaining an even narrower range of conditions than the mean range describes. The Riley Hall lounge is the only space in either of the two buildings measured that does not have operable windows. Physical observation inside and outside the residence halls reveals that operable windows in the two buildings are used frequently by occupants.

It appears that the differences in temperature ranges in spaces with operable windows and the lounge space in Riley Hall that does not have operable windows are due to occupant thermal preferences rather than to building systems and controls. This assumption is supported by survey data, which suggests that opening and closing

windows is a primary adaptive strategy that students in both buildings frequently utilize to adjust their comfort and to expand the range of conditions in their rooms.

The solar orientation of rooms also appears to impact mean, maximum, and minimum temperatures in the spaces measured, particularly in Riley Hall where approximately half of the student rooms face south. For example conditions in room #281 are warmer, and half of the rooms face north, for example conditions in room #241 and room #341, are cooler. A survey question asked respondents to provide the orientation of their room, but it proved challenging to accurately categorize responses according to room orientation due to the open-ended nature of the question and a lack of respondent awareness of the orientation of their rooms.

Table 5.6: Statistical summary of residence hall indoor and outdoor climate data. Measurement location abbreviations: SR=student room, L=lounge, OD=outdoor.

Residence Hall		Riley Hall					LLC South				
Measurement Location		SR 218	SR 241	SR 341	L 208	OD	SR 234	SR 334	SR 403	L 340	OD
Air Temperature (°F)	Mean	75.3	72.1	72.6	74.8	53.3	70.8	68.7	67.2	65.5	50.1
	Std Dev	1.5	2.2	1.5	0.8	4.3	1.3	1.9	1.6	2.1	6.5
	Max	79.7	76.3	76.2	77.1	68.6	74.4	71.8	71.8	73.9	81.0
	Min	72.1	63.2	61.6	73.0	42.0	61.6	62.0	59.6	61.4	38.0
Relative Humidity (%)	Mean	47.3	44.0	43.6	38.1	67.5	43.9	45.7	45.5	51.8	72.9
	Std Dev	3.4	3.8	4.7	4.0	5.5	4.7	5.1	4.7	5.8	9.0
	Max	55.0	54.9	55.7	49.6	79.2	56.6	60.6	59.4	67.3	85.0
	Min	34.5	35.4	31.9	30.8	48.0	34.5	36.0	37.3	40.1	35.3

Comparing Measurements to the ASHRAE Comfort Zone

The minimum and maximum mean temperatures and relative humidities for each of the four indoor spaces measured in LLC South and Riley Hall were averaged to determine an overall mean indoor temperature and relative humidity for each building. These indoor means are: LLC South, minimum 61.2°F, 37.0% RH and maximum 72.96°F, 61.0% RH; Riley Hall, minimum 67.5°F, 33.1% RH and maximum 77.3°F, 53.8% RH. These mean minimum and maximum conditions were plotted on modified psychrometric charts to show the relationship between the conditions in each building and the ASHRAE Comfort Zone⁶. Lines are used to connect the minimum and maximum points on the graph, which illustrates the range of conditions. (See Figure 5.7 and Appendix E)

Results from the Comfort Zone comparison indicate that the conditions measured in Riley Hall fall within the Winter Comfort Zone boundaries to a greater extent than do the conditions measured in LLC South. Conditions in Riley Hall extend only slightly beyond the boundaries of the Comfort Zone at the lower (cooler) and upper (warmer) ends of the range. By contrast, the majority of the conditions in LLC South fall outside boundaries of the Comfort Zone at the lower (cooler) end of the range only.

This thermal data is supported by survey data, which indicates that conditions that are “too hot” are perceived more frequently in Riley Hall than in LLC South. In addition, survey data indicates that conditions that are “too cold” are perceived less frequently in Riley Hall than in LLC South.

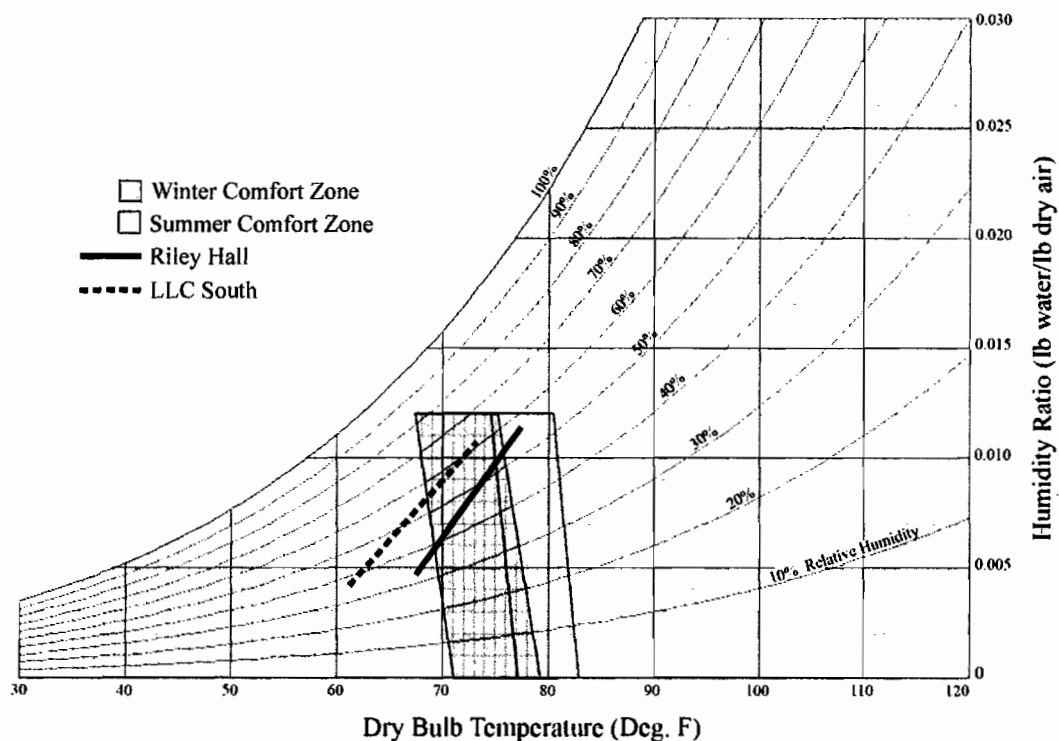


Figure 5.7: Mean minimum and maximum temperatures and relative humidities in relation to the ASHRAE Comfort Zone⁷.

Utility Data

Electricity data obtained through the University of Oregon Department of Utilities and Energy Management describes the aggregate monthly and annual consumption in Riley Hall and the LLC complex (both the North and South buildings). The data reveals variations in consumption from month-to-month that reflect the beginnings and ends of academic terms, summer recesses, and breaks in winter and spring. These findings are consistent with the results of the post-occupancy evaluation conducted in the LLC Complex in 2009.⁸

Riley Hall used 310,960 kWh of electricity from January to December 2009. This annual consumption figure was a 0.7% increase over the 2008 total and a 1.8% increase over the 2007 total. The electricity consumption in 2009 per gross square foot of floor space is 7.3 kWh/SF. LLC used 1,276,954 kWh/SF of electricity from January to December 2009. This annual consumption figure was a 1.4% decrease over the 2008 total and a 3.4% decrease over the 2007 total. The electricity consumption in 2009 per gross square foot of floor space is 10.3 kWh/SF.

When compared with benchmark data from CBECS⁹ and CIBSE¹⁰, which were described in detail in Chapter 2 section 2.5, the annual consumption for Riley Hall is low by approximately 2-2.4 kWh/SF (typical residence halls would be 9.3-9.7 kWh/SF) and the annual consumption for the LLC complex is high by approximately 2.4 kWh/SF (a good practice residence hall would be 7.9 kWh/SF). Benchmark data on residence hall electricity consumption does not distinguish between buildings that are predominantly student rooms with some common lounge space, like Riley Hall, and buildings that are mixed-use residence hall complexes that incorporate dining facilities, classrooms, and faculty offices in addition to student rooms, like the LLC complex. As a result, the differences in electricity consumption in Riley Hall and LLC South is likely due to the differences in the building programs.

Figure 5.8 shows the variation between monthly consumption figures for Riley Hall and the LLC complex for 2009. Peaks and valleys in the graph lines appear to follow the university academic calendar and the seasonal changes. The Winter Term began in early January, a one week spring break occurred in March, the Spring Term

ended in mid-June, the Fall Term began toward the end of September, and the winter break began in mid-December. The peaks in consumption appear to occur during months with no breaks and valleys appear to occur during months with breaks, since students are not occupying the buildings.

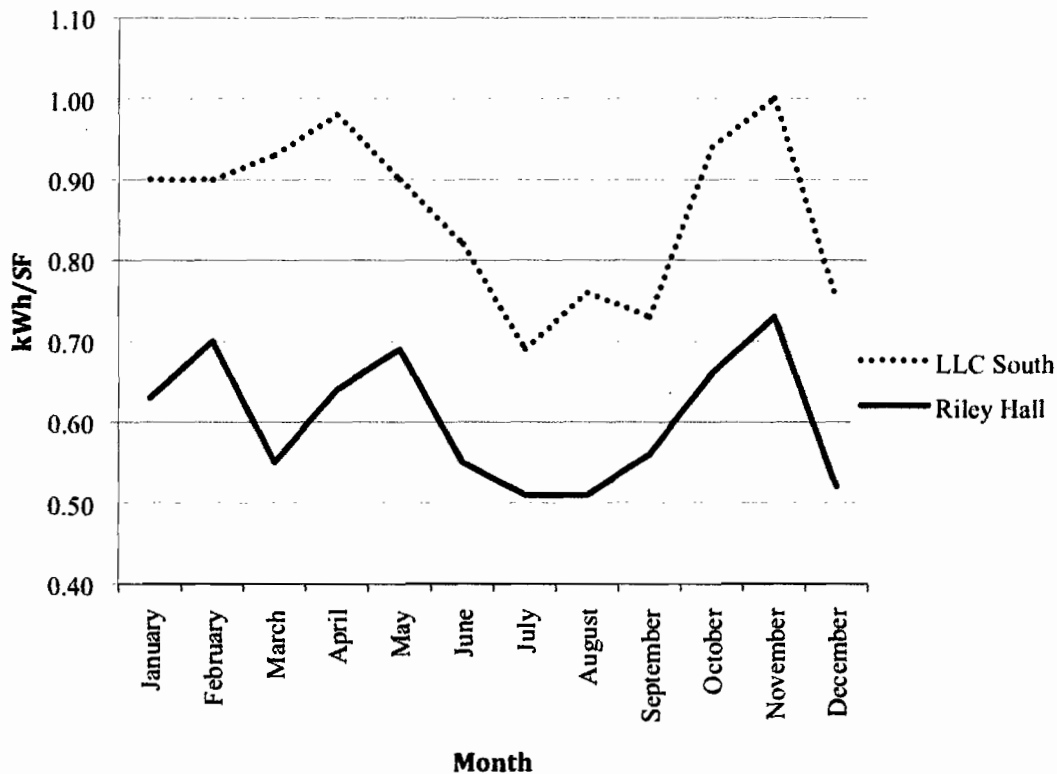


Figure 5.8: Monthly kWh/SF for 2009.

Few students were living in Riley Hall from mid-June to the end of September or during the two week winter break. It seems reasonable to assume that the consumption figures at those times, approximately 0.52 kWh/SF or between 22,000 and 23,000 kWh/month represent non-occupant related energy loads. The month with the highest consumption is November with 31,200 kWh of electricity used. Therefore, the

unoccupied building may be using 25-35% less electricity. By contrast, the LLC Complex houses orientation groups during the summer recess and the dining facility operates 50 weeks per year. The average consumption during the summer months is 85,000 kWh compared with 128,806 kWh during the peak month of January. Therefore, even with summer occupancy and the dining facility in operation, LLC is using 35% less electricity. Energy inefficiencies in the older building are revealed. Nevertheless, the data describes an electricity consumption regime that differs from other building types that operate throughout the year. Therefore, unique opportunities for conserving electricity may exist for institutions during times when buildings are unoccupied or minimally occupied.

5.5. Summary

This chapter presents the results and analysis of survey, thermal measurement, and utility data collected in Riley Hall and LLC South, two residence hall buildings on the University of Oregon campus. Section 5.1 presents survey respondent demographic information. Section 5.2 presents survey response data related to occupant behavior: perceptions of comfort and energy consumption, and comfort and energy consumption actions. Survey findings indicate few statistically significant differences between the response groups in Riley Hall and LLC South, which appear to disprove the project hypotheses. Additional group comparisons with dependent variables such as gender, age, and class standing appear to generate more significant results. Section 5.3 presents thermal data, which indicate that the range of conditions found in Riley Hall fall within

the boundaries of the ASHRAE Comfort Zone to a greater extent than the range of conditions found in LLC South. Section 5.4 presents utility data, which reveals that electricity consumption in Riley Hall falls below, and LLC falls above, benchmarks for residence hall building types. Results indicate that the academic calendar has a significant impact on electricity consumption in residence halls and that new buildings such as LLC appear to conserve more electricity at times of low occupancy than older buildings such as Riley Hall.

5.6. Endnotes

- ¹ Smith, William G. "Does Gender Influence Online Survey Participation?: A Record-linkage Analysis of University Faculty Online Survey Response Behavior." *Educational Resources Information Center*. Jun 2008. Web. 17 Feb 2010.
- ² University of Oregon. "Residence Halls: What to Bring." *University Housing*. University of Oregon. Web. 7 Mar 2010.
- ³ Energy Star. "Products: Refrigerators & Freezers." *Energy Star*. U.S. Environmental Protection Agency & U.S. Department of Energy. Web. 16 Feb 2010.
- ⁴ Kahler, Shelley. "The Ripple Effect: How One Dorm Room Can Affect a University's Energy Use." *International Journal of Sustainability in Higher Education*. 4. 3 (2003): 230-238. Print.
- ⁵ Energy Star. "Labeling Energy Efficient Office Equipment: Desktop vs Laptop." *EU-Energy Star*. U.S. Environmental Protection Agency & The European Commission. Web. 16 Feb 2010.
- ⁶ American Society of Heating, Refrigerating and Air-Conditioning Engineers. *Thermal Environmental Conditions for Human Occupancy*. ASHRAE standard. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2004. 4-5, 22. Print.
- ⁷ Ibid.

- ⁸ Bill, Martina. *Living and Learning Center-Post-Occupancy Evaluation-Final Draft*. University of Oregon Campus Planning and Real Estate, 12 Aug 2009. E-mail. 24 Aug 2009.
- ⁹ United States. "Table C13A: Total Electricity Consumption and Expenditures for All Buildings, 2003." *Commercial Buildings Energy Consumption Survey (CBECS)*. U.S. Energy Information Agency. Unpublished survey data, 2008.
- ¹⁰ Chartered Institution of Building Services Engineers. *Energy Efficiency in Buildings: CIBSE Guide F*. London: CIBSE, 2004. 18-1-18-31. Print.

CHAPTER VI

DISCUSSION

6.1. Introduction

This Chapter presents a discussion of research findings in relation to the initial research questions posed in Chapter 1. General attitudes and trends revealed through the data analysis process are addressed. In addition, the results of this thesis investigation are discussed with respect to expected outcomes.

6.2. What Are the Ranges of Perceptions and Behaviors that Residence Hall Occupants Have in Response to Thermal Comfort and Energy Consumption in Their Living Environments?

Survey findings in two residence halls indicate wide ranges of occupant perceptions and actions with regard to thermal comfort and electricity consumption. In general, respondents perceive that they have control over their comfort and the energy usage in their rooms. In addition, a majority of respondents perceive saving energy to be important, even though few participate in campus groups that promote resource conservation and awareness. Survey responses also reveal that occupants feel that their actions to adjust their comfort are effective. Certain actions, such as opening windows, are more widely employed by respondents. However, actions such as adjusting thermostats or reporting discomfort are less popular. The results of this study indicate a

wider range of occupant perceptions than occupant actions with respect to comfort and energy consumption in residence halls. For instance, respondents in both buildings consistently choose a small number of preferred actions from larger lists of possible actions.

6.3. What Role Does Building Age Play in the Occupant Perceptions of Thermal Comfort and Energy Consumption in Residence Halls?

An analysis of survey data suggests that building age does not play a significant role in occupant perceptions of comfort and energy consumption in the two residence halls investigated. This finding contradicts the first research hypothesis and reveals similar ranges of behavior in the older and newer buildings. The majority of the variables tested reveal no statistically significant differences between the groups. Nevertheless, significant differences are found among a small number of specific variables. For example: LLC South is uncomfortably hot and temperature impacts sleeping activities less often than in Riley Hall; Riley Hall is humid more often than LLC South; and residents in LLC South have more lamps, printers, and laptop computers.

6.4. What Role Does Building Age Play in the Ways That Occupants Interact with Thermal Comfort Conditions and Energy Consumption in Residence Halls?

Based on data collection and analysis in Riley Hall and LLC South, there is little evidence that significant differences exist in the ways that occupants interact with older and newer buildings. This finding contradicts the second research hypothesis and

suggests that behavior in older and newer residence halls is similar. Survey and thermal measurement data indicate that occupants take actions to adjust comfort and to save electricity. Comparisons using other variables, such as gender, age, class standing, and number of years that residents have lived in student housing, reveal greater statistical differences between groups.

6.5. What Are the Ranges of Thermal Conditions Found in Old and New Residence Hall Buildings?

Wide ranges of thermal conditions are found in residence hall spaces with operable windows. In contrast, the lounge space in Riley Hall does not have operable windows and the range of temperatures measured is less than 4°F. Findings suggest that adaptive opportunities, such as operable windows, allow occupants a measure of control over the conditions routinely provided by building mechanical systems. For example, opening or closing windows and doors are more popular strategies than adjusting thermostats or leaving the room according to survey respondents. This suggests that the presence of an adaptive opportunity within a living space does not guarantee that occupants will utilize it to regulate their comfort. In addition, opportunities for occupant control of the environment have an impact on the ranges of conditions found in residence halls.

6.6. What Is the Aggregate Electricity Consumption in Old and New Residence Hall Buildings?

A simple comparison of the aggregate electricity consumption in Riley Hall and LLC South is hindered by the metering differences between the two buildings. Riley Hall has one electricity meter for the building. Determining monthly and annual aggregate electricity consumption is a straightforward exercise. However, the building metering in the LLC Complex makes determining the aggregate electricity consumption more complicated. The north and south buildings of LLC are not completely submetered. In addition, the dining facility in LLC North is not submetered from the residence hall rooms and common spaces, which has a large impact on aggregate electricity consumption. LLC South submeters electrical plugload consumption in student rooms, whereas Riley Hall does not. Furthermore, the university does not record or use the submetered data from LLC South. Consistent metering, and submetering, in residence halls would enable institutions to more easily compare electricity consumption among facilities.

6.7. Summary

This Chapter presents a discussion of research findings within the context of the research questions described in the introduction of this document. The results of survey, thermal, and utility data analyses are summarized and discussed with respect to the problems that form the foundation of this thesis inquiry.

CHAPTER VII

CONCLUSIONS

7.1. Conclusions

The most significant finding of this thesis project is that building age does not appear to play a significant role in occupant perceptions and actions with respect to comfort and electricity consumption in the two residence halls investigated. Although building age, layout, room sizes, personal controls, and building systems differ between the two residence halls studied, occupants share many of the same strategies for adjusting their thermal comfort and for conserving energy.

Comparisons using variables other than building age, such as respondent gender, age, class standing, and years in campus housing, reveal more statistically significant differences between groups.

Thermal data indicates that environmental conditions in Riley Hall fall within the boundaries of the ASHRAE Comfort Zone to a greater extent than in LLC South. In addition, thermal measurements and observations in both buildings reveal that occupants like to open windows, which results in lower temperatures in interior spaces with operable windows and likely contributes to wasted energy. If occupants enjoy the opportunity to open and close windows, it is imperative that mechanical systems are designed to effectively detect these occupant actions in order to help conserve energy. In

addition, it is critical that occupants be made aware of the energy implications of their actions.

Students living in Riley Hall and LLC South appear to be relatively unaware of campus programs, organizations, or initiatives that promote and encourage resource conservation. Survey respondents indicate that saving energy is important to them, yet they are disinterested in learning new conservation strategies or participating in groups that promote resource awareness. The majority of students currently living in residence halls at the University of Oregon will move off-campus after their first year. As a result, it is critical to raise student awareness as early as possible. This could be effectively accomplished at summer student orientation sessions.

Finally, although many universities are adopting strategic plans to replace aged residence hall buildings on their campuses, this study finds that older buildings may provide satisfactory comfort conditions when compared with newer buildings. In addition, occupant perceptions and actions with regard to comfort and energy consumption are not significantly different in older and newer halls. Careful analysis of older residence hall buildings is necessary for institutions to fully understand the performance and long-term value of these facilities.

7.2. Suggestions for Future Research

Research available on comfort and energy consumption in residence halls is limited. Therefore, more research in this area is needed. This study was limited to two buildings on a single university campus in the Pacific Northwest. However, comparative

studies of residence halls on different campuses in different parts of the United States may allow researchers to determine which conditions appear to be unique to specific settings and which conditions appear to be common to populations living in residence hall buildings more generally.

This study was unable to use interviews or focus group techniques, due to limited access to residence hall buildings and student populations. These methods could provide a qualitative perspective on student behavior and preferences that compliment survey, thermal, and utility data.

The majority of sample subjects in this study were young freshmen students that had been living in residence halls for about one month. Future studies should consider surveying students in the Winter or Spring Terms, after they have had a chance to acclimate to their living environments. Also, a study comparing similar size samples of older and younger students may reveal differences in perceptions and actions in residence hall environments that develop over time.

Finally, future research should compare residence halls and off-campus apartments to assess whether student perceptions and actions with respect to comfort and energy consumption differ in these two settings. In particular, students paying a monthly utility bill may be more aware of energy conservation issues than students that do not pay directly for their energy.

APPENDIX A
SURVEY

Energy and Comfort in Residence Halls Survey[Exit This Survey](#)**Introduction**

6%

This survey concerns energy consumption and thermal comfort in student residence halls. You are invited to participate in this study if you are currently living in **Riley Hall** or the **Living and Learning Center South** residence halls at the University of Oregon. You will be asked questions about your thoughts, behaviors, and experiences in your single or shared room as well as in common areas within your residence hall such as lounges, corridors, meeting rooms, and classrooms.

The results of this survey will assist researchers and institutions in improving student housing accommodations. The feedback that you will provide in this survey is very important to us. At the conclusion of the survey, you will have an opportunity to enter your e-mail address in a drawing to win one of four \$50.00 UO Duck Store gift card prizes.

Please Note: Your response to this survey is voluntary. By clicking on the "next" button below you are indicating that you are giving your consent to participate in this study. All information provided will be kept anonymous and confidential. If you have any questions, please contact Thomas Collins, the principal investigator of the study, at 617-721-8713 or at thomasc@uoregon.edu.

[Next](#)

Energy and Comfort in Residence Halls Survey Exit This Survey

Instructions

12%

It should take you about **5 minutes** to answer 29 questions. You may move forward or backward through the questions. However, once you click "submit" at the end of the survey you will be unable to change or resubmit your answers. Click "exit this survey" in the upper right-hand corner of the screen should you choose not to complete the survey at this time. Please choose only one answer for each multiple choice question line unless special instructions are provided next to specific questions. You will be unable to take the survey more than one time.

The terms "thermal comfort" and "energy consumption" will appear throughout this survey. Please keep the following definitions in mind when answering the questions.

Thermal comfort is the combination of air temperature, humidity, air movement, surface temperatures of materials, clothing, and activity that makes you feel comfortable, not too hot and not too cold.

Energy consumption is the use of electricity and other resources for personal devices such as computers and desk lamps and for building services such as heating and lighting.

Energy and Comfort in Residence Halls Survey Exit This Survey

Part 1: Your Thoughts and Opinions About Your Room

19%

In this section, we would like to know your thoughts and opinions about thermal comfort and energy consumption in your residence hall room within the past week.

1. How much control do you have over the temperature in your residence hall room?

None at all Not much Some A fair amount A lot

2. How often are the environmental conditions in your room:

	Always	Often	Sometimes	Rarely	Never
-Hot	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Cold	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Stuffy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Drafty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Humid or Damp	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Dry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Energy and Comfort in Residence Halls Survey

[Exit This Survey](#)

Part 1: Your Comfort and Energy Usage In Your Residence Hall Room

25%

3. How frequently does the temperature in your room prevent you from doing the following activities?

	Always	Often	Sometimes	Rarely	Never
-Completing school work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Sleeping	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Relaxing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Socializing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Other (please type below)					

4. How often do you and your roommate(s) agree that the temperature of your room is comfortable?

- Never
 Rarely
 Sometimes
 Often
 Always
 Not applicable

[Prev](#) [Next](#)

Energy and Comfort in Residence Halls Survey

[Exit This Survey](#)

Part 1: Your Comfort and Energy Usage In Your Residence Hall Room

31%

5. How much control do you have over the electricity being used in your residence hall room?

- None at all
 Not much
 Some
 A fair amount
 A lot

6. How important is it for you to save electricity within your living space?

- Not important
 Slightly important
 Important
 Very important
 Essential

[Prev](#) [Next](#)

Energy and Comfort in Residence Halls Survey

[Exit This Survey](#)

Part 2: Your Routines and Behaviors in Your Residence Hall Room

38%

In this section, we would like to know about your habits and routines in your residence hall room environment within the past week.

7. When the temperature in your room is too hot or cold, how often do you take the following actions?

	Never	Rarely	Sometimes	Often	Always	Not Applicable
-Open or close the windows	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Open or close the door	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Adjust the heater thermostat	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Turn your computer on or off	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Change clothing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Eat or drink something warm or cold	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Turn the lights on or off	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Turn electric equipment on or off	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Turn a fan on or off	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Move to another area of your room	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Leave your room to go to another room or common area	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Leave your residence hall building altogether	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Reduce or increase your activity level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Complain to the RA or housing office	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Take no actions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Other (please type below)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. How frequently do the actions listed above in question 7 improve the comfort conditions in your room?

Never Rarely Sometimes Often Always

9. How often does the weather influence the actions that you take to adjust the comfort conditions in your room?

Never Rarely Sometimes Often Always

[Prev](#) [Next](#)

Energy and Comfort in Residence Halls Survey[Exit This Survey](#)**Part 2: Your Routines and Behaviors in Your Residence Hall Room**

44%

10. When you leave your room, how often do you perform the following tasks?

	Never	Rarely	Sometimes	Often	Always	Not Applicable
-Open the windows	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Close the windows	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Turn off the lights	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Turn off your computer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Charge your computer battery	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Leave a fan running	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Adjust the thermostat or heater controls	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Other (please type below)						

11. How frequently do you take actions to conserve electricity in your room?

Never Rarely Sometimes Often Always

12. How important would learning new resource conservation strategies be in helping you to save more energy in your room?

Not important Slightly important Important Very important Essential

[Prev](#) [Next](#)

[Exit This Survey](#)

Energy and Comfort in Residence Halls Survey

Part 3: Your Residence Hall Common Areas

50%

In this section, we would like to know your thoughts about and behaviors in the common areas of your residence hall within the past week.

13. How much time do you spend in the common areas of your residence hall?

None at all
 Not much
 Some
 A fair amount
 A lot

14. How much control do you have over the consumption of electricity in the common areas of your residence hall?

None at all
 Not much
 Some
 A fair amount
 A lot

15. In general, how do the thermal comfort conditions in the common areas compare with the conditions in your room?

Much Worse
 Somewhat worse
 The same
 Somewhat better
 Much better

[Exit This Survey](#)

Energy and Comfort in Residence Halls Survey

Part 4: Your Overall Residence Hall Experience

56%

In this section, we would like to know about your overall experience living in your residence hall.

16. How much time do you spend in your residence hall room at the following times of day?

	None at all	Not much	Some	A fair amount	A lot
-Early morning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Late morning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Midday/Noon	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Afternoon	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Early evening	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Late evening	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. How would you rate the thermal comfort of your residence hall compared with other places that you have lived?

Much worse
 Somewhat worse
 The same
 Somewhat better
 Much better

Energy and Comfort in Residence Halls Survey						Exit This Survey
Part 4: Your Overall Residence Hall Experience						
						62%
18. Please specify how many of the following devices are located in your room.						
	0 Devices	1 Devices	2 Devices	3 Devices	4+ Devices	
-Small mini refrigerator	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-Large mini refrigerator	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-Laptop computer	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-Desktop computer	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-External hard drive	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-Printer	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-TV	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-DVD player	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-Sound system or iPod dock	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-Plug-in Lamp	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-Desk or window fan	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-Game system	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
-Other (please type device and number below)						
<input type="text"/>						
<input type="button" value="Prev"/> <input type="button" value="Next"/>						

Energy and Comfort in Residence Halls Survey

[Exit This Survey](#)

Part 4: Your Overall Residence Hall Experience

69%

19. How aware are you of the following campus programs, campaigns, or initiatives that promote and encourage resource conservation in campus housing?

	Not at all aware	Slightly aware	Somewhat aware	Moderately aware	Extremely aware
-Better Rooms Competition (Greenest Room category)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Reduce the Juice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Do it in the Dark	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-RecycleMania	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Ducks for Sustainability	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-UO Resource Conservation Team	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Use Wisely, Every Watt Counts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Community Conversations on environmental topics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Other (please type below)					

20. Do you actively participate in any of these programs, campaigns, or initiatives?

- Yes
- No

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Energy and Comfort in Residence Halls Survey[Exit This Survey](#)**Part 5: Demographics**

75%

Finally, in this section we would like to know a little more about you so that we can see how different types of people feel about the issues that we are examining.

21. What is your gender?

- Male
 Female

22. What is your age in years?

- Under 18 18 19 20 21 22+

23. What is your class year?

- Freshman Sophomore Junior Senior

Other (please type below)

[Prev](#) [Next](#)

Energy and Comfort in Residence Halls Survey

[Exit This Survey](#)

Part 5: Demographics

81%

24. Which residence hall do you currently live in?

- Living and Learning Center (LLC) South Building
 Riley Hall

25. On what floor is your residence hall room located?

- 1st or ground
 2nd
 3rd
 4th

26. Which direction do the windows in your room face? (select all that apply)

- North
 South
 East
 West
 Corner room
 I'm not sure

Other (please specify a building, landmark, or street that you can see from your window)

27. How many years have you lived in residence halls?

- 0-1
 1-2
 2-3
 3-4
 4+

Energy and Comfort in Residence Halls Survey

[Exit This Survey](#)

Part 5: Demographics

88%

28. Where have you lived for most of your life? (please type city, state, and country below)

29. Do you have any additional comments about your residence hall that have not been covered in this survey? (please type below)

Energy and Comfort in Residence Halls Survey		Exit This Survey
Prize Drawing		
		94%
<p>30. Please enter your e-mail address in the text box below if you wish to be entered in a drawing for a chance to win one of four \$50.00 UO Duck Store gift card prizes. The estimated odds of winning are 1:37.</p>		
<input type="text"/>		
<input type="button" value="Prev"/> <input type="button" value="Next"/>		

Energy and Comfort in Residence Halls Survey		Exit This Survey
The End		
		100%
<p>Thank you for taking the time to complete this survey.</p>		
<p>If you have any questions, please contact Thomas Collins, the principal investigator of the study, at 617-721-8713 or at thomasc@uoregon.edu.</p>		
<input type="button" value="Prev"/> <input type="button" value="Submit"/>		

APPENDIX B
RECRUITMENT FLIERS

Hello Riley Hall!

Energy & Comfort Survey

www.surveymonkey.com/energy-and-comfort

Riley Hall has been selected to participate in a research study about student energy consumption and thermal comfort in residence halls.

Please Spread The Word To Your Friends

The online survey will ask you to tell us about your thoughts, behaviors, and experiences in your residence hall building.

It Will Only Take About 5 Minutes

Your feedback is very important to our study.
The last day to take the survey is Monday November 16th!

ENTER TO WIN

A \$50.00 Duck Store Gift Card

4 prizes will be awarded. The odds of winning are approximately 1:37

.....

Energy & Comfort
In Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

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Energy & Comfort
In Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

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Energy & Comfort
In Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

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Energy & Comfort
In Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

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Energy & Comfort
In Residence Halls Survey

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Energy & Comfort
In Residence Halls Survey

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Energy & Comfort
In Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

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Energy & Comfort
In Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

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Energy & Comfort
In Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

.....

Hello LLC South!

Energy & Comfort Survey

www.surveymonkey.com/energy-and-comfort

LLC South has been selected to participate in a research study about student energy consumption and thermal comfort in residence halls.

Please Spread The Word To Your Friends

The online survey will ask you to tell us about your thoughts, behaviors, and experiences in your residence hall building.

It Will Only Take About 5 Minutes

Your feedback is very important to our study.

The last day to take the survey is Monday November 16th!

ENTER TO WIN

A \$50.00 Duck Store Gift Card

4 prizes will be awarded. The odds of winning are approximately 1:37

Energy & Comfort
in Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

Energy & Comfort
in Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

Energy & Comfort
in Residence Halls Survey

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in Residence Halls Survey

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in Residence Halls Survey

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in Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

Energy & Comfort
in Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

Energy & Comfort
in Residence Halls Survey

www.surveymonkey.com/energy-and-comfort

Hello Riley Hall!

Energy & Comfort Survey

www.surveymonkey.com/energy-and-comfort

Riley Hall has been selected to participate in a research study about student energy consumption and thermal comfort in residence halls.

Please Spread The Word To Your Friends

The online survey will ask you to tell us about your thoughts, behaviors, and experiences in your residence hall building.

It Will Only Take About 5 Minutes

Your feedback is very important to our study.

The last day to take the survey is Monday November 16th!

ENTER TO WIN

A \$50.00 Duck Store Gift Card

4 prizes will be awarded. The odds of winning are approximately 1:37

Hello LLC South!

Energy & Comfort Survey

www.surveymonkey.com/energy-and-comfort

LLC South has been selected to participate in a research study about student energy consumption and thermal comfort in residence halls.

Please Spread The Word To Your Friends

The online survey will ask you to tell us about your thoughts, behaviors, and experiences in your residence hall building.

It Will Only Take About 5 Minutes

Your feedback is very important to our study.

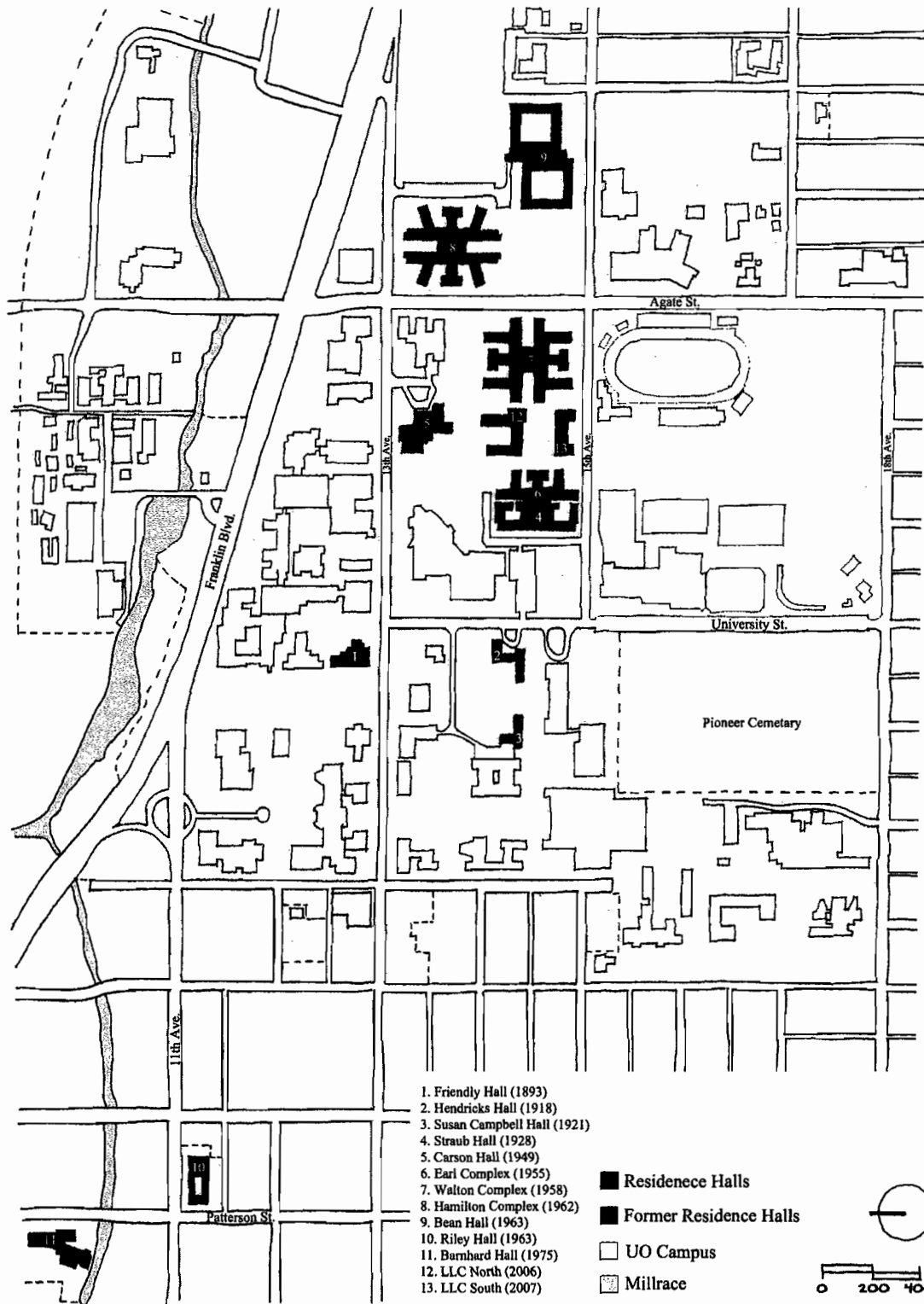
The last day to take the survey is Monday November 16th

ENTER TO WIN

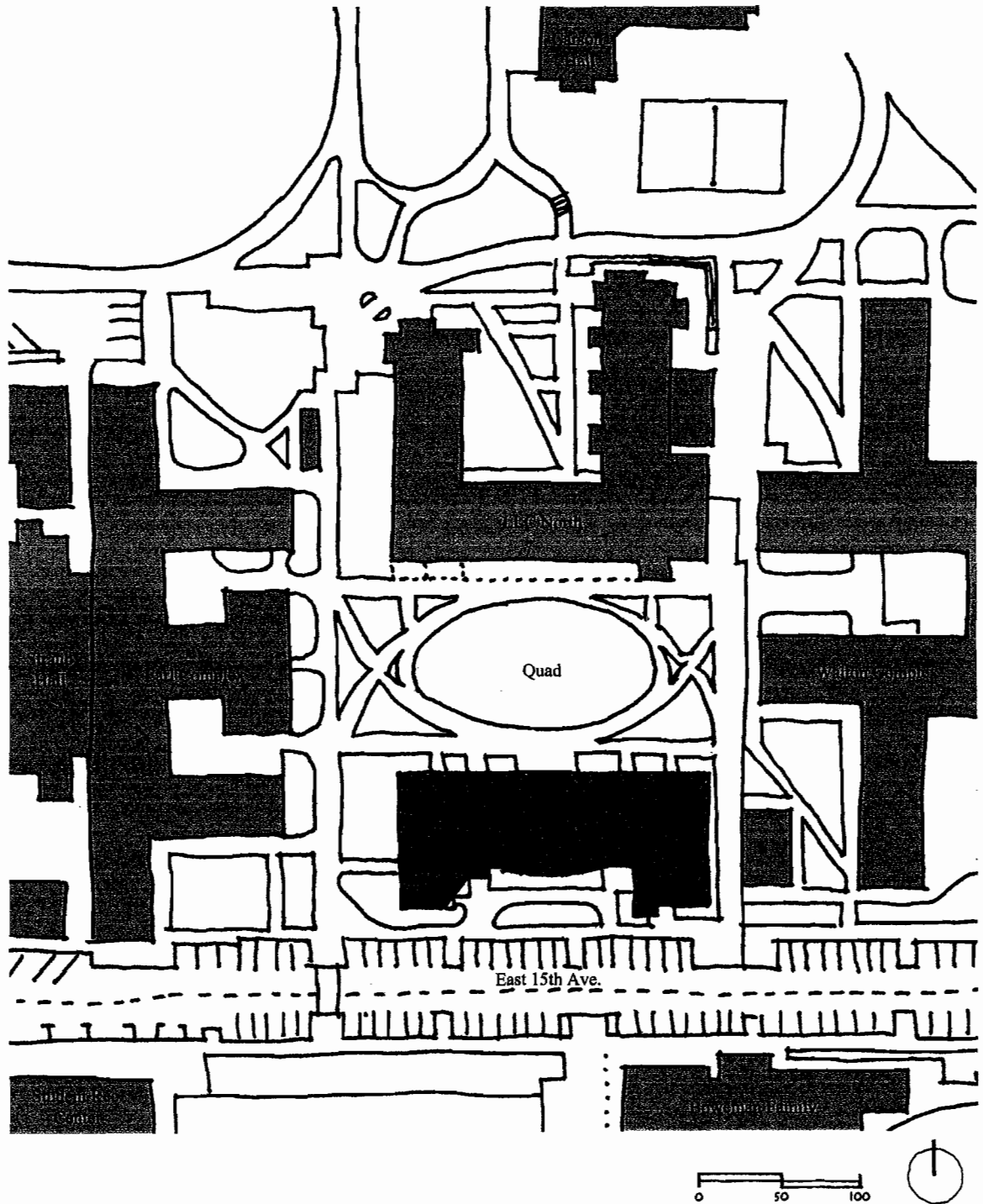
A \$50.00 Duck Store Gift Card

4 prizes will be awarded. The odds of winning are approximately 1:37

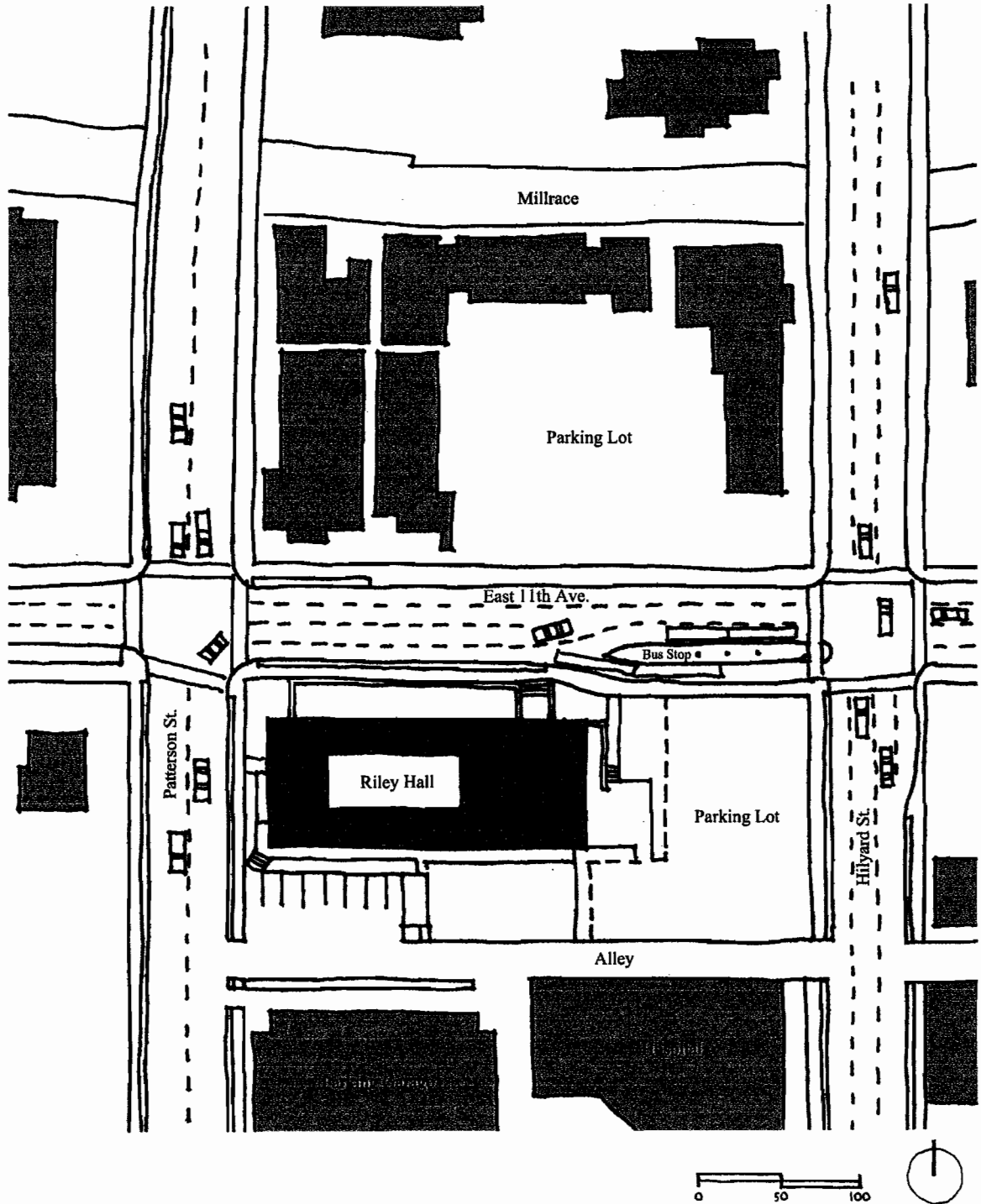
APPENDIX C
RESIDENCE HALL DRAWINGS



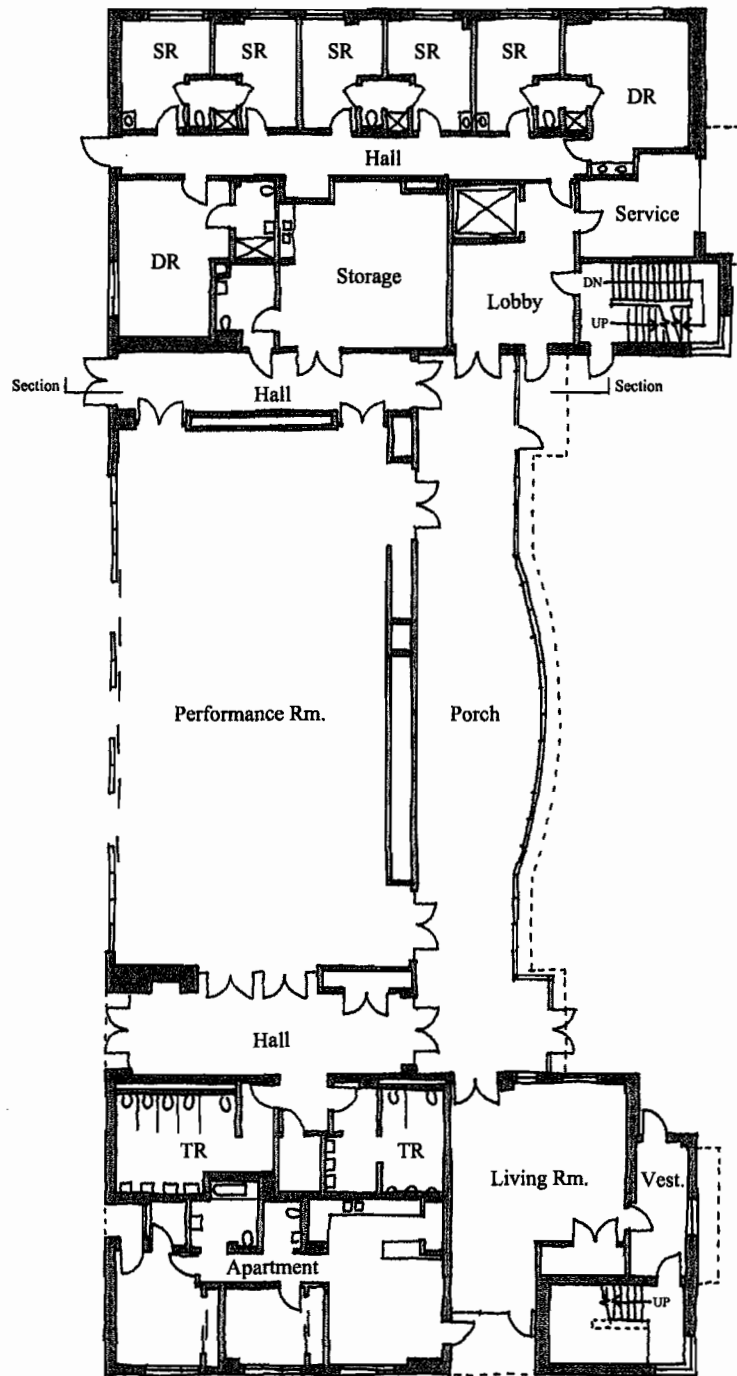
University of Oregon Campus Map Showing Residence Hall Locations



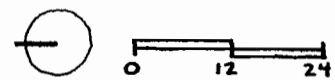
LLC South Site Plan



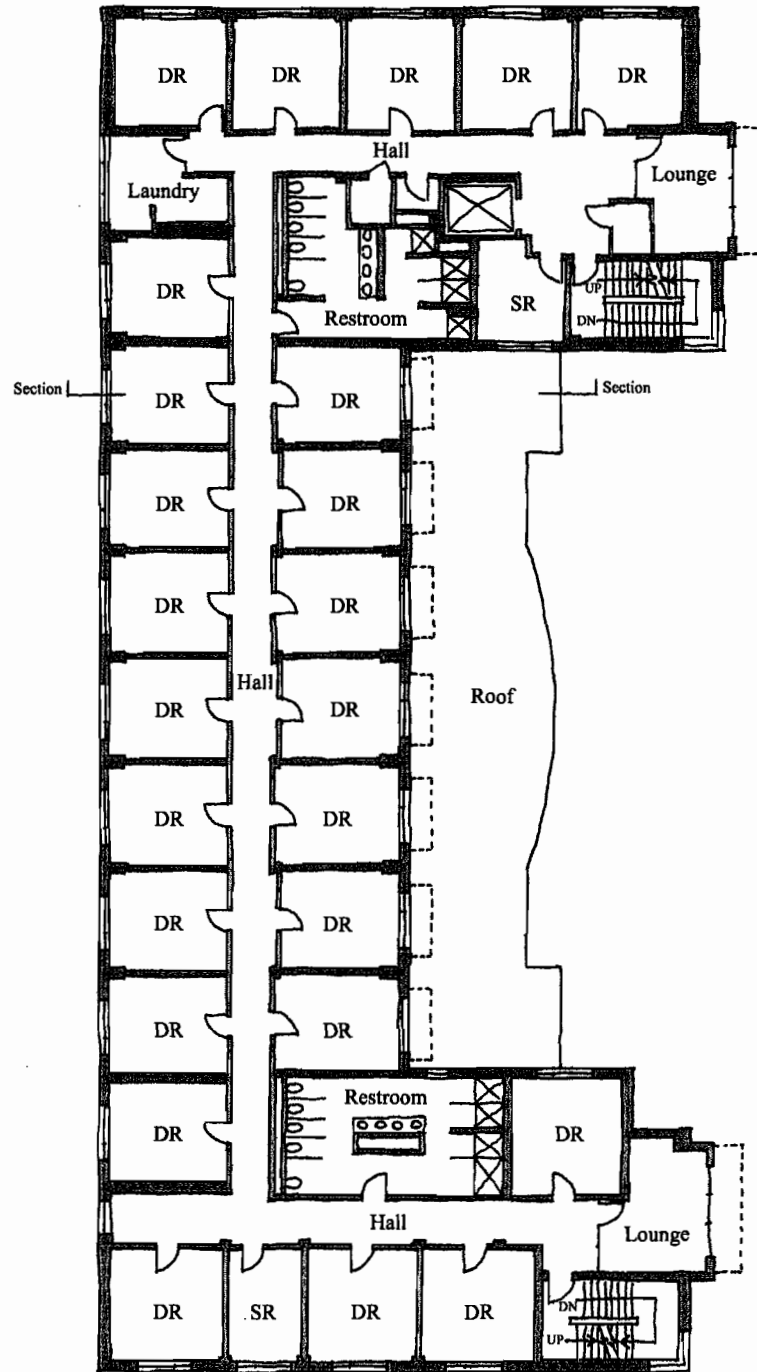
Riley Hall Site Plan



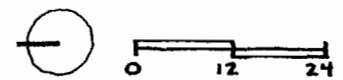
Key:
DR=Double Bedroom
SR=Single Bedroom
TR=Toilet Room
Vest.=Vestibule



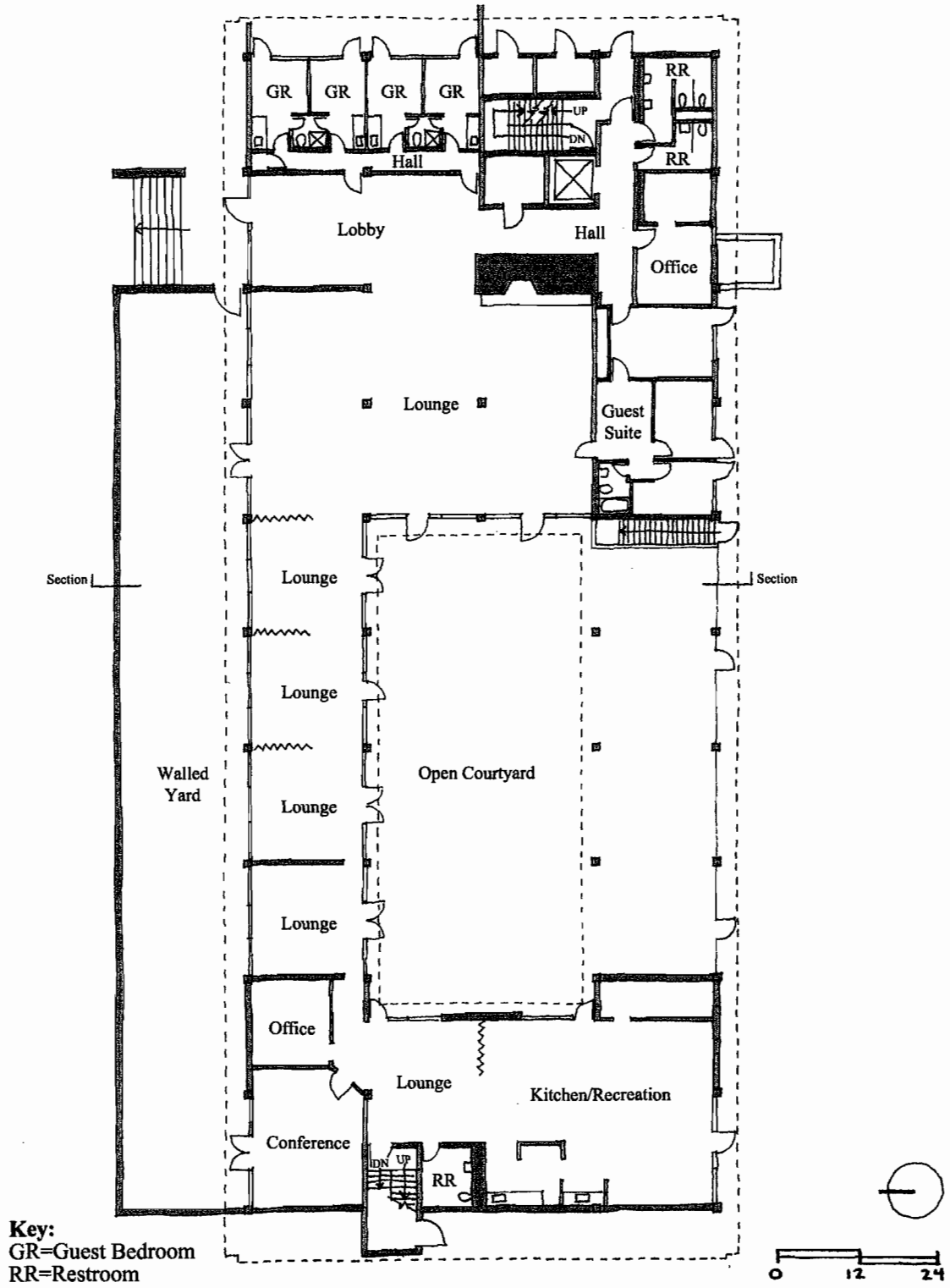
LLC South: First Floor Plan – Scale: 1" = 24'-0"



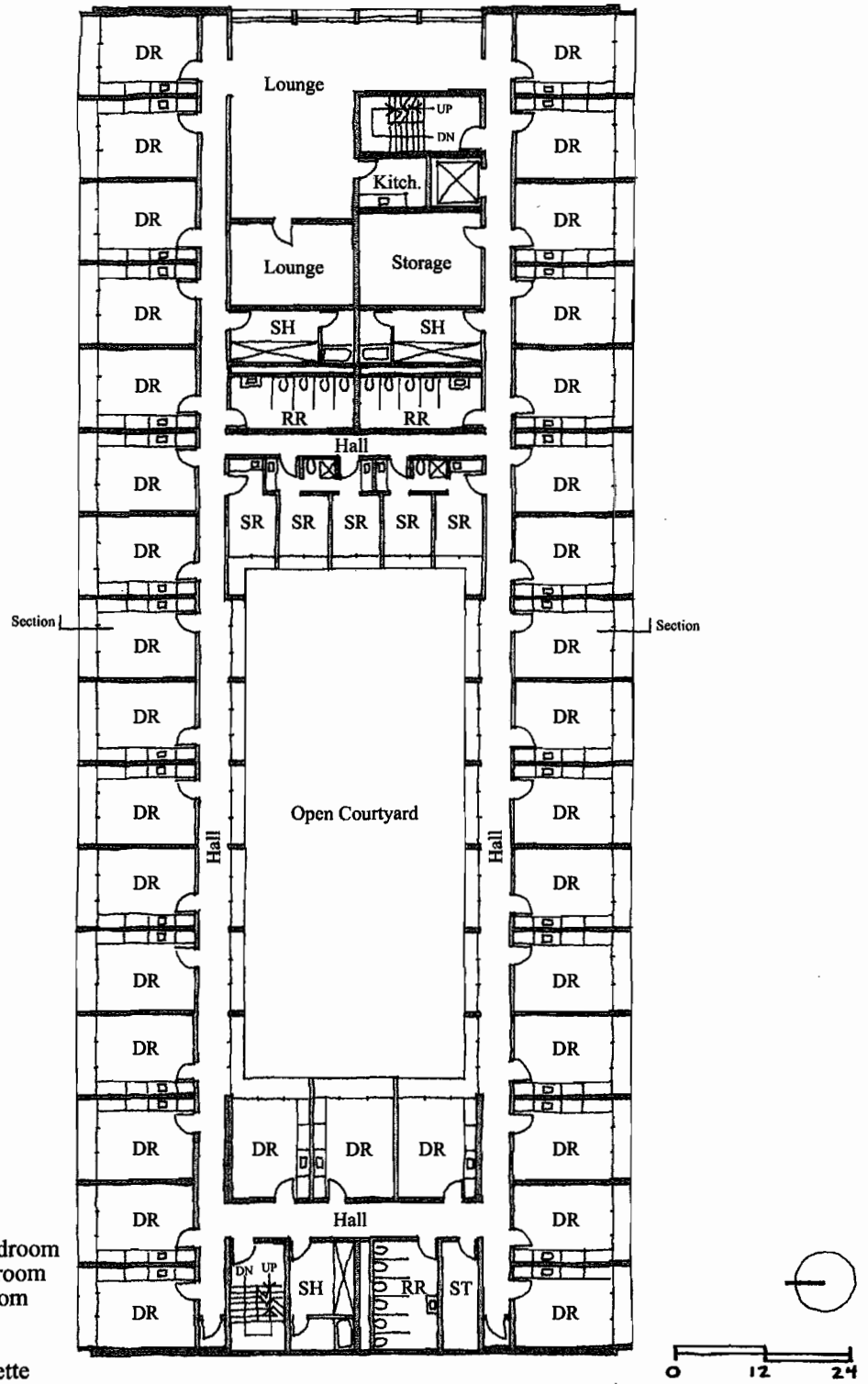
Key:
DR=Double Bedroom
SR=Single Bedroom



LLC South: Typical Upper Floor Plan – Scale: 1" = 24'-0"

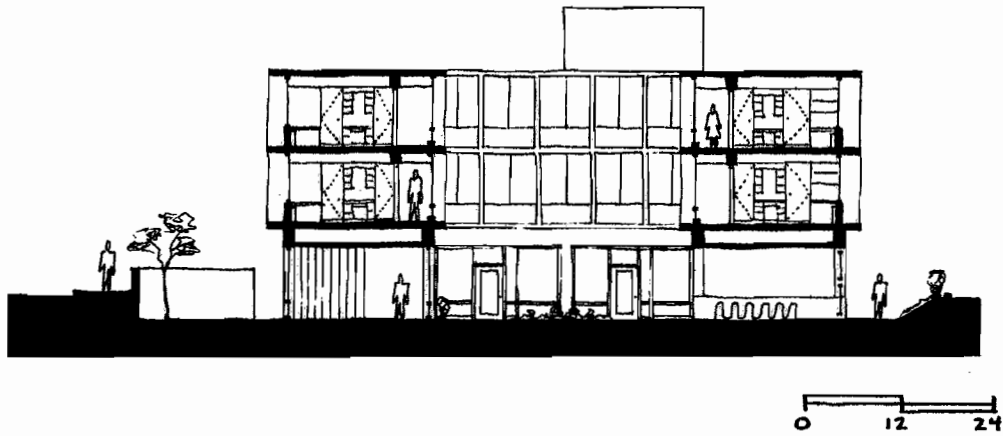


Riley Hall: First Floor Plan – Scale: 1" = 24'-0"

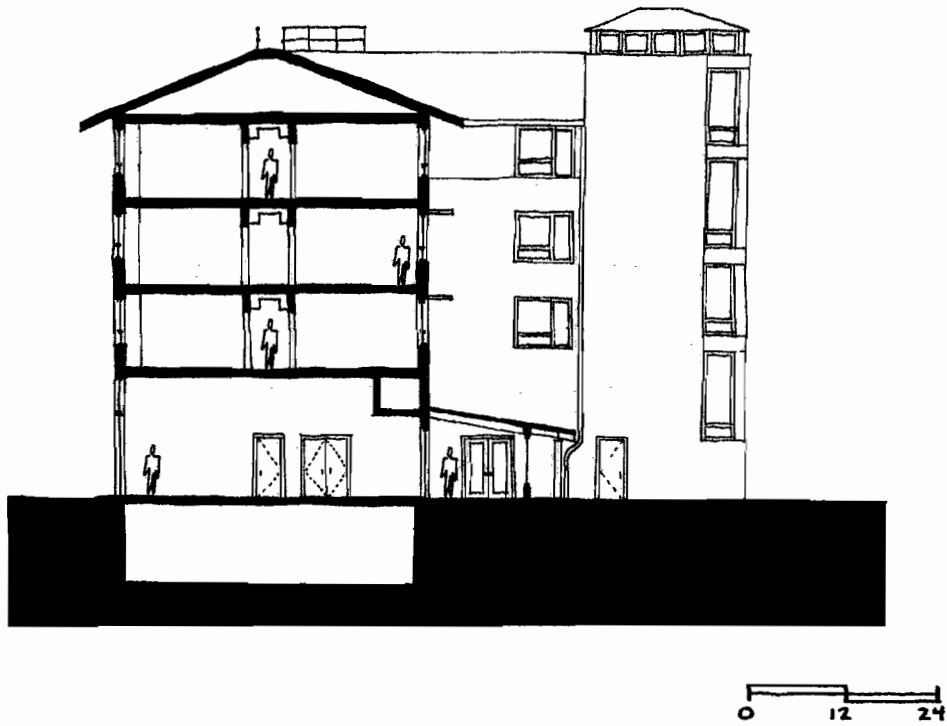


Key:
 DR=Double Bedroom
 SR=Single Bedroom
 SH=Shower Room
 RR=Restroom
 ST=Storage
 Kitch.=Kitchenette

Riley Hall: Typical Upper Floor Plan – Scale: 1" = 24'-0"



Riley Hall: Typical North-South Section Through Courtyard – Scale: 1" = 24'-0



LLC South: Typical North-South Section – Scale: 1" = 24'-0

APPENDIX D
RESIDENCE HALL PHOTOGRAPHS

LLC South



Exterior Photo: Looking Northeast
Photo by Author



Exterior Photo: Looking Southwest
Photo by Author



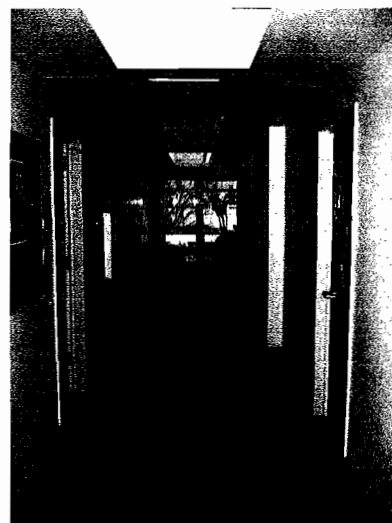
Interior Photo: First Floor Porch
Photo by Author



Interior Photo: Typical Lounge Space
Photo by Author



Interior Photo: Typical Corridor
Photo by Author

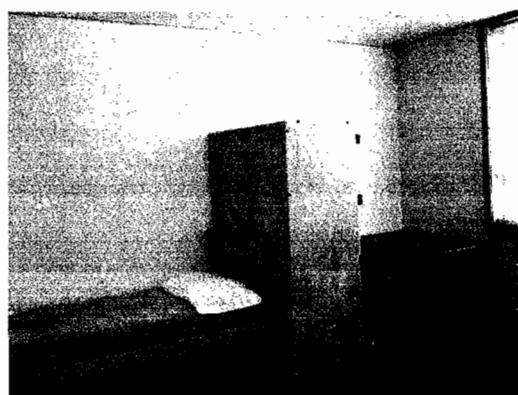


Interior Photo: Typical Corridor
Photo by Author

LLC South



Interior Photo: Typical Student Room
Photo Courtesy of University Housing



Interior Photo: Typical Student Room
Photo Courtesy of University Housing

Riley Hall



Exterior Photo: Looking Southeast
Photo by Author



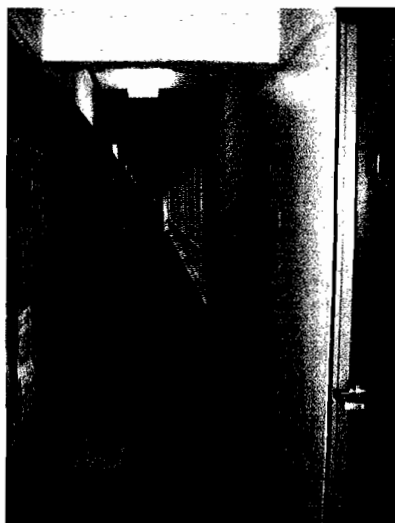
Exterior Photo: Looking Northeast
Photo by Author



Interior Photo: Typical Student Room
Photo Courtesy of University Housing



Interior Photo: Typical Lounge
Photo by Author

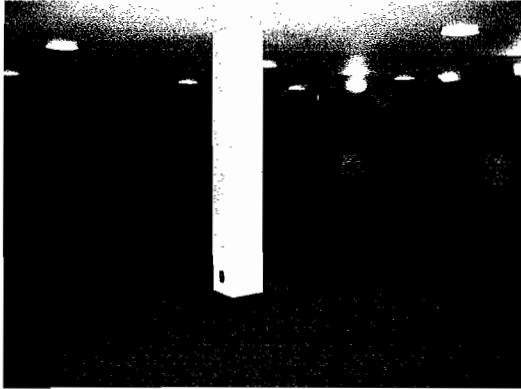


Interior Photo: Typical Corridor
Photo by Author

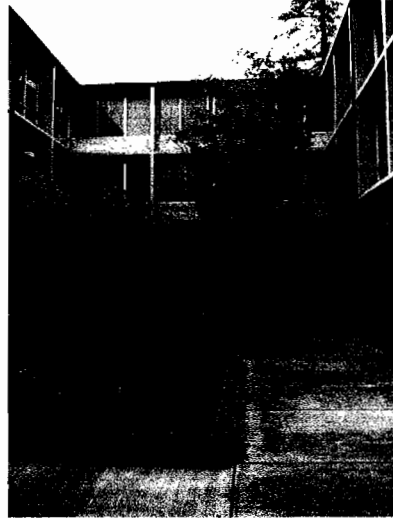


Interior Photo: Typical Corridor
Photo by Author

Riley Hall

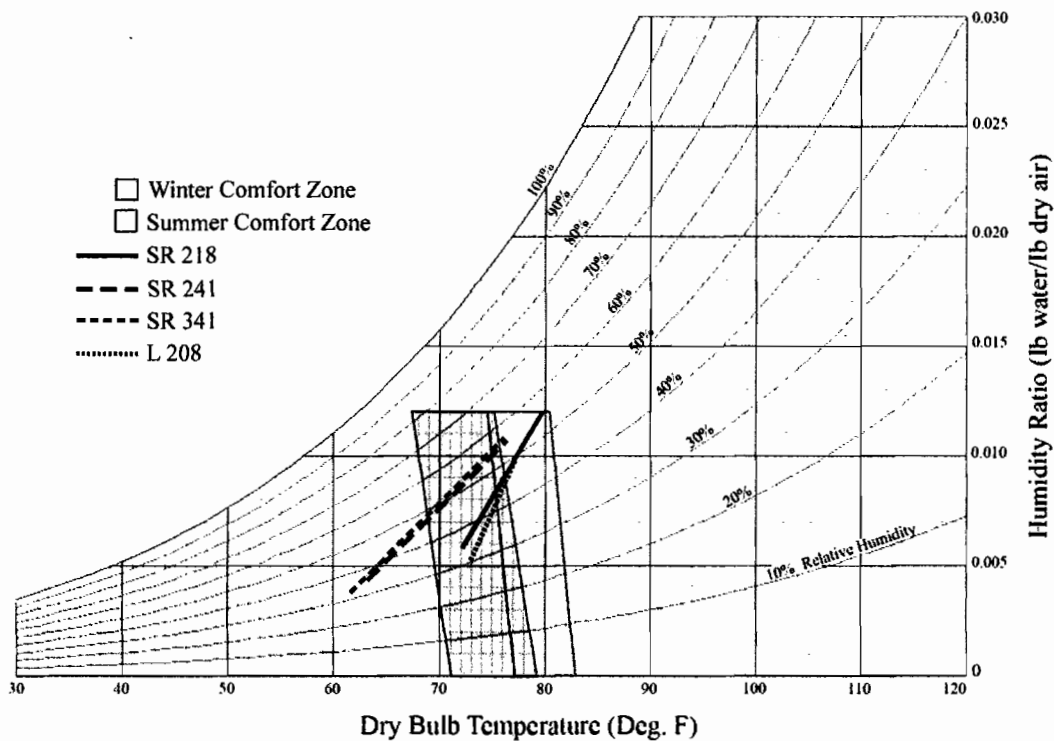


Interior Photo: First Floor Lounge
Photo by Author

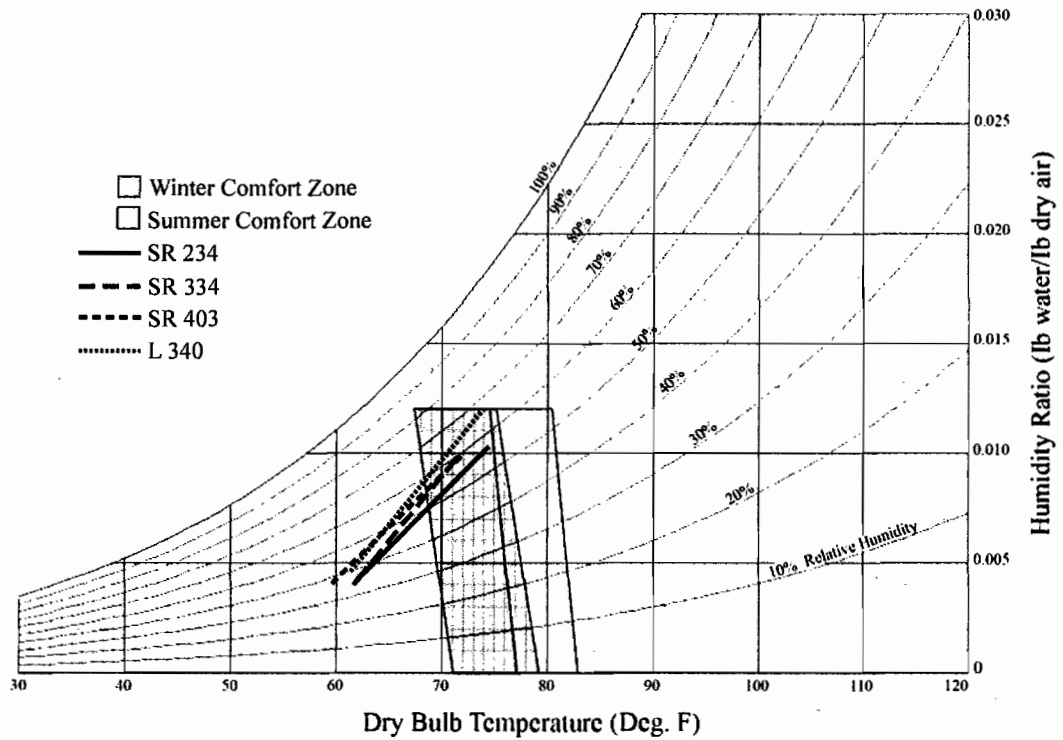


Exterior Photo: Courtyard
Photo by Author

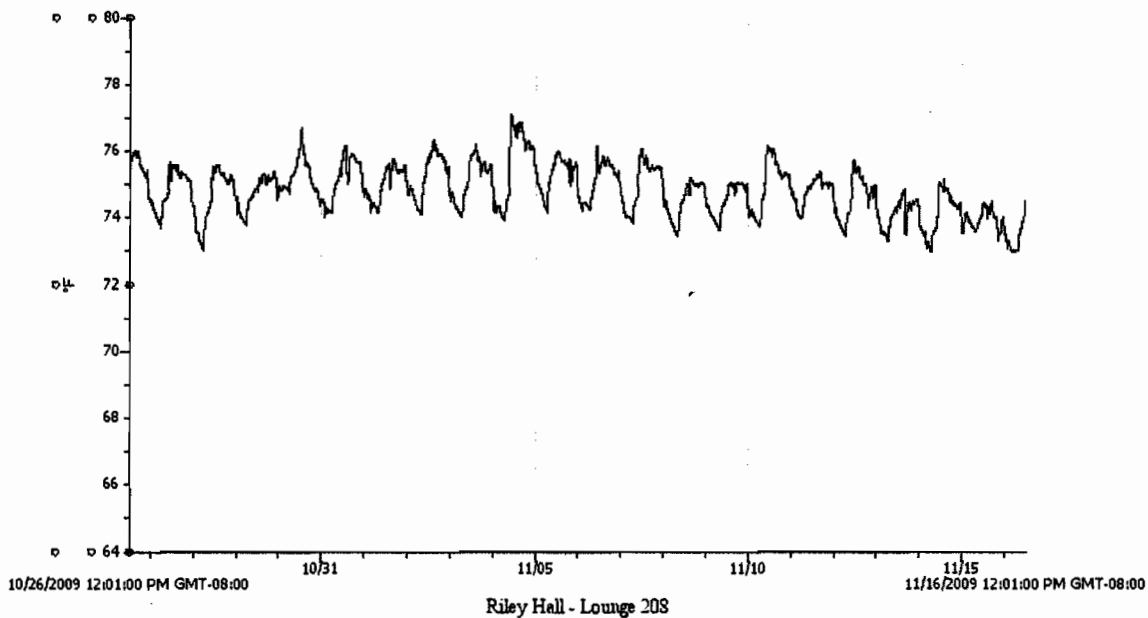
APPENDIX E
THERMAL MEASUREMENTS



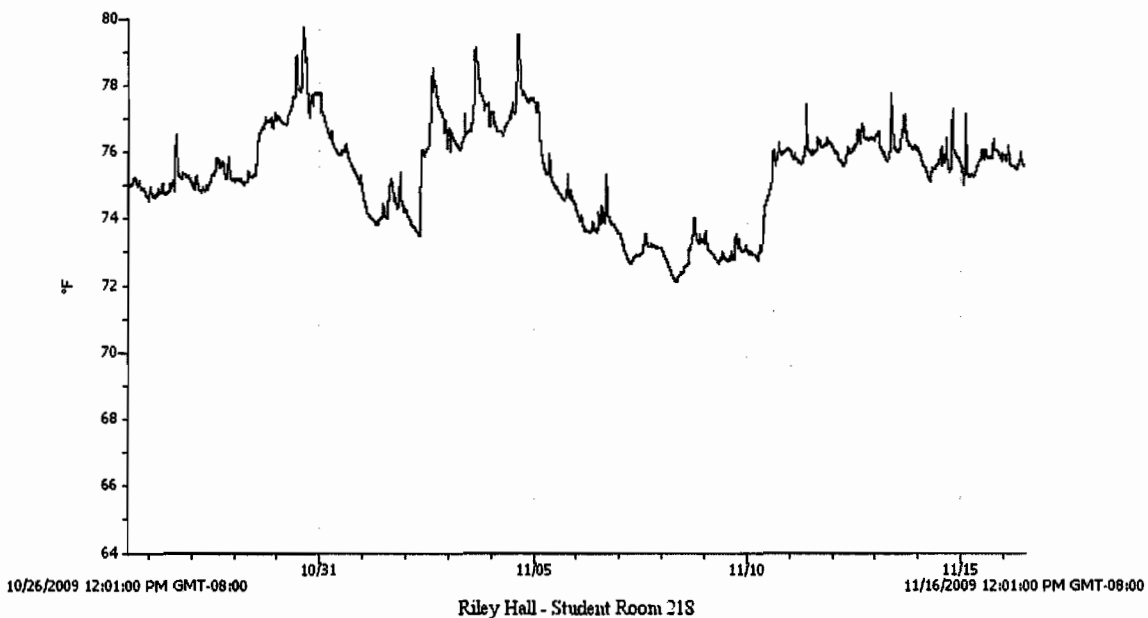
Riley Hall: Mean minimum and maximum temperatures and relative humidities in specific spaces in relation to the ASHRAE Comfort Zone. SR=Student Room. L=Lounge.



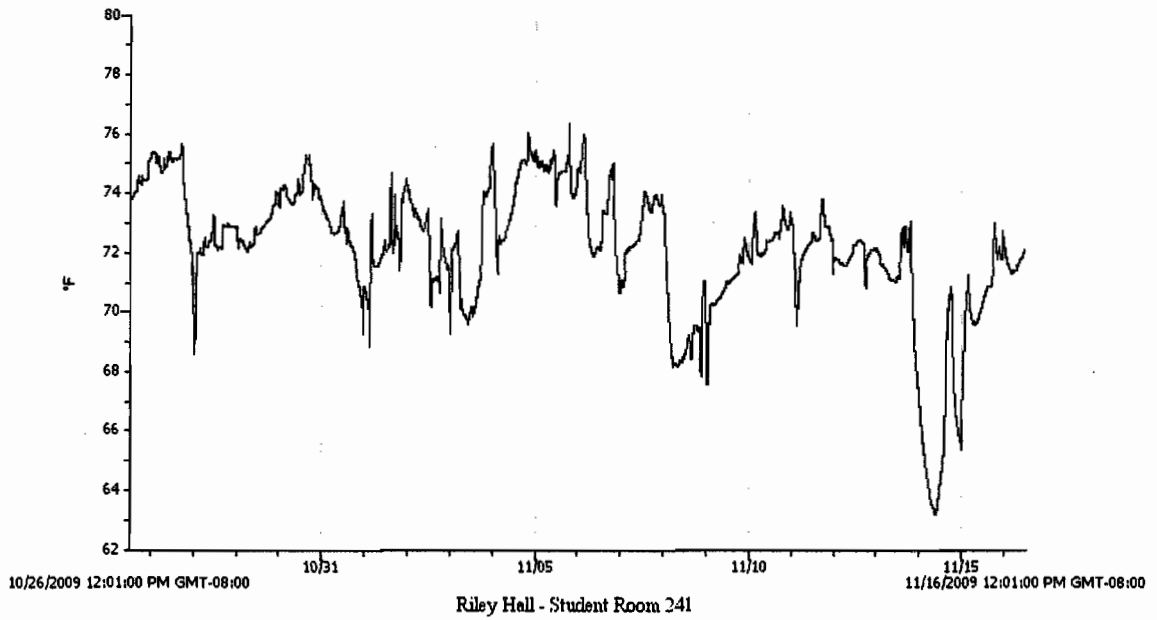
LLC South: Mean minimum and maximum temperatures and relative humidities in specific spaces in relation to the ASHRAE Comfort Zone. SR=Student Room. L=Lounge.



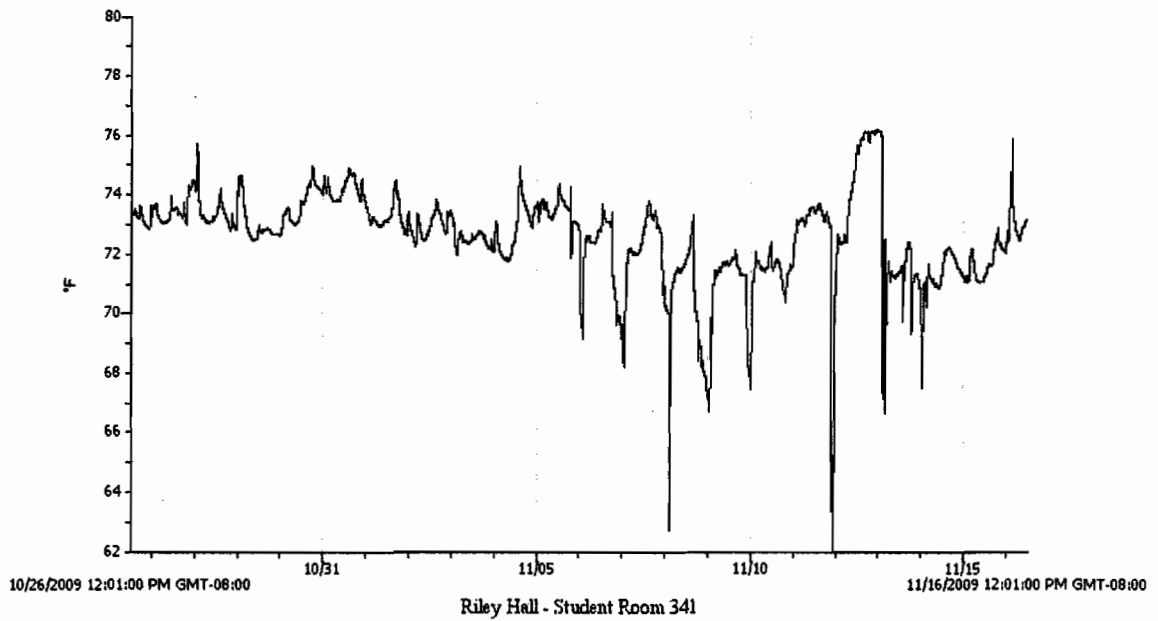
Riley Hall: Temperatures logged in Lounge 208.



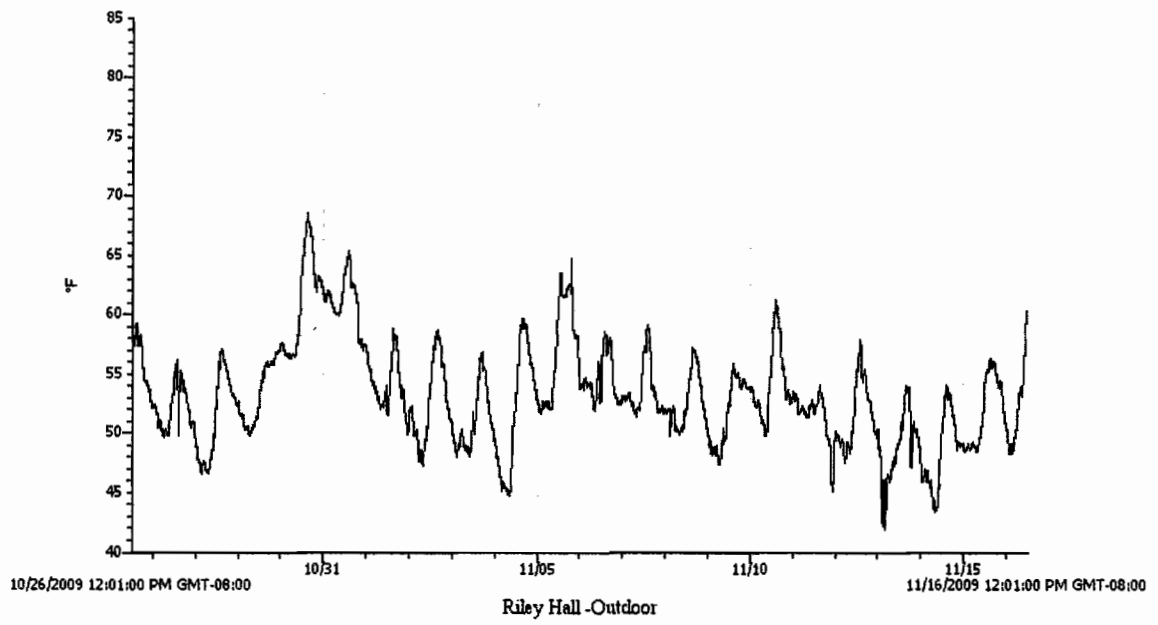
Riley Hall: Temperatures logged in Student Room 218.



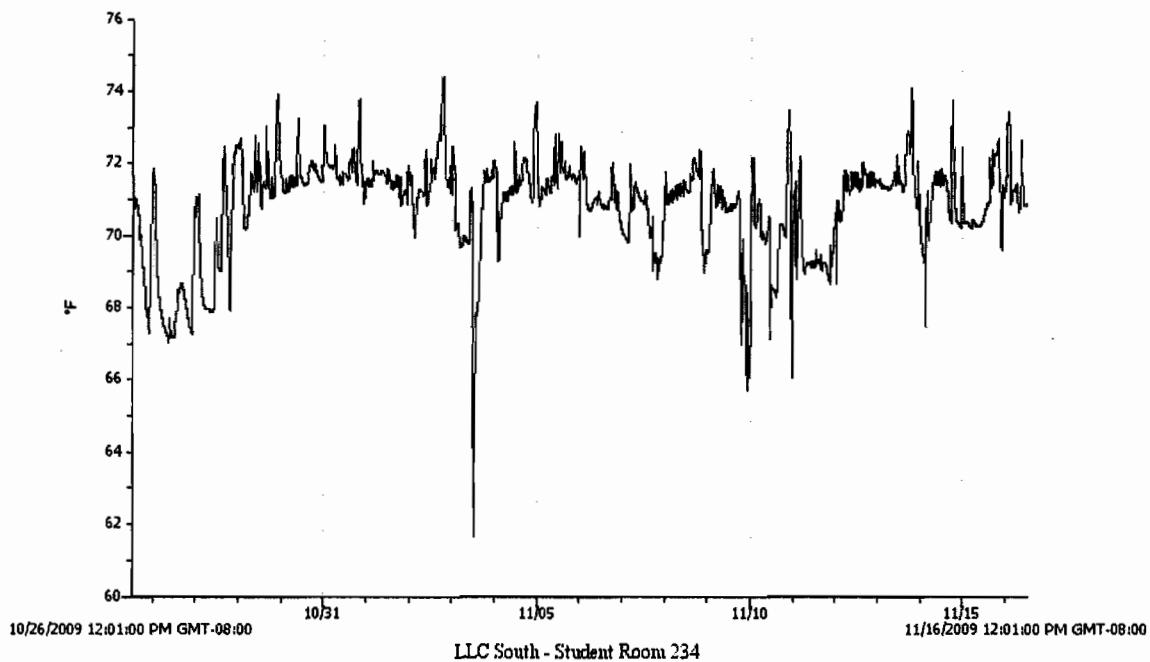
Riley Hall: Temperatures logged in Student Room 241.



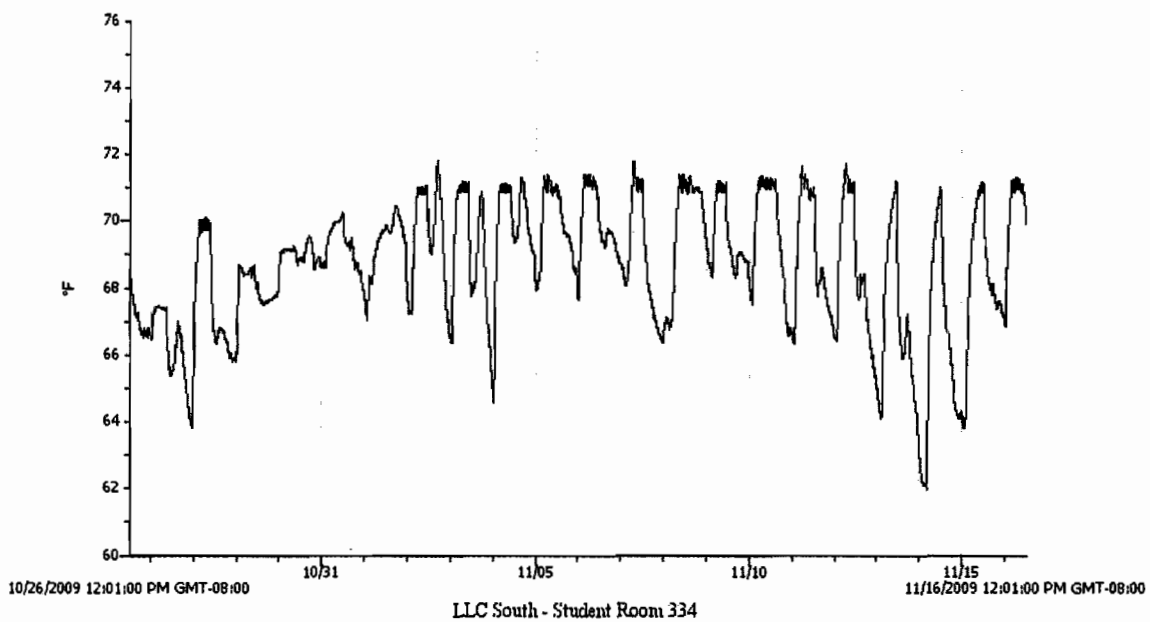
Riley Hall: Temperatures logged in Student Room 341.



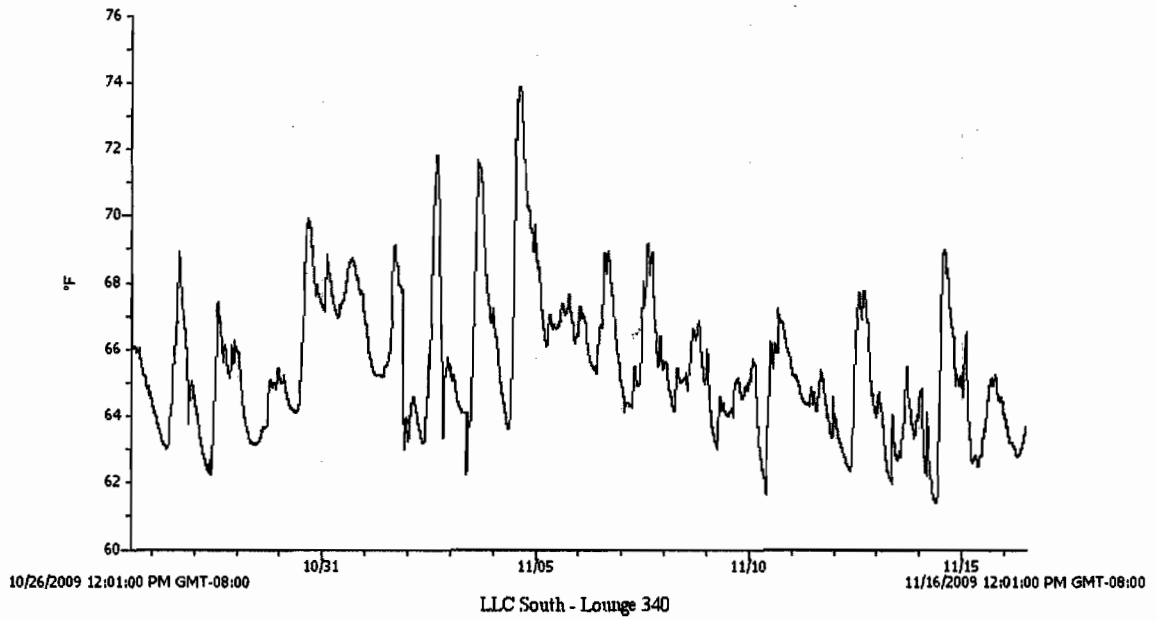
Riley Hall: Outdoor Temperatures logged.



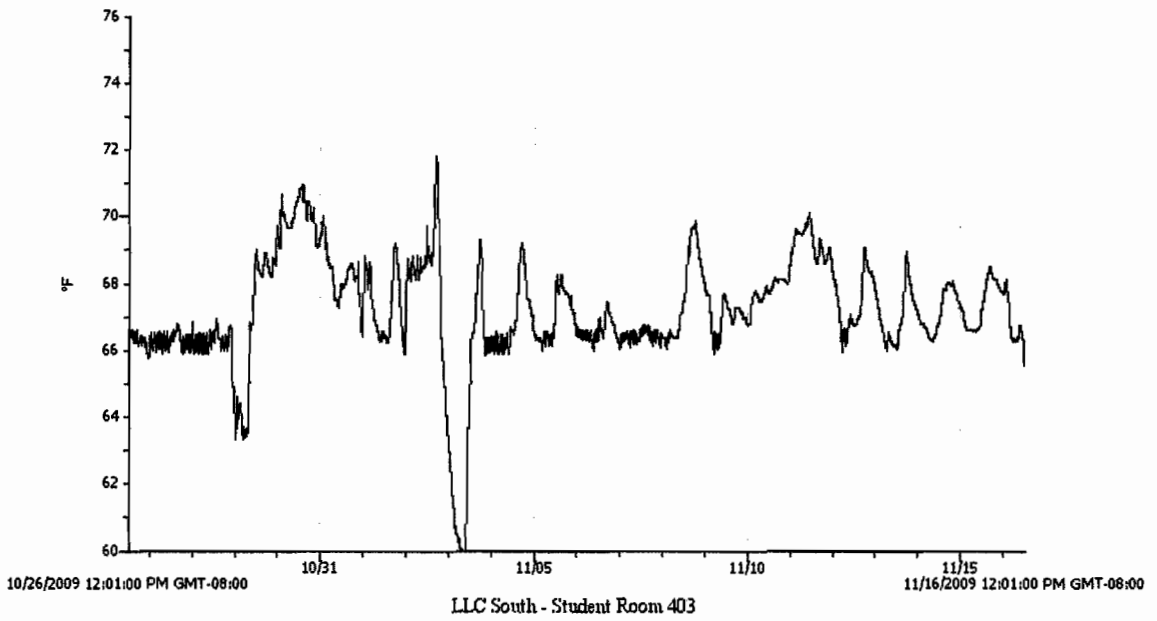
LLC South: Temperatures logged in Student Room 234.



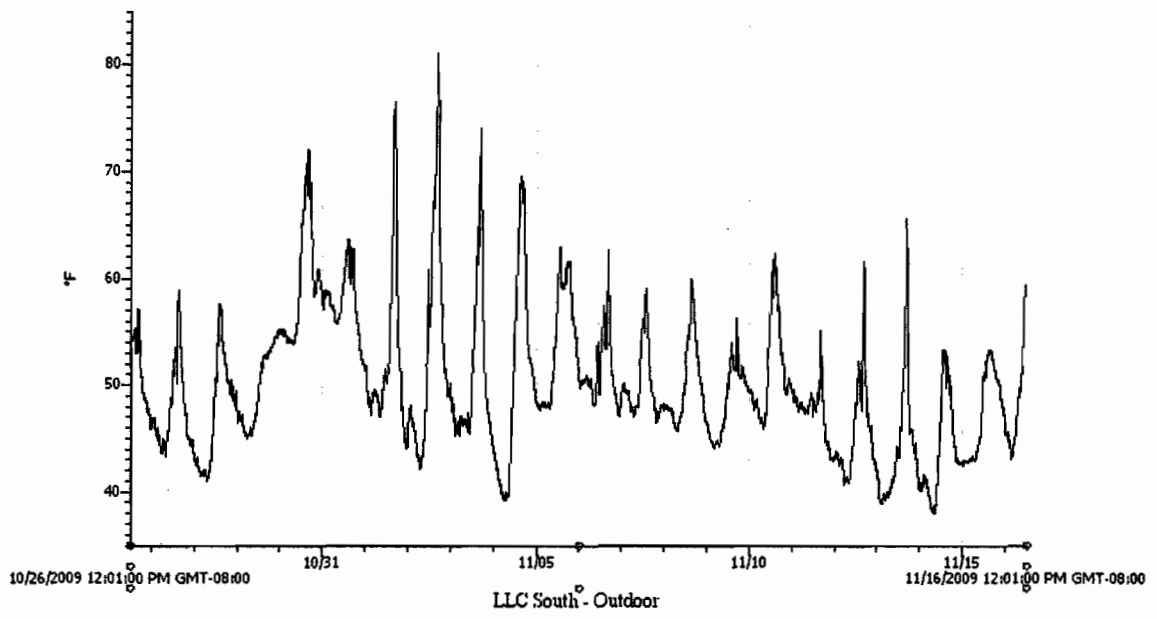
LLC South: Temperatures logged in Student Room 334.



LLC South: Temperatures logged in Lounge 340.



LLC South: Temperatures logged in Student Room 403.



LLC South: Outdoor temperatures logged.

APPENDIX F
FINAL PRESENTATION

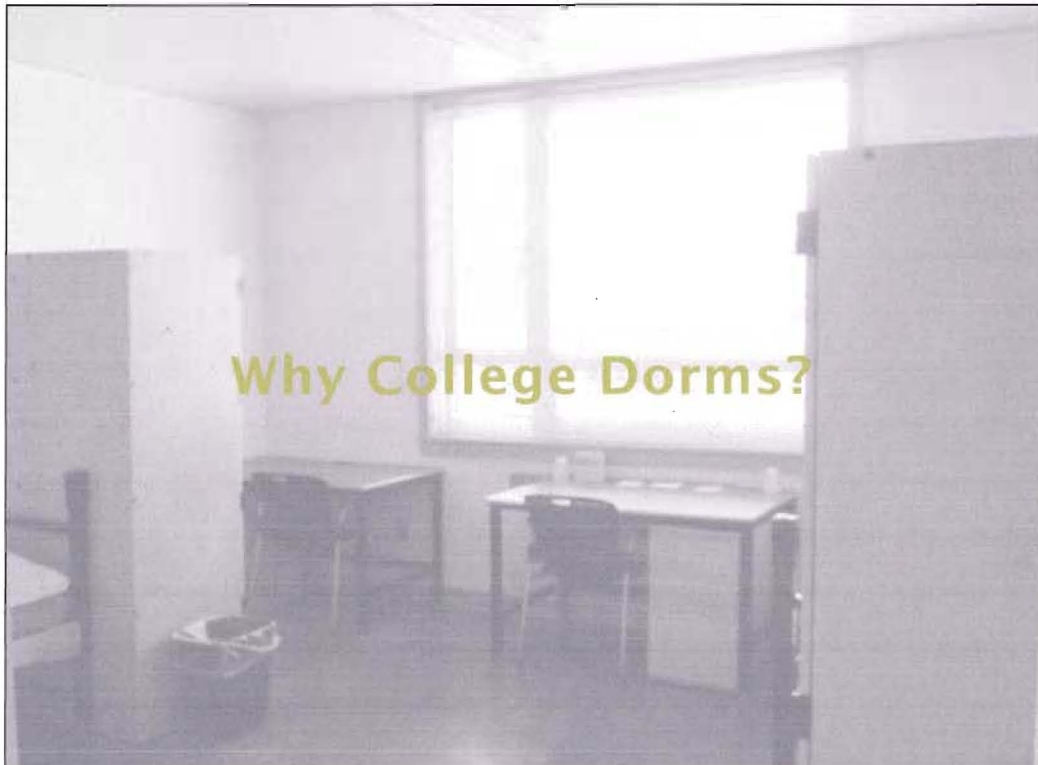
Presentation Slides

Behavior, Comfort, and Energy Consumption In Student Residence Halls

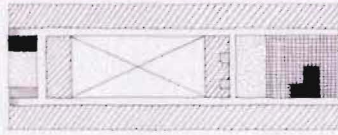


A Thesis by Thomas Collins
Final Presentation
February 26, 2010

Why College Dorms?

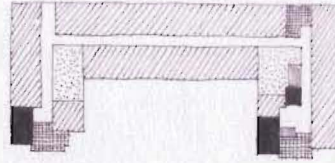


Riley Hall



Age: 47 Yrs (1963)
Gross SF: 42,719
Net Assign. SF: 22,355
Bldg. Efficiency: 0.52
Occupancy: 143 Students (M/F:56/44)
Double Rooms: 70 (163 SF)
Single Rooms: 10 (88 SF)
Utilities: EWEB Electricity & Steam (hydronic heating/domestic hot water)
Controls: None in lounges, occupants control room temperatures (72°F Max), & no air-conditioning.

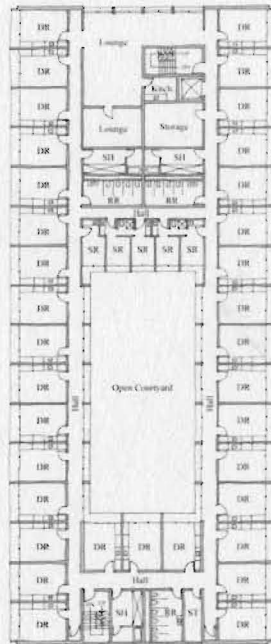
LLC South



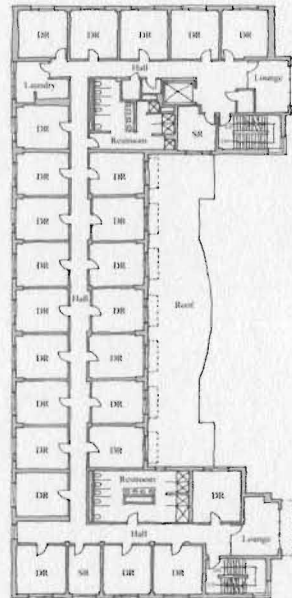
Age: 4 Yrs (2006)
Gross SF: 48,748
Net Assign. SF: 26,280
Bldg. Efficiency: 0.54
Occupancy: 165 Students (M/F: 41/59)
Double Rooms: 77 (215 SF)
Single Rooms: 11 (139 SF)
Utilities: Campus Electricity & Steam (hydronic heating/domestic hot water)
Controls: None in lounges, occupants control room temperatures (70°F +/- 2°F, 72°F Max), & no air-conditioning.

- Circulation
- Vertical Circulation
- ▨ Bedroom
- ▩ Common Area
- ▧ Service
- ▦ Restroom

Riley Hall



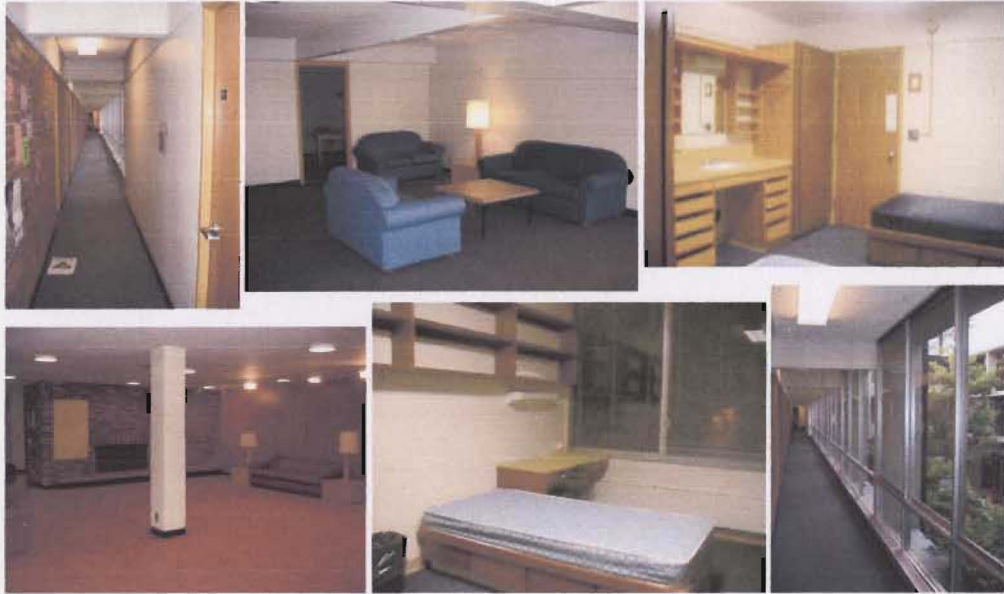
LLC South



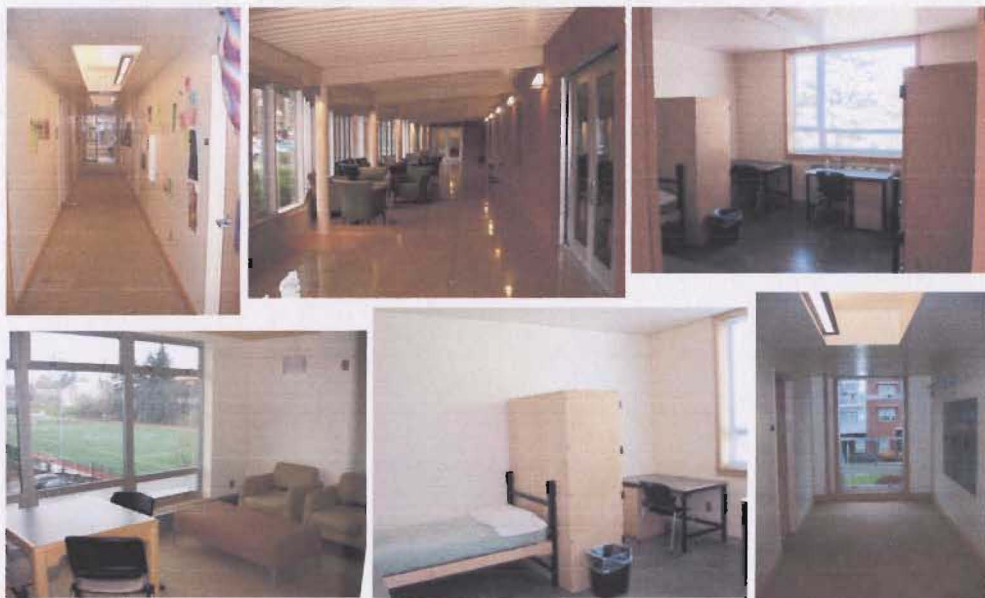
- DK- Double Bedroom
- SR- Single Bedroom
- SH- Shower Room
- RR- Restroom
- ST- Storage
- Kitch- Kitchenette



Riley Hall *Interior Spaces*



LLC South *Interior Spaces*



Hypotheses

1. Occupants in older halls perceive greater discomfort and fewer opportunities for conservation
2. Older halls demand greater occupant interaction

Secondary Hypothesis

Comfort actions are taken with little regard for energy consumption

Research Questions

Ranges of perceptions & actions?

Role of building age?

Ranges of thermal conditions?

Electricity consumption?

Methodology

Physical Conditions



Thermal Data Logging



Utility Data

Methodology

Perceptions

Energy and Comfort in Residence Halls Survey Exit This Survey

Part 1: Your Thoughts and Opinions About Your Room

In this section, we would like to know your thoughts and opinions about thermal comfort and energy consumption in your residence hall room within the past week.

1. How much control do you have over the temperature in your residence hall room?

None at all
 Not much
 Some
 A fair amount
 A lot

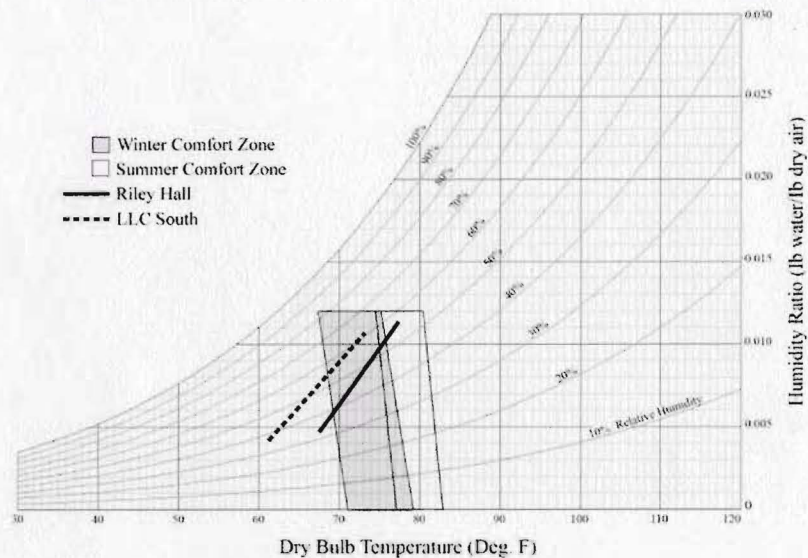
2. How often are the environmental conditions in your room:

	Always	Often	Sometimes	Rarely	Never
-Hot	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Cold	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Stuffy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Drafty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Humid or Damp	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
-Dry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Occupant Survey

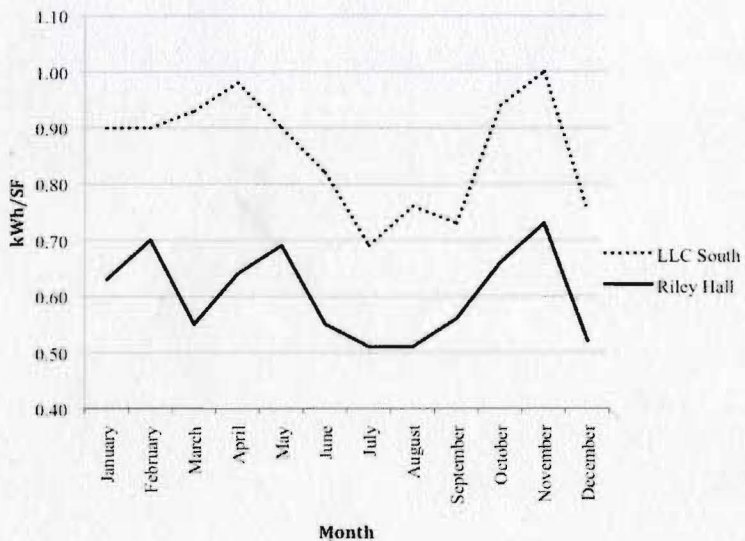
Thermal Measurement Results

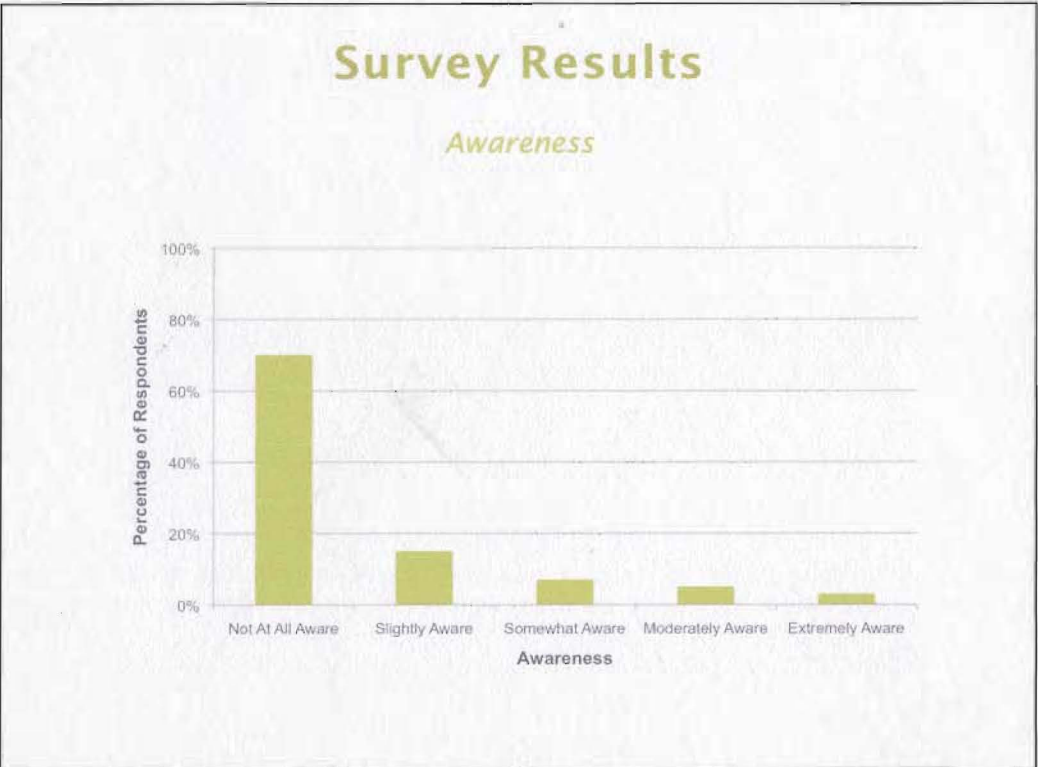
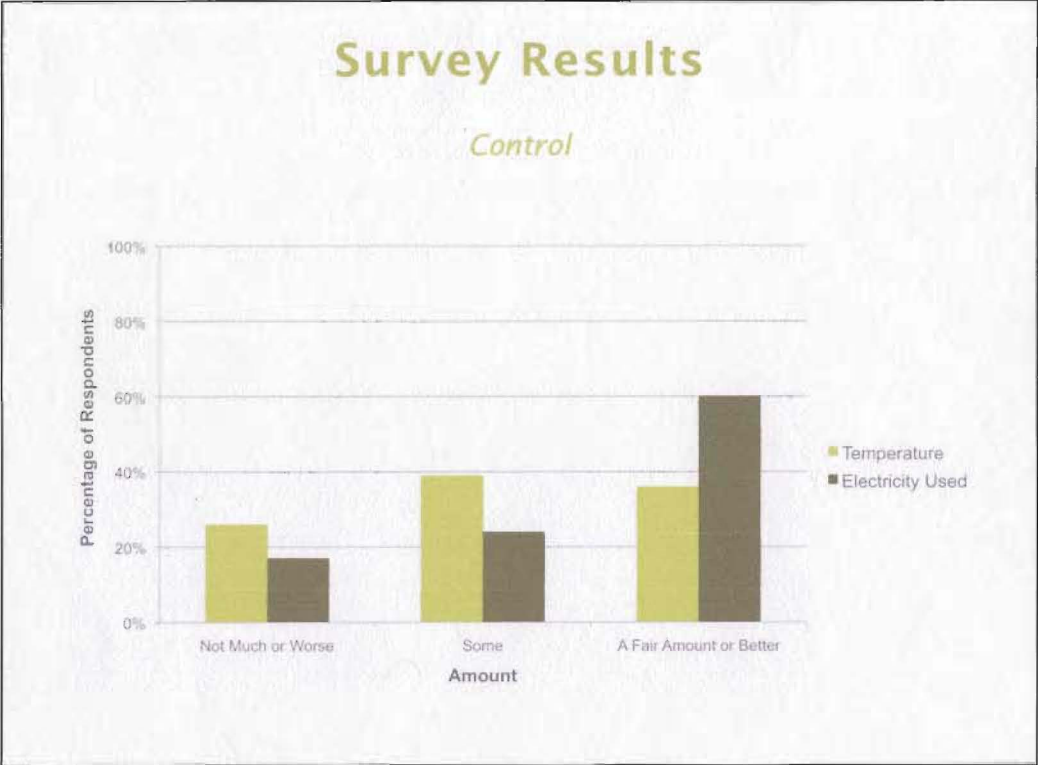
Ranges of Conditions and the Comfort Zone



Electricity Consumption Results

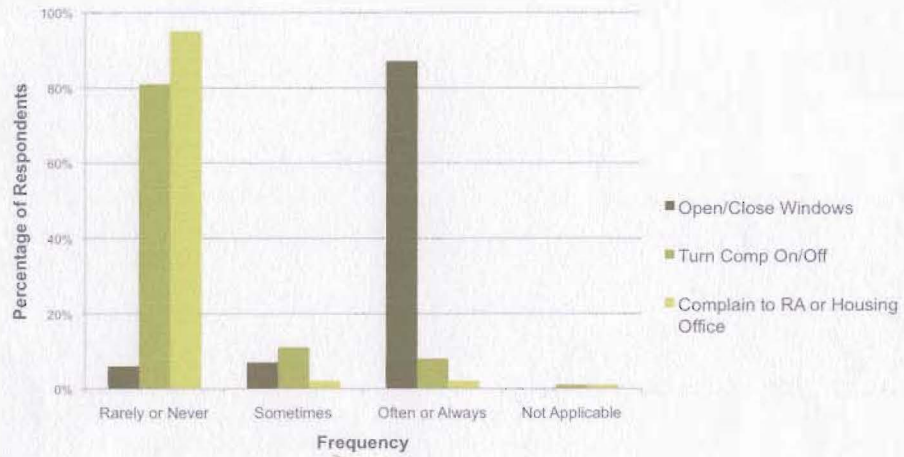
Impact of the Academic Calendar





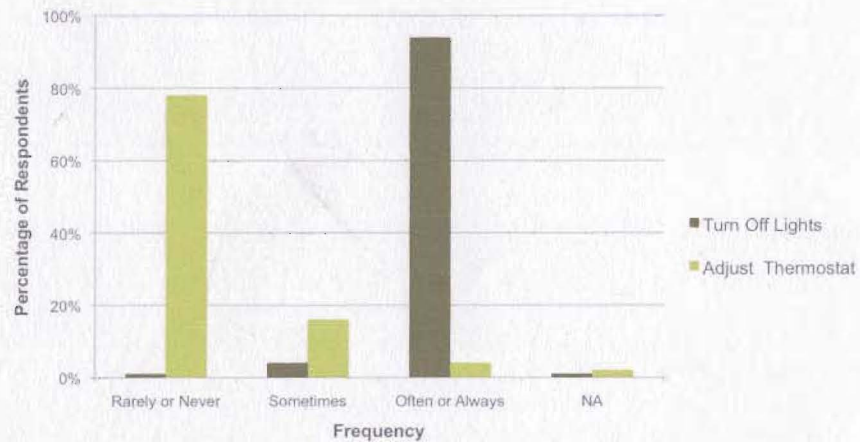
Survey Results

Comfort Actions



Survey Results

Conservation Actions



Conclusions

Building age

Awareness

Ranges of Conditions

Building Metering

Future Research

Incorporating additional methods

Gender, age, & class standing

Windows and appliances

Comparing campuses, regions, building types



Thank you

Thomas Collins
M.Arch Candidate
Option 1 Program
University of Oregon
Department of Architecture

Email:
thomasc@uoregon.edu
thomasc203@gmail.com

Transcription of the Questions and Answers at the Conclusion of the Presentation

Chris Stratton (graduate student): I was wondering if you looked at just electricity in terms of energy of if you included any of the heating or chilled water because the heating for these buildings is ostensibly steam? And, I'm wondering if you omitted it for a certain reason?

Tom Collins: I chose, pretty early-on, not to look at the steam systems and one of the reasons was because, very early-on, it became apparent to me that the steam for the Living and Learning Center actually wasn't submetered and that it would be difficult to assess how much steam was being used, particularly because the north building has the kitchen. And, then, as the process went on and on and on, what we found out was that this situation was also the case with the electricity consumption, maybe to a different degree. But, I think that this goes back to that whole issue of metering and how difficult it is to assess how buildings are performing in terms of the utilities they are using, in terms of the metering. But definitely, I think that would have been really interesting to look at.

John Reynolds: You asked the students about turning off their computer. What are the devices that they wouldn't tend to leave on all night, like a computer, that you could ask them about?

Tom Collins: In my slide I just picked a few of the highlights, but I did ask, in terms of appliances, about a fairly wide range of appliances. I actually gave students the ability to type in additional appliances that they have in their room in an open-ended question format. So, there are a wide variety of appliances: I asked about things like: TVs, DVD players, desktop computers, laptop computers, mini-refrigerators, different sizes of mini-refrigerators, hair dryers, stereos, game systems. We tried to exhaust the list, although it's impossible to get everything. But, it's interesting, even with 15-20 different options, students did actually add other appliances in at the end. We got "hair dryer", "cup warmer", these different things. But, clearly I know that a lot of studies have focused on refrigerators. I know that there have been some studies at other universities that have looked at the issue of whether institutions promote students unplugging and defrosting their refrigerators when they go for break and how much energy is actually saved during those periods. I don't think that there is a similar program in place here, but clearly there are a large number of refrigerators. Almost every single room has a refrigerator.

John Reynolds: And that would be something that would potentially matter a lot during the nighttime, unlike a lot of the other appliances?

Tom Collins: Correct. That's definitely a big one.

Chris Stratton (graduate student): Have you seen other models at universities that are incorporating some of the conclusions that you came up with at the end of your project, schools that we should emulate?

Tom Collins: There appear to be a few schools in the United States that are pretty actively engaged at looking at energy consumption in dorms. There are extremely few studies that deal with comfort, student comfort, in residence halls. I think that it has to do with the difficulty of assessing comfort in residence halls, whether it be the intrusiveness issue or whether it has to do with the fact that these buildings are very compartmentalized. It's a lot easier to go into say an office space and survey and measure all of us in this particular room versus rooms two-by-two. It seems that there are not a lot of studies dealing with comfort, even though I think there should be. In terms of energy consumption, there are some schools that have been pretty interested in energy competitions. So, for instance, Oberlin, Williams College in Massachusetts; they have started these programs where they are trying to promote competition among students in terms of saving electricity. Usually it's done where every year there will be one month, the energy saving month. "How much energy can we save?" There's also been a fair amount of interest in creating dashboard systems in dorms. This is something that they built into the LLC Complex in terms of the ability to submeter electrical consumption in student rooms, plug loads in student rooms. I think that it was intended to be hooked-up to a dashboard system in the lobby so that students could see that "floor four is actually using more energy than floor three." It wasn't actually fully implemented, but in the new

dorm that they're planning on campus that's also part of the design. But, you're starting to see that. There are some universities that are interested in implementing that. They've had some collaboration with software engineers to develop ways of communicating that information, not just measuring but how students can access it online and things like that. Raising that level of awareness doesn't seem to have happened here yet, but hopefully it will.

Fred Tepfer: One of the great things about comparing these two buildings is that, in both cases, most of the rooms are either facing north or south. In your survey did you capture orientation?

Tom Collins: I did. This was actually a really difficult thing because I went through many different versions of the question. What we were afraid of is that if you ask people "what direction does your room face: north, south, east, or west" and they could only choose one, students may be confused because they don't know which way their room faces. We experimented with "what if you just let them select whichever ones they want?" If they wanted to, they could select "north" and "south;" if they had a corner room they could select "north" and "east." So, I did that. And, then I decided that students may not answer the question correctly because they may not actually know which direction they face. So, then I asked students: "If you don't know which direction your room faces, tell me a landmark that you can see from your window." So, I asked students that and then you get some people that say "when I look out my window I can

see Patterson Manor” or “I can see the athletic fields” or whatever. But, the problem became that when I tried to decipher how many of the respondents were living on different sides there was too much information. It started to become apparent that there were some people that, the way they answered it, you didn’t actually know whether they were facing north or south. This was something that I really wanted to look at and I was trying to find a way to measure it. But, one of the things I found is that students just don’t seem to know, they don’t know which direction their rooms face. It becomes problematic, but it would be interesting to try it again, try a different method and see if you could get better results.

John Reynolds: Another thing to deal with at orientation.

Tom Collins: Right, another thing to deal at orientation. I know that, for instance, in some studies I’ve seen the paper surveys provided a map. The survey would ask, “What side of the building is yours on?” and they would show the streets that are around it. In my survey, it was an online survey; I couldn’t really get into that level of detail. I think that it would have been interesting particularly if I was able to collect much more thermal and energy data in specific rooms. Then the ability to compare that data with the percentages of people facing north and south and east and west would have been really powerful. But, because I could only measure in three rooms in each building, I wasn’t sure how to make all of that work.

Fred Tepfer: One of the things that really struck me going through that was that, clearly, people open their windows. One of these buildings opens on to a major arterial. One of the given truths that we've always had is that people wouldn't open their window in that situation. You pretty well demonstrated that they would. If you have some directional data, even if it's poor, it might be interesting--give me your data and I might actually be interested in looking at that--to find out if it's really true because it upsets one of the givens, in my mind, pretty effectively. That people in residence halls won't open their windows on to a major arterial: it's too noisy, too dusty, it's too smelly. It's one of the things that mechanical engineers will tell you every time you mention the subject of operable windows.

Tom Collins: It's certainly not what the survey and the physical measurements found. One of the interesting things is that if we were to actually look at some more detailed information about the thermal conditions in some of the rooms that were measured on the north versus on the south, clearly the conditions on the north were cooler than on the south side because of the orientation. But, yet if you walk by any of these buildings on any given day, whether it be a warm day or a cold day, the windows are always open. It seems that students like the ability to open a window even if the conditions are a little bit colder. I don't know if it has to do with the fresh air that they're getting, but it seems to be a very popular action. It would be interesting to look at student rooms that have no access to an operable window, that were air-conditioned in a hot climate for instance.

Will Smith (undergraduate student): Is there any part of your study where you asked students if they thought their heating or cooling was working properly, performing at a level that would be expected? I know in our rooms half of our registers actually went too hot when they should have been—kind of you know how Pacific usually overheats?

Tom Collins: Well, we asked students a pretty wide range of questions about their comfort, different aspects of their comfort whether it be the control over their comfort, whether it be the perceptions of the conditions themselves—actions that they take in the presence of discomfort. We didn't specifically ask about whether people thought that the mechanical equipment was working properly. I think that maybe one of the reasons that I didn't do that was because I wasn't sure how valuable that information would really be. What you think might be mechanical equipment working properly might not be what I think. I wasn't sure if people would actually know how the equipment was supposed to be operating. It might be interesting to look at how some of those questions could be phrased. I did ask people "How frequently are your conditions hot, cold, damp, dry? Those types of things. People seemed to be able to respond pretty easily to that.

Alison Kwok: I'm just curious, the students that are in here, how many of you have lived in dorms? And, how many of you that have your hands up now live in apartments, have moved off-campus? See, you've got another survey group here. How have attitudes changed after the dorm experience to how you're living in your apartment? Do you tend

to save energy in your own apartment? I heard from Hiroshi who said, “We don’t even use the heat, we just turn everything off.”

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