THE INFLUENCE OF DESIGN, OPERATIONS, AND OCCUPANCY ON PLUG LOADS IN STUDENT HOUSING

by

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A DISSERTATION

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DISSERTATION ABSTRACT

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Plug loads—traditionally viewed as behaviorally motivated and beyond the control of designers and operations—are now seen as an integral part of achieving low-energy building targets. Higher education institutions are increasingly recognizing the environmental impacts of campus facilities through holistic approaches to energy savings including energy efficient design and occupant engagement. Residence halls are a compelling example because students bring large numbers of electronics to their rooms and have unlimited access to power for an all-inclusive room rate and resource usage competitions and campaigns are commonplace. However, limited research exists on residence halls plug loads.

This dissertation asked the following of residence halls: (1) What are the measured plug loads and how do they compare with design estimates? (2) What role do building design characteristics play in plug loads? (3) What are the specific occupant behaviors that could influence future design? (4) How can plug loads be better understood in terms of behavior, design, and operations? To answer these questions, a sequential mixed methods study included field measurements and student surveys in six residence halls on three Oregon campuses followed by 24 interviews with designers, operators, and students.

Findings suggest that plug loads in occupied residence halls are higher and usage profiles differ from design predictions. Results do not show significant correlations between design characteristics and plug loads but suggest that some room/suite level features may play a somewhat stronger role. Survey responses indicated that students are doing more with fewer smart devices, which suggests opportunities for students sharing energy intensive devices. Lighting emerged as both a practical and a social consideration. Finally, the data revealed “balance of power” as a coherent process that explicates the relationships between design, operations, and behavior. Designers have the power to recommend plug load strategies and technologies but are limited by costs, maintenance, and political concerns; operations personnel have the power to impose limits on student power usage but are often reluctant to interfere with the overall living experience; and students have the power to use plug load electricity with few restrictions. This suggests that the balance may be skewed toward student behavior.

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DEDICATION

To my wife Erica and my sons Adrian and Declan.
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CHAPTER I

INTRODUCTION

1.1. Topic Area

Institutions of higher education are increasingly recognizing the massive environmental impacts of their campus facilities and operations (Corcoran & Wals, 2004) and taking significant and strategic steps to address these pressing challenges through internal efforts (i.e. policies, green campus initiatives, and curricula) (Rappaport & Creighton, 2007) as well as participation in highly visible, external efforts such as the Presidents' Climate Commitment (Acupcc, 2015). The nearly 4,500 degree granting institutions in the United States ("College Navigator," 2014) are well-poised to tackle the complex problem of sustainability for several reasons: their primary mission is the education of students; their inherent stability and permanence routinely result in campus planning focused on long-term, life-cycle cost concerns (Calhoun & Cortese, 2006); and the academic setting encourages dialog and engagement in deeper social, cultural, technical, and ecological contexts (Rappaport, 2008). Prominent green campus advocates argue that higher education could and should become the model for an effective and integrated approach to sustainability in the future (Cortese, 2003).

The burning of fossil fuels for the heating, cooling, ventilation, and lighting of campus buildings represents a significant portion of institutional greenhouse gas emissions (Rappaport & Creighton, 2007), in some cases as high as 80-90% of overall emissions (Kinsley, 2009). Therefore, many colleges and universities target new and existing campus buildings as opportunities for energy efficiency improvements and the implementation of sustainable design strategies.

Residence halls are a compelling case study for energy-conscious campus facility design and operations because student residents: live and spend greater amounts of time there; bring their own electrical and electronic devices that are infrequently regulated by the university; and have access to power that they do not pay directly for. In addition, trends in residence hall design suggest increasing expectations for amenities, space, technologies, and systems (Abramson, 2012), which have energy-use implications for designers and facilities managers. Finally, designers and institutions now conceive modern residence halls as "living laboratories" where residents gain hands-on experience learning responsible resource use and conservation strategies rather than simply places to sleep.

1.2. Research Problem

The research gap underlying this dissertation is that there is a lack of knowledge about plug loads in residence halls, which limits how these facilities are designed and operated to address and satisfy institutional sustainability and carbon neutrality targets, goals, and commitments. The problem has technical and behavioral components.

From the technical perspective, residence hall designs have historically given priority to issues of efficiency (i.e. maximizing the number of student beds) and first-cost (minimizing the complexity of systems and equipment). As a result, residence halls have large numbers of student residents living in compartmentalized rooms or suites with very little energy metering or monitoring capabilities. As campuses move in the direction of low-energy, carbon neutral, and net-zero energy buildings designed to achieve specific performance and long-term energy use outcomes, it is critical to have more detailed information on energy end-uses that are not easily or typically metered or measured, such as plug loads.

From the behavioral perspective, residence halls have historically allowed students the freedom to bring their own electronic devices, provided unlimited access to power, and charged an all-inclusive room rate that includes utilities. As a result, residence halls have little control over student devices or usage and students lack an incentive to save energy because they do not pay directly for their electricity. Occupant behavior change can be an effective strategy to enhance energy conservation in residence halls, but it requires knowing what the student energy use behaviors are and how they vary among students, rooms, buildings, etc.

Architects and engineers need this information to inform predictions in their energy models that will be representative of actual building usage patterns and spatial organization that might influence use patterns. Facilities managers need this information to inform strategic energy efficiency enhancements to new and existing residence halls. Students need this information to make informed energy decisions. This research seeks to address the lack of information related to plug loads in residence halls by providing measured data and expanding the overall understanding of how building design, facilities management, and occupant behavior influence this measured usage.

1.3. Research Objectives

This dissertation has three primary objectives:

1. The first objective is to develop a field-based method capable of: measuring plug loads in buildings with limited capability of metering or monitoring electricity by

end-use; recording occupant subjective assessments of plug load energy consumption and conservation; and describing the processes that inform and influence the overall culture of electricity usage.

2. The second objective is to establish baseline plug load metrics for a series of residence halls to: inform benchmarks for the building typology, validate predicted performance used during the design process, and facilitate comparisons across spaces and buildings with different architectural characteristics.
3. The third objective is to explore how design, building operations, and occupant behavior influence, and are influenced by, plug loads in residence halls by illuminating the range of factors, attitudes, experiences, barriers, and opportunities at play.

1.4. Research Questions

This research addresses plug loads in campus residence hall buildings from the perspectives of: measuring plug load energy; calculating plug load metrics that describe power and energy usage in relation to building size, occupancy, and other characteristics; understanding occupant behavior with regard to using electricity from wall receptacles to power devices and appliances; and describing how plug loads influence and are influenced by design, operations, and occupancy.

The following research questions apply to any residence hall building to examine and assess plug loads as an energy end-use:

1. What are the baseline metrics for plug load energy in residence halls and how closely do plug load metric design predictions reflect the actual metrics from data in occupied buildings?

2. How important are building design characteristics or factors on plug load energy usage in residence halls?
3. What are the specific target occupant behaviors that could influence or inform future design and energy conservation efforts in residence halls?
4. How can the culture of plug load usage in residence halls be better understood in terms of the influence and interactions between design, building operations, and occupant behaviors?

1.5. Hypotheses

Two hypotheses inform the quantitative phase of this research:

1. The assumptions used to predict plug load electricity usage in residence halls during design energy modeling are lower than plug load electricity measurements and estimates taken in occupied residence halls.
2. There are strong correlations between building design characteristics and plug load energy use in residence halls.

The qualitative phase of the dissertation is not framed by any preconceived hypotheses, which is consistent with methodological approaches in the field that focus on an inductive approach where theory emerges from the narratives of participants (Charmaz, 2000, p. 512).

1.6. Theoretical Model

This dissertation proposes a theoretical model for conceptualizing the context of energy use in campus residence halls. (See Figure 1.1) The model suggests that the *context of energy use*, here defined as the interrelated conditions of energy consumption in a specific building or space, are influenced by three realms: behavior, consisting of building occupants, their attitudes, and their actions; operations, consisting of facilities managers, building administrators, and sustainability officers; and design, consisting of architects and engineers.

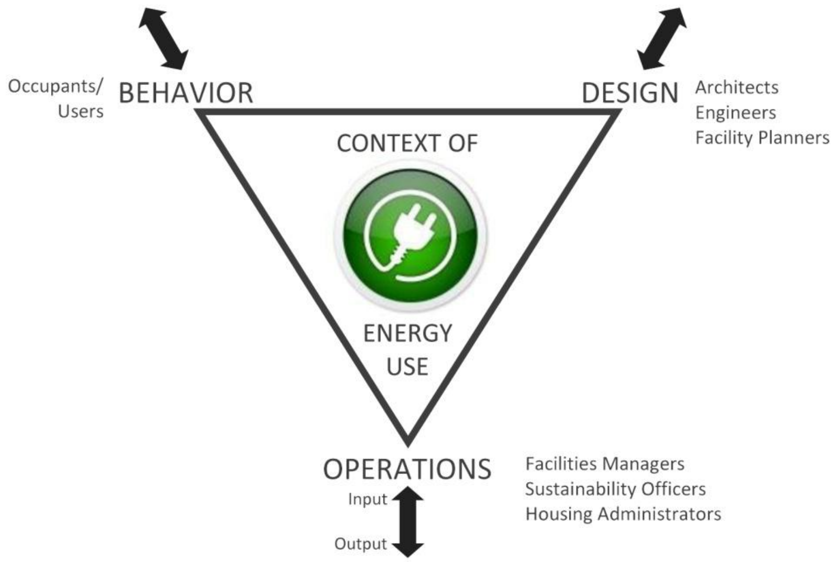


Figure 1.1: Theoretical model for conceptualizing
the context of energy use in residence halls

Typically, these three realms are conceptualized as stages in the process of achieving optimal building performance and emphasize a cyclical, closed-loop relationship between the parts. The premise of this approach is that information gathered during the operation and occupancy of a building makes its way back to the design team to inform and improve future design work. This new model builds upon the existing model by acknowledging that processes and actors are involved in influencing building performance outcomes.

1.7. Approach

This research used a sequential mixed-methods design and included: preparatory work related to evaluating potential study sites, a preliminary quantitative field study phase in residence halls, and an interview phase with residence hall stakeholders:

Quantitative Field Study: Phase I examined plug load energy in six residence halls on three Oregon campuses. Student self-audit surveys; spot metering in student rooms; and electrical panel metering were the plug load data collection methods. The data described energy consumption patterns as well as student perceptions, preferences, and actions with regard to electricity use.

Qualitative Interviews: Phase II expanded upon the Phase I field study and examined plug load energy in residence halls through interviews with three student housing stakeholder groups: student occupants; housing operations and administrative personnel; and building designers such as architects and engineers. A total of 24 interviews (30-40 minutes in length on average) were transcribed, coded, and analyzed using qualitative analysis techniques and software and revealed emergent themes in and among the participant narratives.

1.8. Relevance

Buildings play a disproportionately large and critical role in helping campuses achieve fossil fuel emissions reductions and carbon neutrality goals. Low-energy design can dramatically reduce: building loads (heating, cooling, lighting, plug loads, etc.), which can, in-turn, reduce the need for energy-intensive mechanical and electrical systems and equipment. However, as long as building occupants have access to power, predicting plug loads during the design process and managing plug loads during occupancy will remain challenges that can adversely affect energy goals and outcomes. This problem is, perhaps, most acute in residence halls because students have relatively few restrictions on power usage and the devices they bring with them to their rooms. However, there is very limited information available on plug loads in residence halls with regard to the intersection of design, facilities management, and occupancy patterns. The literature review will address the broader context.

Architects, engineers, and energy modelers routinely use assumptions about occupant energy use patterns of the spaces that they are designing. This may result in ineffective design solutions to satisfy occupant needs and/or inaccurate performance predictions used to inform state or green building energy compliance. Since many designers of residence halls specialize in this building type and often do repeat work for higher education clients, plug load data from buildings-in-use could inform their future design work and allow them to make more reliable energy predictions.

Campus operations personnel typically interact with residence hall plug loads indirectly through efficiency upgrades, maintenance, or monthly meter readings. The sheer number of buildings in campus portfolios often means that metering capabilities are limited. Therefore facilities managers often have only anecdotal evidence of plug load usage in their buildings. Plug load data from occupied buildings could inform ongoing operations and decision-making for future energy-efficiency measures.

Campus housing and sustainability offices actively use residence halls as sites for energy conservation efforts that aim to reduce energy expenses, connect with campus sustainability goals/commitments, and educate students for future life outside the university. Although well-intentioned and based on sound psychological constructs (i.e.

pledging, commitments, and social influence), these efforts rarely identify specific behaviors or energy usage patterns to target. Plug load data from occupied buildings could inform future occupant engagement strategies to enhance energy conservation.

Although residence halls have been and continue to be a popular study setting for research, this dissertation is the first comprehensive investigation of plug loads in this building type. As such, the research will contribute to the growing body of knowledge related to: plug loads in other building types (offices, residences, schools); energy awareness and behavior change efforts in student housing; and the role of plug loads in building design and operations.

1.9. Expected Outcomes

The expected results of this study are to:

1. Provide plug load measurements and metrics for residence halls to inform building design and management, and to form the basis for future comparisons across campuses, in other geographic regions, and potentially with other building types
2. Document the range of student plug load energy use behaviors that may prove useful for designers, housing administrators, and facilities managers
3. Explain the relationship between student plug load energy design characteristics as a way strengthening the idea that plug loads are within the realm of what designers can influence in their work

4. Illuminate and describe the ways in which design, operations, and occupancy influence, and are influenced by, the context and culture of electricity usage in student housing

1.10. Scope & Limitations

The scope of this study encompasses student energy use for devices plugged into wall receptacles. This includes small appliances (i.e. refrigerators, microwaves, etc.), personal electronics (i.e. notebook computers, smart phones, TVs etc.), personal care devices (i.e. curling irons, hair dryers, etc.), and lighting (task and decorative). The scope does not include commercial kitchen or laundry equipment.

This study acknowledges the relationship between hardwired devices (building lighting, ventilation fans, HVAC units, etc.) and non-hardwired devices allocated to plug loads in the student surveys, which include questions related to lighting preferences, etc. However, the scope of this study does not include the measurement of these hard-wired devices or factors of the heat implications of non-hardwired devices (plug loads) on other building loads (i.e. cooling loads for air-conditioning).

At each field site building, it was not possible to measure plug loads for the entire building for three reasons: building sizes and configurations (large numbers of rooms/suites/apartments and electrical panels); practical limitations associated with the cost of renting monitoring equipment; and the lack of a single point or meter served all receptacle circuits for the building. Therefore, a more practical alternative was to select representative spaces. Chapter III describes the data collection methods.

The plug loads calculated from the student self-audit inventories and usage times relied on self-reported information from building occupants. Furthermore, students were not required to provide name-plate power ratings for each device they listed. Therefore, the calculations used power estimates for various types of electronic devices. However, at a fine-grained level this approach does not distinguish between different devices of the same type (i.e. Apple MacBook Air and Dell Inspiron notebook computers), which are likely to have different peak wattages and different power saver wattages and functions.

It was not possible to arrange for the same student resident to be included in the panel-level metering, the spot metering, and the survey due to limitations with access to the student populations living in the buildings. Nevertheless, some overlaps occurred.

Finally, the instructions for the spot metering volunteers was to plug-in all of the devices they personally own and to plug-in and unplug devices as need be. The intention was that students measure all of their personal electronic devices within reason. However, there was no provision made for the volunteers to inventory which devices they plugged-in and it was impossible to verify if there were other devices or shared devices between roommates that were not included.

It is important to note that these limitations likely impact the accuracy of the results. However, the methodology favored including as many student residents in the study sample as possible, which simply would not have been possible with fine-grained audits performed by the researcher in individual student rooms.

1.11. Organization of the Dissertation

Chapter II: Literature review related to sustainability in higher education, student housing, and plug load energy

Chapter III: Research methods employed in the study including the research design, the data collection and analysis techniques, and the measurement equipment used

Chapter IV: Quantitative analysis of Phase I field study including descriptive and inferential statistics and energy end-use metrics

Chapter V: Qualitative analysis of Phase II interviews including emergent coding, emergent themes, analytic categories, and a coherent process

Chapter VI: Discussion of the results with respect to the questions and hypotheses

Chapter VII: Conclusion and suggestions for future research based on the field study and interview results of this dissertation

CHAPTER II

LITERATURE REVIEW

2.1. Introduction

There is limited literature related to the specific focus of this research: plug load energy in campus residence halls. However, a diverse body of literature exists that informs this research area. The purpose of this literature review is to frame this study within the broader context of issues including: campus sustainability, residence hall buildings, and plug load energy.

2.2. Campus Sustainability

2.2.1. Approach

Much has been written about sustainability in higher education institutions, including a number of useful texts that describe the multifaceted process of addressing environmental problems and provide recommendations to help institutions make progress in these areas (Creighton, 1998; M'Gonigle & Starke, 2006; Rappaport & Creighton, 2007; Simpson, 2008).

Campus sustainability began in the 1970s, but it wasn't until the 1990s that institutions began drafting and signing sustainability declarations (Wright, 2002, 2004). Many institutions are now conceptualizing campus sustainability issues within a broader, holistic campus framework (Koester, Eflin, & Vann, 2006; Sharp, 2002), which include high-level commitments from the administration, ambitious long-term carbon neutrality goals, specific short-term "tangible actions," and the tracking of progress toward goals (Acupcc, 2015; Martin, 2011; Wright, 2010).

2.2.2. Motivations

Advocates of campus sustainability efforts argue that educational institutions must solve problems related to their environmental impact, but that they also have a responsibility to model sustainability in a way that contributes to their educational missions, engages the campus community, and prepares students for future environmental stewardship (Cortese, 2003; Hales, 2008). Sustainability in this context is concerned with cultural change on campuses in response to environmental, social, and economic goals and problems. It seeks to address how the existing culture of institutions either presents a barrier to change or fosters engagement and actions that contribute to a more sustainable future (Orr, 2006; Rowe, 2007).

2.2.3. Impact of Facilities

Buildings can account for as much as 80-90% of carbon emissions at colleges and universities (Kinsley, 2009, p. 24) and much attention has been paid to greening campus facilities. One trend has been the incorporation of green building rating systems (i.e. LEED) into campus green building policies (A. Cupido, Baetz, Pujari, & Chidiac, 2010; A. F. Cupido, 2011).

2.3. Residence Halls

2.3.1. Student Housing Research

In recent decades there has been renewed interest in student housing, particularly with the notion that housing should be connected to the academic mission of colleges and universities (Winston & Anchors, 1993). Students living in residence halls have long been used for research focused on issues including social dynamics (Festinger, 1950;

Moos, Van Dort, Smail, & DeYoung, 1975; Sommer, 1969); student learning (Bringer, Johnston, & Brackenridge, 2006; Shushok, Scales, Sriram, & Kidd, 2011); predictors of student satisfaction (Foubert, Tepper, & Morrison, 1998); spatial configuration (Devlin, Donovan, Nicolov, Nold, & Zandan, 2008; Van der Ryn & Silverstein, 1967); and sense of place and community (Berger, 1997; Clemons, McKelfresh, & Banning, 2005).

2.3.2. Design Trends

Over the past decade, there has been a significant trend toward green residence halls designed to meet green building standards, connect with campus sustainability commitments, and provide opportunities for sustainability education (Dunkel, 2009). Increasingly, these green halls are using the building and its features as learning laboratories (Fabris, 2011). New residence halls feature energy saving technologies and better controls for occupants, and as such are a departure from the mid-century dormitories prevalent on campuses (Ellis, 2006). (Fig. 2.1)

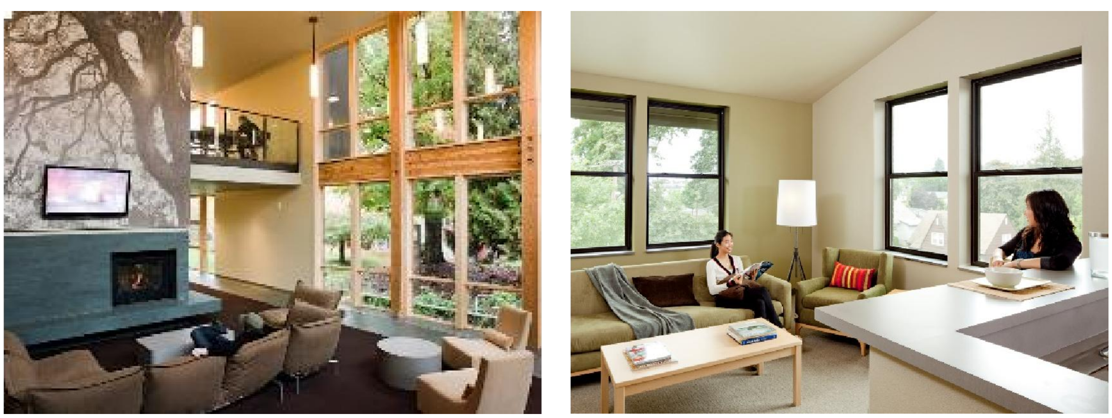


Figure 2.1: Contemporary residence hall interior spaces: communal lounge (left) and residential suite lounge (right). (Photos courtesy of Lincoln Barbour)

The 2014 College Housing Report suggests the following trends based upon their annual survey. Private institutions build smaller halls than public institutions (79,000 sf vs. 134,000 sf on average). Double rooms housing two students appear to account for nearly half of the students living in residence halls. The occupancy of new halls ranged from 50-1500 beds (340 beds on average). The cost per student bed in new residence hall construction is on the rise and the average building cost is $34 million (Abramson, 2014).

2.3.3. Student Engagement

Colleges and universities appear to be focusing many of their sustainability efforts on student engagement in residence halls. The most common examples of such engagement include: themed housing options (eco-houses, sustainability floors, green/LEED certified halls, etc.); utilizing eco-reps to help residents learn and implement green habits and practices; providing model rooms that demonstrate sustainable options for incoming students; incorporating sustainability into new student orientation; and hosting competitions (recycling, water reductions, energy conservation, etc.) (Collins, 2013; Erickson & Skoglund, 2008).

2.3.4. Energy Conservation

One recent study looked at the effectiveness of different electricity conservation strategies over several terms and found that consumption reductions in residence halls can be achieved even when financial incentives are absent (Tammy, Younos, Grossman, & Geller, 2013). Another study discussed specific types of electricity usage in residence halls (i.e. plug loads), but focused on a wide variety of campus building types (Andrews, Easton, Johnson, Sabo, & Simpson, 2006). A small study inventoried student devices as a way of estimating student energy usage and behavior (Steingard, 2009).

2.3.5. Energy Feedback

Studies suggest that providing feedback to energy consumers can be effective in raising awareness and reducing consumption (Darby, 2001, 2006, 2008). A number of studies examine the use of energy feedback in campus residence halls with a particular emphasis on using emerging technologies to engage students in conservation efforts such as competitions. One noteworthy study takes a comprehensive and experimental approach by examining the effectiveness of combining varying types of socio-technical feedback combined with incentives in reducing student consumption. Findings suggest that more detailed "high-resolution" feedback produced the greatest savings. These savings ranged from 31-55% overall. Also, students reported through surveys that they intended to continue savings patterns even in the absence of the feedback (Petersen, Shunturov, Janda, Platt, & Weinberger, 2007).

Since feedback systems, sometimes called dashboards or eco-visualization tools, are relatively new to the market, several papers have focused on the technical aspects of designing systems and interfaces to provide energy or resource usage information (Brewer, Lee, & Johnson, 2011; Odom, Pierce, & Roedl, 2008).

In the absence of technologies to provide real-time energy feedback to students, at least one housing office created simulated utility bills and tickets for energy hogs to raise awareness and spur competition between residents (Nearing, 2011).

2.4. Plug Loads

2.4.1. Background

Energy consumption in buildings can be broken-down into various energy loads or the energy used for specific end-uses such as heating, cooling, lighting, ventilation, equipment, and plug loads. Plug loads differ from other loads because they result from electrical devices plugged into receptacles rather than hard-wired into the buildings. Research shows that plug loads can represent a significant percentage of building electricity use in buildings and offer opportunities for harnessing energy savings (Lobato, Pless, Sheppy, & Torcellini, 2011; Metzger, Kandt, & VanGeet, 2011; Murray & Mills, 2011; USDOE, 2013). Additionally, Moorefield suggests that plug load energy consumption has grown from 800 billion kWh in 2005 to projected estimates of 1,100 billion kWh in 2015 and 1,500 billion kWh in 2030 (2011), an upward trend.

2.4.2. Regulation

Plug loads are often viewed as "unregulated, meaning these loads traditionally do not come under the influence of design decisions, as do the main building systems" (Hootman, 2013, p. 353). However, emerging standards, codes, and building policies play critical roles in influencing plug load usage in buildings.

Article 210 of the National Electrical Code (NEC) addresses branch circuits for receptacles in dwelling units. Receptacles must be spaced such that no point measured horizontally along a wall may be more than six feet from a receptacle and two feet along a wall countertop. In addition, the placement of receptacles must avoid contact between a bed and plugged-in devices. (NFPA, 2013).

California's Title 24 energy code now requires plug load controls (i.e. switchable receptacles tied to an occupancy sensor (See Fig. 2.2)) and the ability to meter plug load end-uses separately (CEC, 2012). The current trend appears to be pointing toward stricter regulation of plug loads.

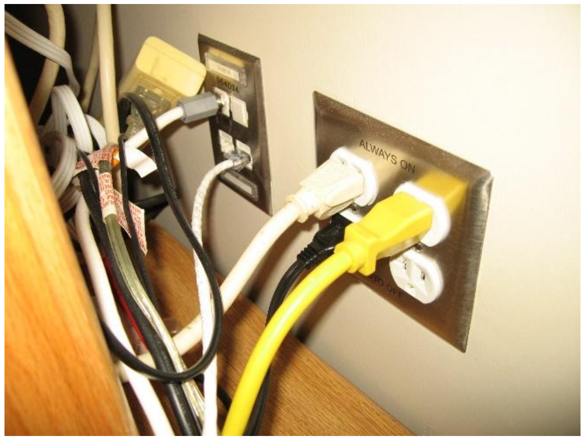


Figure 2.2: Switchable outlets tied to an occupancy sensor
(Photo courtesy of Mahlum Architects).

Building owners are also beginning to regulate plug loads in-house. The Bullitt Center in Seattle: established plug load budgets for tenants of 7.03 kbtus/sf/yr or 2.06 kWh/sf/yr); provided guidelines for energy efficiency and smart power strips to track energy usage; and made provisions for an internal cap and trade system (Azari-N & Peña, 2012, p. 5).

2.4.3. Measurement & Metrics

Power (watts) and energy (watt/hours or kilowatt/hours) comprise the basic units of plug load measurements. Plug load power density represents the "potential" or peak power per square foot of building area (watts/square foot or w/sf) and is the most commonly used plug load metric in building design. Other common metrics include: kWh/sf, kWh/sf/year, and kbtus/sf/year (plug load energy use intensity or EUI).

Wilkins and Hosni describe plug loads in terms of load factors (i.e. w/sf) and diversity factors (energy usage patterns). Usage patterns form the basis for plug load profiles or schedules that describe the percentage of the peak load at various times of day (Wilkins & Hosni, 2011).

Standby, phantom, or vampire power are one type plug load use. Standby power occurs when electronic devices are in “ready” mode, which allows for instant usability, but consumes power (LBL, 2015; McGarry, 2004). The terms phantom or vampire loads are sometimes used synonymously with the term standby power, but typically refer to power used by a device when it is powered off (Rivas, 2009).

Inventorying and monitoring specific devices is common and can be useful in identifying low/no cost savings potential, but can be time-intensive (Harris & Higgins, 2013; Mercier & Moorefield, 2011). One study found that students at Ithaca College effectively conducted plug load equipment audits and self-reported their findings, which reduced the time commitment and logistical challenges for operations personnel (Andrews et al., 2006). Several studies have effectively used energy management system capabilities designed into the buildings to meter and monitor plug load end-use (Harris & Higgins, 2013; Metzger et al., 2011; Torcellini, Pless, Lobato, & Sheppy, 2011).

The existing plug load research demonstrates the complexity of measuring and demonstrating electricity savings when building metering does not facilitate the disaggregation of plug load end uses. The literature also highlights an opportunity to harness greater plug load savings in existing buildings through occupant behavior change strategies and/or energy management systems.

2.4.4. Benchmarks

Crowe suggests that plug load benchmarks for specific building types remain elusive (2013). However, Mercier and Moorefield suggest a benchmark of 0.7-1.3 kWh/sf/year for commercial buildings, and acknowledge that there are multiple ways to measure plug loads and that equipment density may be a more useful metric (2011).

The Cascadia Center for Sustainable Design established a 0.8 w/sf goal for the Bullitt Center (Hayes, Court, Hanford, & Schwer, 2011). In stark contrast, plug load assumptions used in an energy model for the design of a residence hall at University of Washington predicted student room plug load densities of 4.5 w/sf (PAE, 2011). This prediction suggests that plug load metrics are critical for accurate building energy simulation during the design process (Srinivasan, Lakshmanan, & Santosa, 2011). Plug load metrics can also be useful in time of day/week and peak-load metrics. However, occupancy density in addition to power density may be a useful metric to examine in future research (Harris & Higgins, 2013).

2.4.5. Plug Loads & Design

Traditionally, the building design industry has viewed plug loads as problematic because they result from unpredictable user actions that can be difficult to control. However, there is a growing recognition that plug loads are a critical factor in the design and operation of low-energy buildings and dominate the energy profile in buildings targeting net zero energy when other building loads are dramatically reduced (Kaneda, Jacobson, & Rumsey, 2010). The Bullitt Center provides a useful example where plug loads are estimated at nearly 50% of the overall energy use for the building (Nelson, 2013). In effect, greater systems efficiencies reduce overall building loads, but often leave plug loads relatively unchanged. With the reduction of overall energy usage, plug loads become a larger piece of the pie.

2.4.6. Building Type Studies

Plug load studies tend to focus on commercial office buildings. Fewer studies exist for institutional building types such as schools (Srinivasan et al., 2011), campus buildings (Andrews et al., 2006), or specifically for residence halls (Anderson, Cunningham, Damon, & de Angel, 2009; Andrews et al., 2006; Steingard, 2009; Zimmerman & De Angel, 2013).

2.4.7. Implications for Residence Halls

The results of interventions to reduce plug loads appear mixed. Kaneda et al. suggest that the barriers to reduction may be primarily behavioral and not technical (2010). However, Mercier and Moorefield found that simple occupant behavior measures saved only 6% on average (2011). Metzger et al. found that automated energy management systems were the most effective savings strategy and that educating occupants had negligible effects. However, studies acknowledge that, in the absence of a sophisticated automation system, behavior change using occupant competition may be the most cost effective strategy (2011). Andrews et al. and others recommend low-cost operational improvements through power saving settings on devices, somewhere in between systems-level and behavioral approaches (2006).

Standards and codes play critical roles in influencing plug load usage in buildings. Article 210 of the National Electrical Code (NEC) addresses branch circuits for receptacles in dwelling units (including dormitory bedrooms) (NFPA, 2013). These requirements suggest that the total number of receptacles in student rooms increase as room sizes increase (greater wall area) and are fitted with more amenities such as kitchenettes and bathrooms. Greater numbers of receptacles suggests greater occupant access to power. However, it is unclear what impact this increase in receptacles has on the total cord and plug-connected loads in spaces.

In addition, California's Title 24 energy code requires plug load controls and sub-metering for plug loads (Commission, 2012). Ackerman Hall at Western Oregon University employed switchable outlets tied to room occupancy sensors, but an experiment at Bridgewater State University determined that occupant behavior could effectively achieve the same results at no cost (Zimmerman & De Angel, 2013). Nevertheless, designers and campuses are considering including plug load management technologies and controls in their residence hall projects including: European hotel-style key cards for power access, switchable outlets, and USB charging outlets. In addition, some campuses are now requiring students to purchase energy-efficient appliances from approved vendors.

Finally, plug loads have a significant impact on the design of carbon neutral and net zero energy residence halls, where dramatic load reductions minimize the need for renewable energy generation. The architecture firm Perkins + Will conducted several pilot studies for net zero energy residence halls in which they model scenarios for student device and appliance energy usage based on estimates in order to evaluate the feasibility of achieving a net zero energy goal. In the standard scenario, plug loads accounted for 34% of total electricity usage. In the Energy Star scenario, plug loads accounted for 31% of the total electricity usage. They also estimated that the annual plug load consumption per student could be reduced from 846 kWh/yr to 560kWh/yr, a 34% reduction (Anderson et al., 2009). In their second net zero pilot study, Perkins + Will proposed spatial solutions to address plug loads such as shared kitchenettes with secure access and recommended policy changes to the university that restricted students from bringing mini-refrigerators (Zimmerman & De Angel, 2013).

2.4.8. Conclusion

The review of literature reveals limited research on plug loads in residence halls. However, research on campus sustainability and green building efforts suggests that occupant energy usage plays an important role in energy and carbon emissions reductions for institutions. In addition, research on plug load measurement and benchmarks for other building types and settings provides a useful precedent for the collection of plug load data in residence halls.

CHAPTER III

METHODOLOGY

3.1. Research Approach

This research used a sequential mixed-methods strategy with a quantitative data collection phase followed by a qualitative data collection phase. The preliminary quantitative component informed and expanded upon the subsequent qualitative exploration.

Mixed methods were the most suitable approach to answering the research questions asked in this inquiry because: they enabled the use of quantitative methods to directly measure plug load electricity consumption and patterns of usage and qualitative methods to explore plug load energy through interviews with a variety of student housing stakeholders. Because mixed methods seek to maximize the inherent strengths of different methods and minimize their non-overlapping weaknesses (Johnson & Turner, 2003, p. 299), they offered considerable flexibility to tailor the research design to suit practical and procedural considerations and to provide a breadth and depth of information in the focus area.

3.2. Research Design

The research design relies on Morgan's *Priority Sequence Model* with a preliminary quantitative component followed by a follow-up qualitative component. This model relies on two assumptions: sequential use of methods (one following the other rather than concurrent or simultaneously) and priority (a principal method paired with a complementary method). (See Figure 3.1)

A review of literature related to mixed methods research and architecture or building energy yielded surprisingly few results. One exception was Brandon and Lewis' sequential mixed methods study in which energy data collection was followed by interviews that examined demographic nuances within the sample (1999), which provided a useful methodological precedent for this study.

Priority Decision

Sequence Decision

	Quantitative Method	Qualitative Method
Complimentary Method Prelim.	1. Qualitative preliminary qual > QUANT	2. Quantitative preliminary quant > QUAL
Complimentary Method Follow-up	3. Qualitative Follow-up QUANT > qual	4. Quantitative Follow-up QUAL > quant

Figure 3.1: Morgan's Priority Sequence Model

3.3. Field Study Sites

Six residence hall buildings on three higher education campuses in Oregon comprised the field study sites for this research. These sites provided access to populations of student residents for surveying purposes, allowed for the collection of physical plug load energy measurements, and formed the basis for interview recruitment. (See Figure 3.2)

3.3.1. Selection Criteria

For practical and logistical reasons, the field study focused on the Pacific Northwest Region of the United States and a series of filters based on national higher education trends and statistics helped to narrow the pool and identify suitable study sites. There are 4,495 degree granting institutions in the United States and 2,774 of these are four-year degree granting institutions ("College Navigator," 2014). Research suggests that the four-year degree institutions are responsible for the vast majority (95%) of new student housing construction (Sagaser, Balogh, & Thompson, 2012). Among the 2,774 four-year institutions, approximately 25% are public and 75% are private. Within the Pacific Northwest region (Oregon and Washington), there are 100 four-year degree-granting institutions and the public/private distribution is similar to the national distribution (29% public and 71% private). Among these 100 institutions, 50 provide student housing ("College Navigator," 2014).

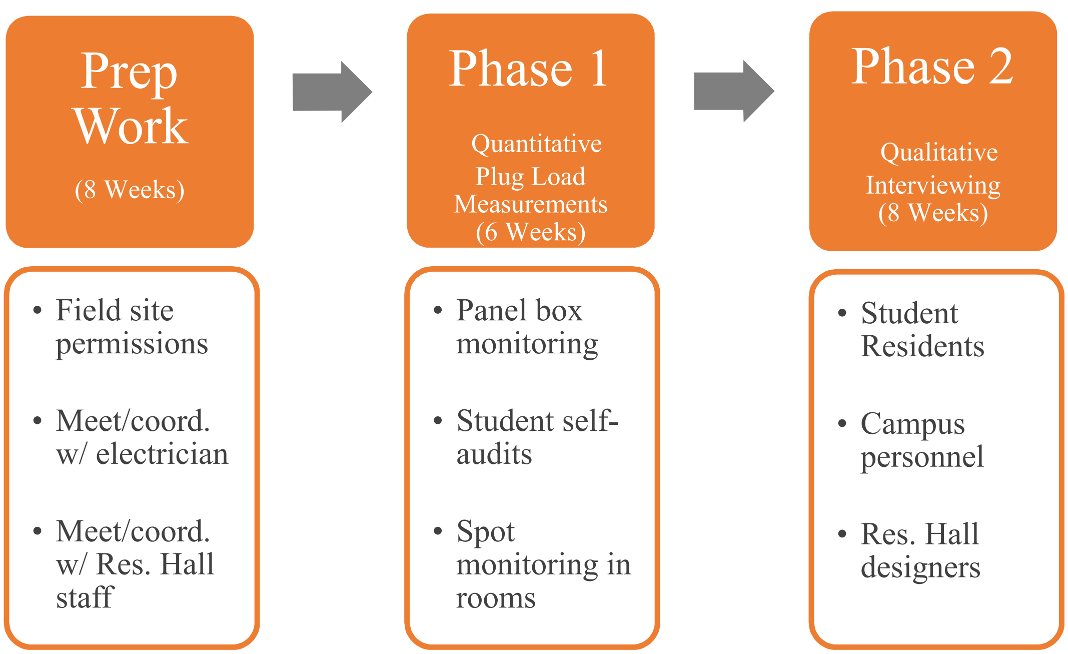


Figure 3.2: Phases of the study

Applying additional filters based on the research topic area further narrowed the field site pool. These filters were as follows:

1. Institutions with public commitments to sustainability as demonstrated by participation in either: (1) the American College and University Presidents' Climate Commitment or (2) the AASHE Sustainability Tracking, Assessment, and Reporting system (STARS).
2. Institutions with new or renovated residence halls no more than 10 years old, which was necessary for consistent and accurate documentation of building conditions, design, and systems.
3. Institutions with residence halls (traditional rooms, suites, or suite-style apartments) rather than separately metered apartments.

3.3.2. Permissions & Coordination

Before beginning the data collection, the IRB at the researcher's home institution approved the research procedures. The researcher then contacted campus housing administrators and sustainability directors via e-mail and phone to explain the purpose of the study and to ask for their participation. In general, reception to the study was quite favorable; however, since each institution and housing office had its own rules and policies regarding research in student housing and since a variety of campus personnel would need to assist with the data collection activities, obtaining formal approvals took many weeks of conversations and coordination. For example, the housing director signed the formal approval, but the residence life staff had to agree to provide access to the buildings and assistance with contacting students, the facilities department had to agree to allow their electricians and other personnel to assist, etc.

Three obstacles emerged that prevented several campuses from participating in the study: (1) the proposed data collection schedule (April-June) was too close to the end of the academic year (i.e. semester schools end in early May); (2) campuses had several other studies occurring in the residence halls and feared that students would be over-surveyed; and (3) the approved IRB protocol from the researcher's home institution was not sufficient for the IRB at the study site institution and required an new submittal.

3.3.3. Schedule

The study occurred in two phases. Phase I included physical measurements and student surveys and took place over approximately 6 weeks (April 28 to June 10, 2014). Phase II included interviews with students, designers, and campus housing and operations personnel and took place over approximately 8 weeks (July 23 to September 26, 2014). Field study data collection occurred before the end of the academic year at each field site institution when students were living in the buildings. Interview data collection occurred over the summer when students were no longer living in the buildings, but included students that had been living in the buildings during the field study phase. One disadvantage of this arrangement was that some students who volunteered to participate in during the school year were no longer interested in participating once they had moved out of the residence halls and were on summer break.

3.3.4. Field Site Institutions

A review of college and university housing websites identified 12 suitable campuses that met the aforementioned selection criteria. Further examination of institutional academic calendars, specific building characteristics, and the presence of at least two possible buildings to examine on each campus resulted in the selection of three field study sites well-suited for data collection: Southern Oregon University, University of Oregon, and Pacific University. Field site buildings were assigned a code (i.e. Building 1) rather than being identified by name in the analysis. (See Table 3.1)

Table 3.1: Field Site Institutions & Buildings

	Southern Oregon University		**University of Oregon**		**Pacific University**	
Location	Ashland, OR		Eugene, OR		Forest Grove, OR	
Private/Public	Public		Public		Private	
Enrollment	24,548		6,140		3,600	
Building	Shasta	McLoughlin	LLC	GSH	Burlingham	Gilbert
Architect	SERA	SERA	ZGF	ZGF	Mahlum	Mahlum
Electrical Engineer	Insite Group	Insite Group	PAE	Balzhiser Hubbard	Interface Engineering	PAE

3.3.5. Field Site Buildings

Shasta Hall:

Completed in 2013, Shasta Hall at Southern Oregon University is part of the new North Campus Village that includes McLoughlin Hall and a dining facility arranged around a landscaped quad. (See Fig 3.3) Shasta Hall is a 4-storey, 105,000 square foot, LEED NC Silver certified facility that includes 430 student beds in 135 single or double semi-suites that share a private bathroom. (See Figs. 3.4. & 3.5) Sustainable design features include a solar PV array. The buildings are air-conditioned.

Figure 3.3: Shasta Hall Exterior

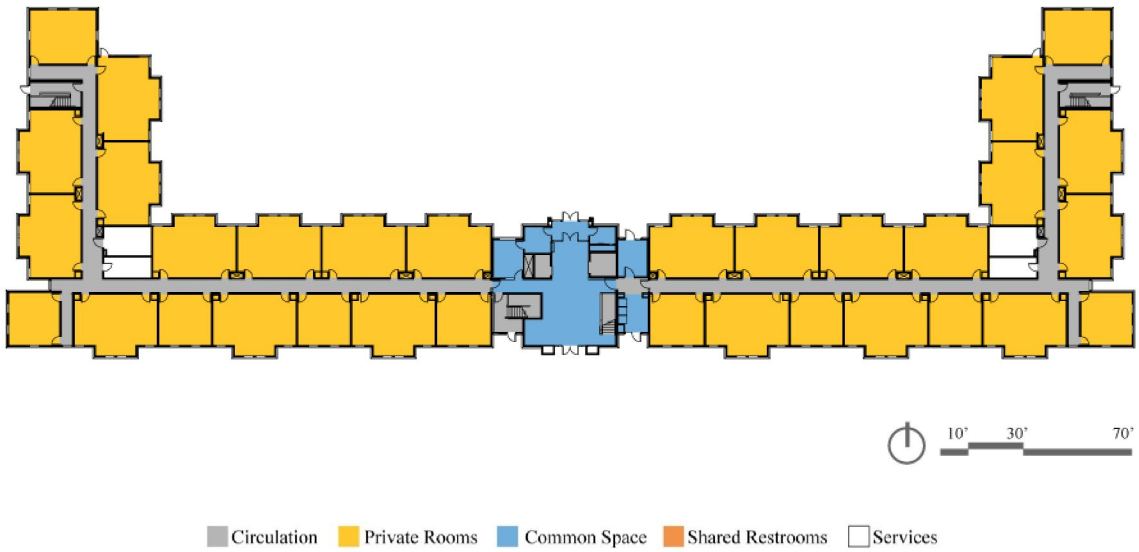


Figure 3.4: Shasta Hall Typical Floor Plan

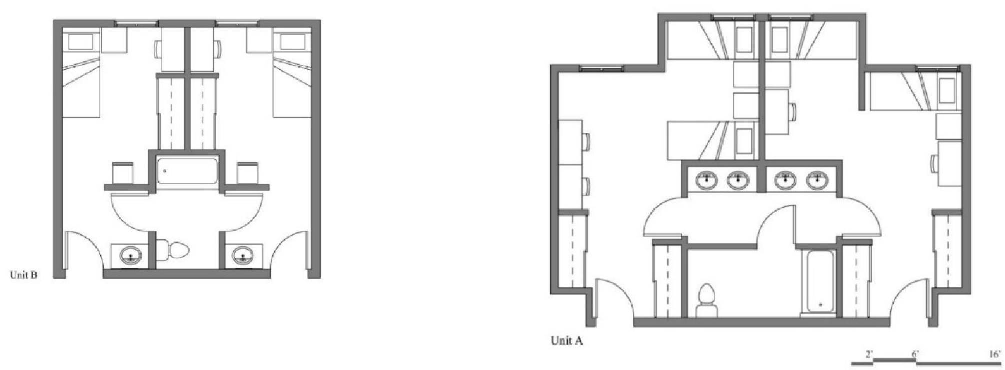


Figure 3.5: Shasta Hall Unit Plans: double rooms sharing a bathroom (above), single rooms sharing a bathroom (below)

SERA Architects and Insight Engineering designed the complex and worked with American Campus Communities and SOU to develop the project. SOU students are not permitted to bring their own mini-fridges or microwaves. Shasta Hall residents must lease or purchase an energy-efficient unit with a load-shedding feature from an approved vendor (MicroFridge, 2015; SERA, 2015; SOU, 2015a, 2015b; Wheeler, 2013).

McLoughlin Hall:

Completed in 2013, McLoughlin Hall at Southern Oregon University is part of the new North Campus Village that includes Shasta Hall and a dining facility arranged around a landscaped quad. (See Fig. 3.6) McLoughlin Hall is a 4-storey, 89,400 square foot, LEED NC Silver certified hall includes 230 student beds in 78 suites-style apartments. (See Figs. 3.7. & 3.8) The apartments have single or double bedrooms, private or shared bathrooms within the units, and a common living space with a kitchen. Sustainable design features include a solar PV array. The buildings are air-conditioned. SERA Architects and Insight Engineering designed the complex and worked with American Campus Communities and SOU to develop the project. Residents are provided with a full-size refrigerator and a microwave in their kitchens (SERA, 2015; SOU, 2015a, 2015b; Wheeler, 2013).

Figure 3.6: McLoughlin Hall Exterior

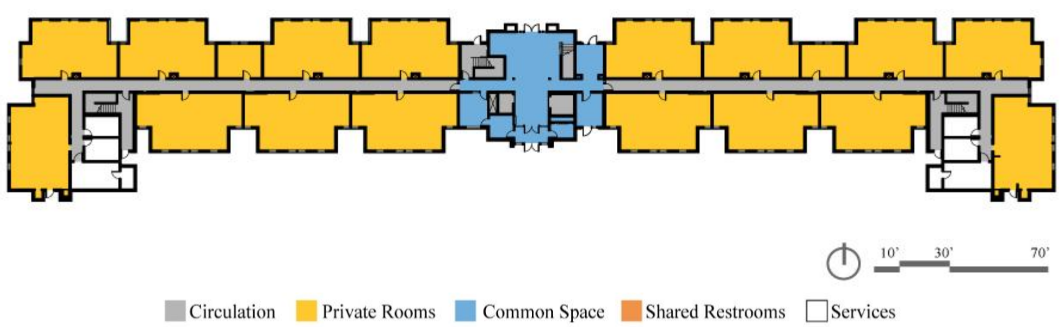


Figure 3.7: McLoughlin Hall Typical Floor Plan

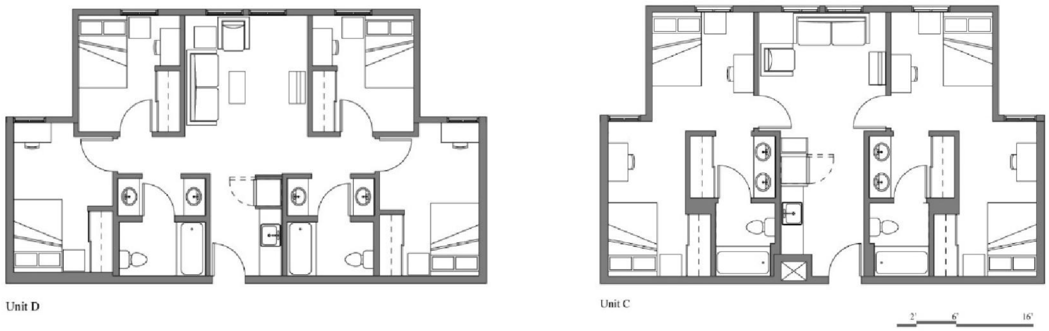


Figure 3.8: McLoughlin Hall Unit Plans: double bedroom suite (left), single bedroom suite (right)

Living-Learning Center:

Completed in 2006, Living-Learning Center (LLC) at University of Oregon is a 120,000 square foot facility that includes 400 student beds in double and single room configurations with shared floor bathrooms. (See Figs. 3.9, 3.10. & 3.11) The complex consists of two 4-storey buildings separated by a landscaped quad. Ground floor amenities include a dining facility, a mailroom, classroom program space, common lounge space, and a performance hall. ZGF Architects and PAE Consulting Engineers designed the complex, which incorporates sustainable design features such natural ventilation (cross and stack), solar thermal heating for domestic hot water, daylighting/clerestory windows (UO, 2015a, 2015c).

Figure 3.9: Living-Learning Center North Building Exterior

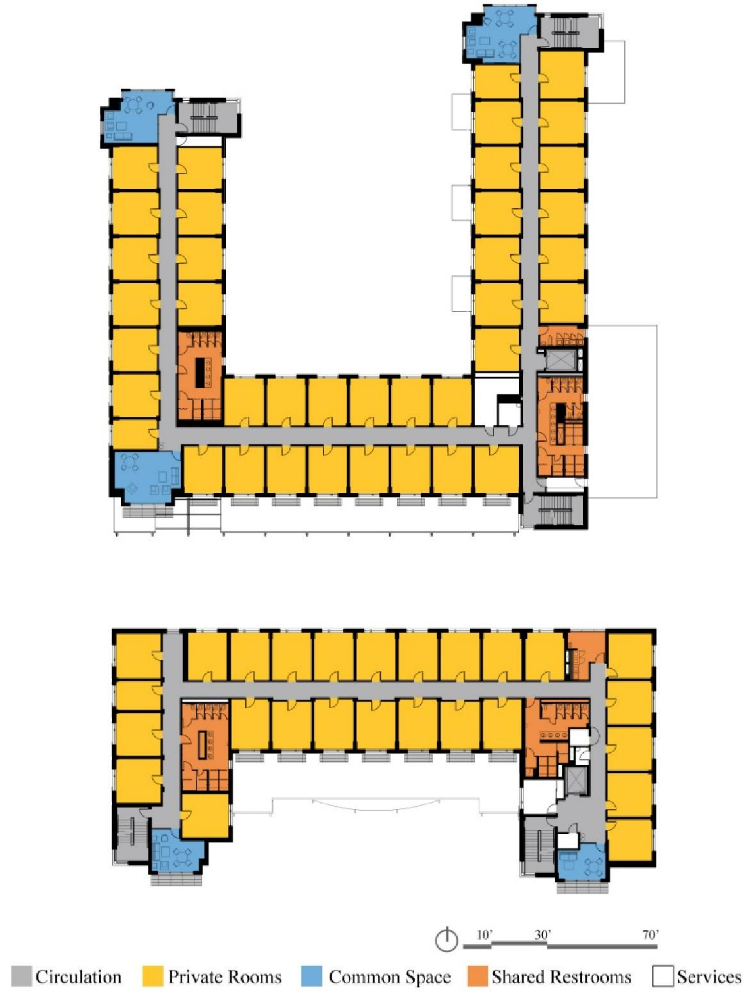


Figure 3.10: Living-Learning Center Typical Resident Floor Plans

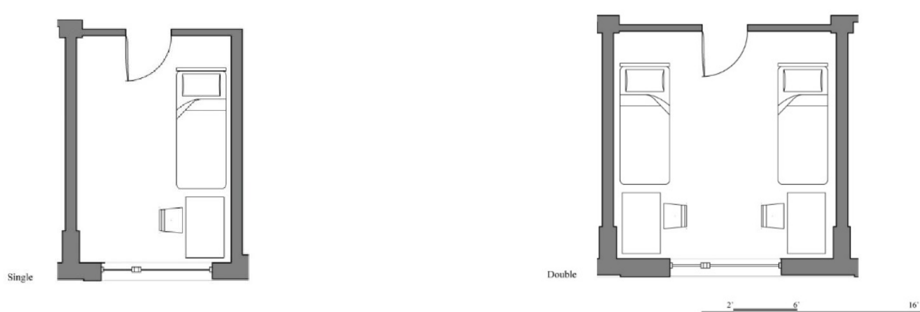


Figure 3.11: Living-Learning Center Unit Plans:
single bedroom (left), double bedroom (right)

Global Scholars Hall:

Completed in 2012, Global Scholars Hall (GSH) at University of Oregon is a 185,000 square foot, LEED BD+C Gold certified facility that includes 475 student beds in single, double, triple, and shared-suite configurations. (See Figs. 3.12 & 3.13) Some rooms share private bathrooms while others share floor bathrooms. All rooms have sinks. (See Figs. 3.14 & 3.15) The complex features three 5-storey residential towers connected by ground floor amenities including a dining facility, a Learning Commons, and academic program space. ZGF Architects and Balzhiser & Hubbard Engineers designed the complex, which incorporates sustainable design features such as solar thermal heating for domestic hot water, rainwater harvesting for toilet flushing, daylight sensors in common spaces, and a green light system to notify occupants to open windows (UO, 2015a, 2015b).

Figure 3.12: Global Scholars Hall Exterior

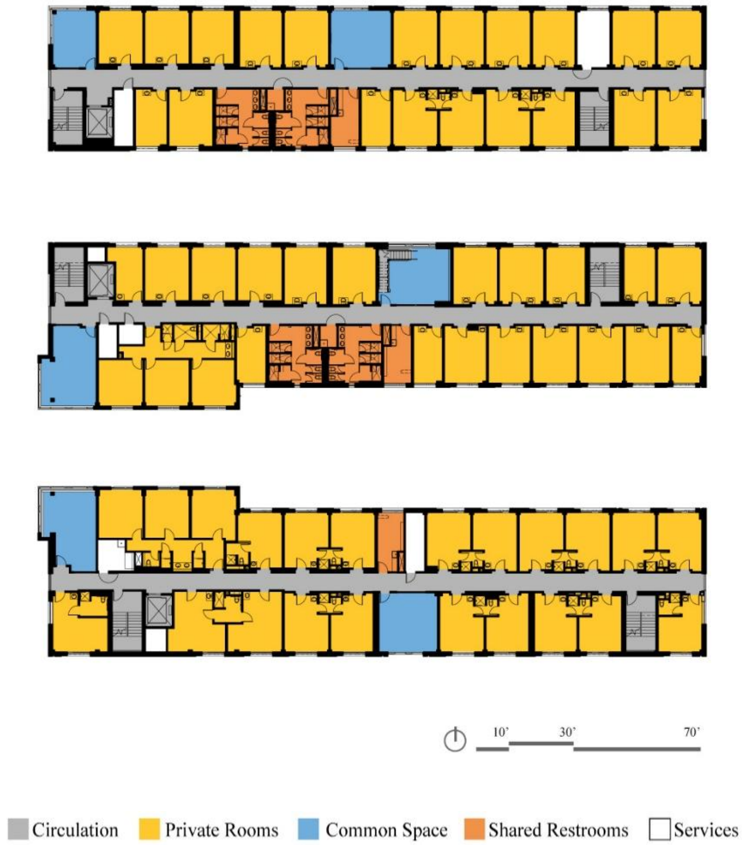


Figure 3.13: Global Scholars Hall Typical Floor Plans: North Tower (top), Center Tower (middle), South Tower (bottom)

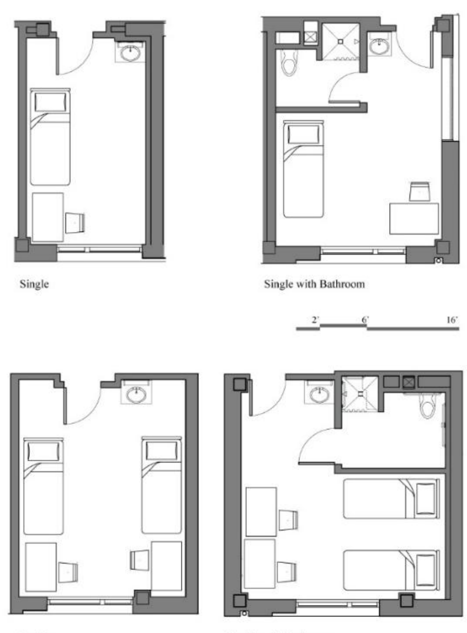


Figure 3.14: Global Scholars Hall Unit Plans

Figure 3.15: Global Scholars Hall Unit Plans

Burlingham Hall:

Completed in 2006, Burlingham Hall at Pacific University is a 59,000 square foot, LEED BD+C Gold certified facility that includes 161 student beds in 9 suites or 30 apartments. (See Figs. 3.16 & 3.17) All suites and apartments include shared common space and bathrooms. Apartments have kitchens. (See Figs. 3.18 & 3.19) The 4-storey building includes shared floor lounges, conference rooms, study spaces, a shared kitchen, laundry facilities, and staff office space. Mahlum Architects and Interface Engineering designed the building, which incorporates sustainable design features such heat recovery, operable windows, daylighting, programmable thermostats, energy efficient appliances, and signage describing features (Pacific, 2015b, n.d.; West, 2015).

Figure 3.16: Burlingham Hall Exterior

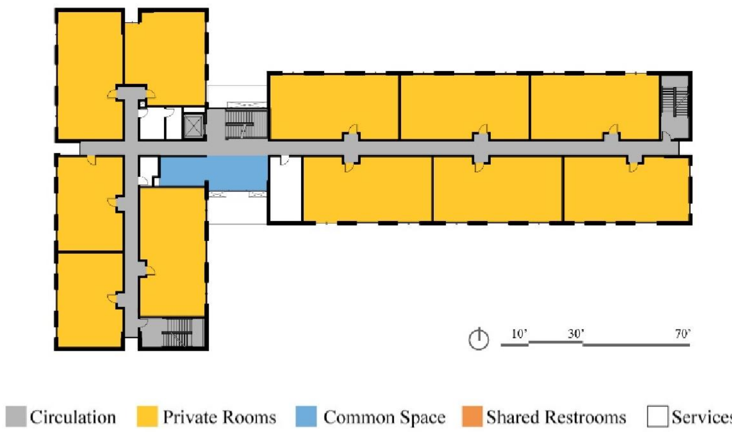


Figure 3.17: Burlingham Hall Typical Floor Plans

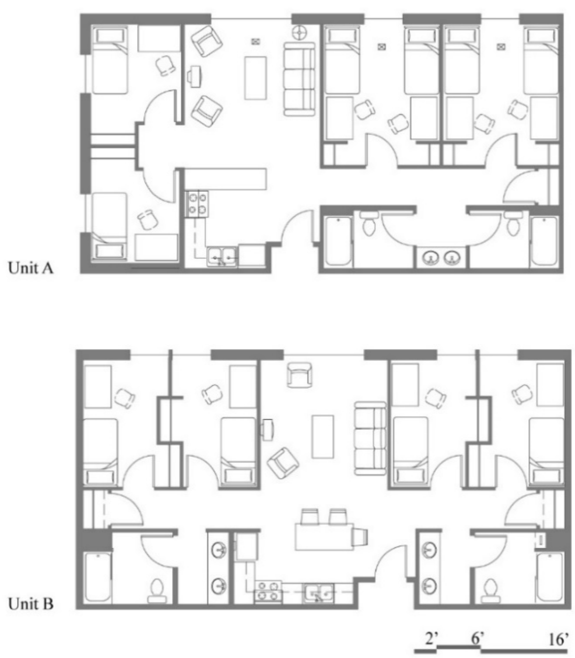


Figure 3.18: Burlingham Hall Unit Plans: Unit A and 6-person suite; Unit B, 4-person suite.

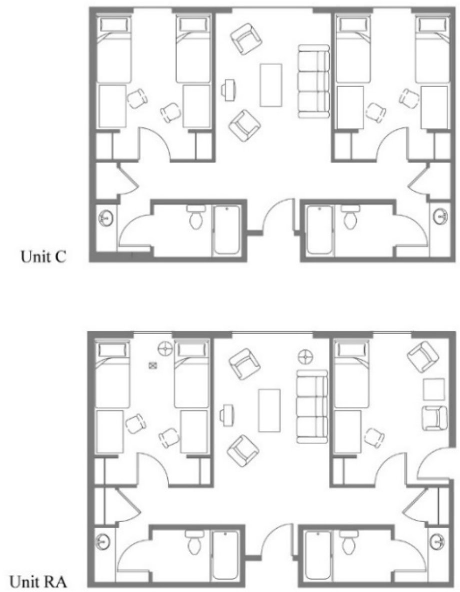


Figure 3.19: Burlingham Hall Unit Plans:
Unit C, 4-person suite and Unit RA, 3-person suite.

Gilbert Hall:

Completed in 2008, Gilbert Hall at Pacific University is a 61,520 square foot, LEED BD+C Gold certified facility that includes 156 student beds in 12 suites or 24 apartments. (See Figs. 3.20 & 3.21) All suites and apartments include shared common space and bathrooms. Suites have kitchenettes and apartments have kitchens. (See Figs. 3.22, 3.23, & 3.24) The 4-storey building includes shared floor lounges, laundry facilities, a shared kitchen, and staff office space. Mahlum Architects and PAE Consulting Engineers designed the building, which incorporates sustainable design features like dual-flush toilets, operable windows, rainwater harvesting, and signage describing features (Architect, 2015; Mahlum, 2015; Pacific, 2015a).

Figure 3.20: Gilbert Hall Exterior

Figure 3.21: Gilbert Hall Typical Floor Plans

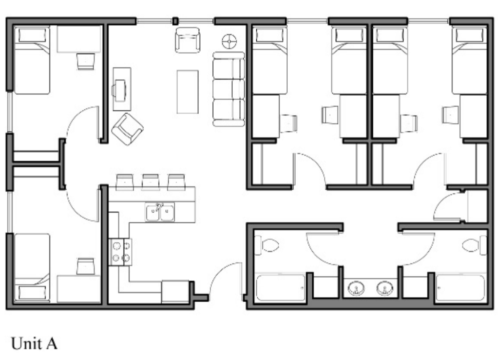
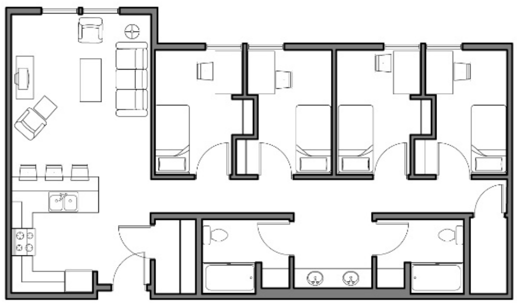


Figure 3.22: Gilbert Hall Unit Plans: Unit A, 6-person suite

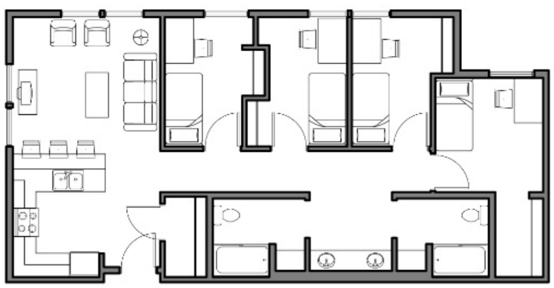
Unit B



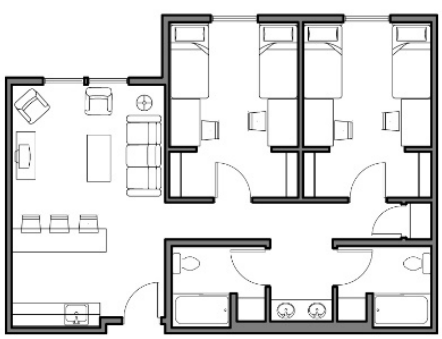
Unit C

2' 6' 16'

Unit D



Unit E



2' 6' 16'

Figure 3.23: Gilbert Hall Unit Plans:
Unit B, 8-person suite; Unit C, 4-person suite;
Unit D, 4-person suite; Unit E, 4-person suite.

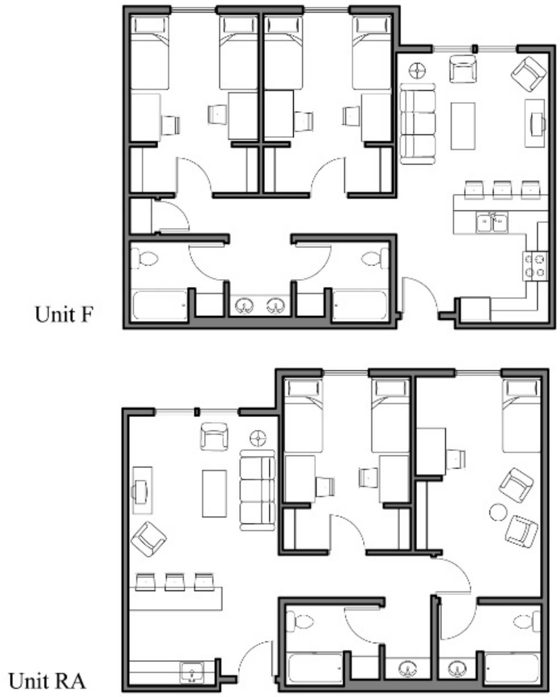


Figure 3.24: Gilbert Hall Unit Plans:
Unit F, 4-person suite; Unit RA, 3-person suite.

3.4. Phase I: Plug Load Measurements & Student Surveys

The Phase I data collection occurred at two scales at six residence hall field sites: the scale of the individual student occupant and the scale of groups of student rooms or suites. Data collection at each field study site included: power and energy measurements in electrical panels; power and energy measurements in student rooms; and device and energy usage patterns in student surveys.

3.4.1. Electrical Panel Measurements

Power quality meters monitored power and energy consumption in select electrical panel boxes at each field site. Although energy codes are changing (Commission, 2012), electrical system designs in many existing residence halls do not provide single point to measure plug load energy. Power distribution to 3-phase electrical panel boxes on each floor of the building was more typical. Often, these panels separated lighting, HVAC, and receptacles end-uses. In some cases, panels served all electricity end-uses within a suite of rooms, which further complicated the separate measurement of plug loads.

Selecting Test Locations:

The aim was to find one panel in each building that: (1) served a large group of rooms; (2) contained primarily or exclusively 120 volt receptacle branch circuits; and (3) could easily and securely accommodate the metering equipment (i.e. not a panel located in a corridor). Construction documents obtained through the campus facilities offices and/or the design architects allowed the researcher to identify the most promising panels that met the aforementioned criteria. The campus electrician then verified the suitability of those panels during building walk-thoughs.

Equipment:

Two rented power quality meters measured electricity in each of the panel boxes (Summit, 2015). Each meter was rented for one month at a, cost of $550.00 per meter. The meters were capable of measuring voltage, kilowatt/hours, and transients. The equipment kit consisted of: the electronic meter unit, a disk with software for set-up/download of data, an AC power adaptor, 4 current transformer (CT) probes/clamps (I_1, I_2, I_3, I_N), and 4 voltage leads (V_1, V_2, V_3, V_N).

Procedure:

The set-up procedure was as follows: the power adaptor, current probes, and voltage leads attached to the designated ports on the meter; the power cord plugged-into a wall outlet; the probes and leads were connected to the appropriate wires within electrical panel; the meter was turned-on and launched. In a 3-phase electrical panel, one voltage lead and one current probe connected to each of the three phase wires and the neutral wire. (See Figure 3.25)

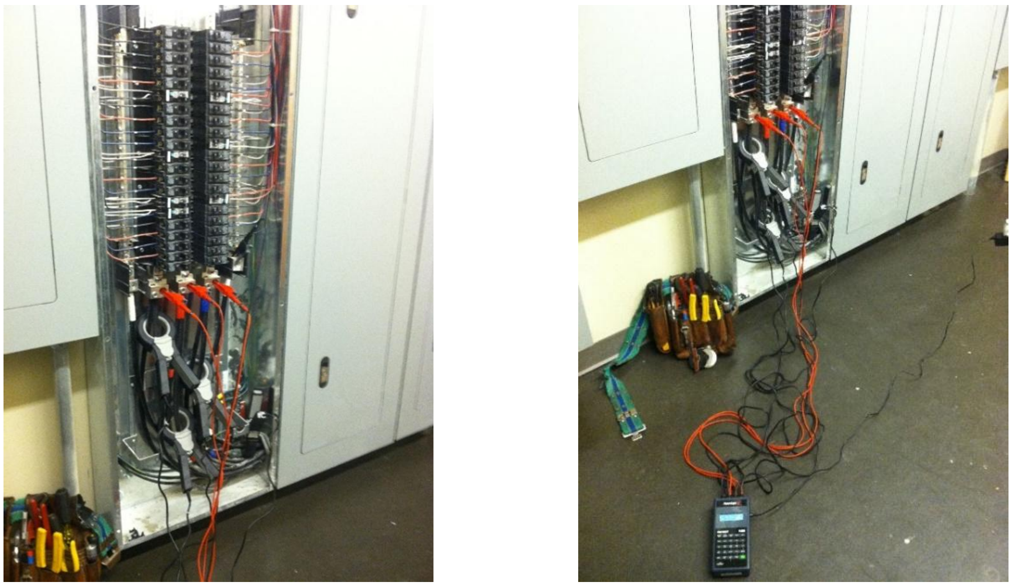


Figure 3.25: Power quality meters/data loggers connected to Select electrical panels to monitor receptacle circuits

When launched, the meter ran a protocol to determine proper probe/lead connections and identified problems with the set-up to allow for correction if necessary. Connecting power quality meters required removing the front of the electrical panel to expose wires and other energized parts. Only a certified electrician was qualified to connect the monitor to the panel.

Since each electrician had to connect equipment that they were not accustomed to using, every effort was made understand and communicate the connection procedures in advance and to walk the electrician through the steps at each installation. However, a number of unforeseen challenges arose when installing the meters in the field including: the lack of an electrical outlet in close proximity to the panel box to power the meter;

insufficient room within the panel box to attach the probes and leads (the CT clamps in particular are large and the panels are tightly packed); and the size of the probes and leads interfering with putting the face plate back on the panel after connection (the electricians were not comfortable leaving the panel faces off or open during the data collection). The researcher returned to assist the electrician in disconnecting the equipment one week later and downloaded the data from the meter to a personal computer for analysis.

Of the 1852 students living in the study site buildings, the electrical panels measured were for rooms totaling 90 residents (4.9% with a range of 2.3-8.7% across the buildings).

3.4.2. Spot Room Measurements

Equipment:

Watts-Up Pro plug load meters measured and logged plug load usage in student rooms (Watts-up?, 2015). The meters are 120 v, 60 Hz, 15 amp units, UL listed, and measure 18 different power or energy parameters including: voltage, current, power factor, watts, and kilowatt hours. It was possible to configure the meters in advance so that students only had to plug them in. A university tool lending library loaned the 20 meters used in the study at no cost. (See Figure 3.26)

Measurements were recorded in the internal memory of each device. The storage capacity was dependent on the parameters and measurement intervals chosen. Measurement parameters configured included: plugging-in the meter, connecting the meter to a personal computer using a USB cable, launching the Watts-up? software, setting the measurement parameters, and saving the settings. The meters do not have an internal clock. When downloading the data from the meters, the software allows the user to input a start or stop time and attach a timestamp to the data points accordingly. Data analysis options include: using the proprietary software or exporting the data as a spreadsheet file.

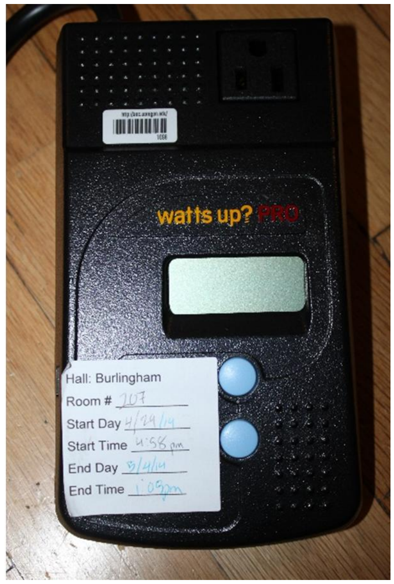


Figure 3.26: Plug load meter/data logger hosted by
student resident volunteers for one week

Recruitment:

At each field site, residence life staff sent an e-mail, drafted by the researcher, to students on their residence hall distribution lists to recruit ten volunteers to host a plug meter in their rooms for one week. The residence life staff created a list of volunteers and confirmed that ten volunteers had signed-up.

Procedure:

To limit the extent to which the researcher would directly interact with student volunteers in their personal rooms, the researcher configured the meters in advance, gave the meters to residence life staff to distribute to students, and collected the meters from residence life staff at the end of the measurement period. Students checked-out the meter and a power strip from their RAs on a specific date, plugged their electronics in their room into the power strip, and plugged the meter into a wall outlet. In addition, a sticker on the meter listed the return date and asked students to list the start time, the stop time, and their room number. A tag clipped to the power cord listed instructions and contact information for any questions or problems. Although the meters have a digital display and students could view real-time feedback on the measured parameters, there was no way for students to change the settings configured by the researcher. At the end of one week, the researcher picked-up the box of meters from the residence life contact and downloaded the data to a personal computer for analysis. Of the 1852 students living in the study site buildings, there were 34 volunteers (1.8% with a range of 1.0-5.6% across the buildings).

3.4.3. Student Surveys

Self-audit surveys asked student residents in the field site buildings to document their electronic devices and usage patterns as well as to comment on habits and attitudes related to plug load electricity consumption and conservation in their living environments. There were a number of advantages to including surveys as a data collection method. Surveys do not require that the researcher interact directly with students in their rooms, which student housing officers felt was intrusive for residents. Furthermore, the compartmentalized layout of residence halls made collecting data in individual rooms prohibitively time consuming. Therefore, surveys allow unobtrusive and efficient access to a larger segment of students living in residence halls.

In addition, research suggests that surveys, particularly those that ask students to evaluate their own behavior or environment, have successfully raised awareness of sustainability issues. In his classic study at the University of California, Berkeley, Van der Ryn had students complete activity logs. "Self-observation devices have a special virtue. The information provides a useful picture of the dynamics of space use over time." These student self-reports were effectively used as one of a variety of data collection methods in the study (1967, p. 87).

Pretest:

Six undergraduate students participated in a survey pretest in April 2014. Results from the pretest confirmed that the survey was an appropriate length and could be completed in 10-15 minutes with relative ease. The pretest also revealed that several questions included confusing or ambiguous wording. Pretest feedback informed revisions to the final survey.

Survey Period:

The survey periods aligned with the plug load metering in the field site buildings. Therefore, metering and surveying occurred simultaneously in both residence halls at each institution. At the end of the one week, the survey period ended at that institution and the survey period began at the next institution. There were three rounds of surveying. Surveying took place from April 28-June 10, 2014.

All student residents in the six field study site buildings were asked to participate in an energy consumption self-audit survey via e-mails sent to residence hall e-mail distribution lists and flyers were posted in the buildings. (See Appendix B) Access limitations to the field site buildings and the student populations living in these buildings prevented the use of random sampling techniques or in-person surveying. The online survey host was *Qualtrics*, which was free of charge to students at the University of Oregon. Students accessed the survey using a web link.

Format:

Plugged-in was the title given to the survey. The survey consisted of five sections:

1. Statement of informed consent (by clicking, students provided their consent to participate)
2. Self-audit: students were asked about four categories of electronic devices and their daily and weekly usage in hours and minutes for those devices. Since this was the most time consuming and detailed portion of the survey, it was placed at the beginning (Babbie, 1991).
3. Habits and attitudes: students were asked about their habits and attitudes related to electricity consumption and conservation, specific energy-saving actions, lighting preferences, etc.
4. Demographics: gender, class year, time spent living in the residence halls, country/state of origin, which residence hall/room they live in, etc.
5. Conclusion: students had the opportunity to provide their e-mail address to be entered in a prize drawing for a $25 gift card to the school bookstore, to provide their e-mail address if they would like to be contacted about participating in an interview, and to comment on any other thoughts they had (open-ended format)

3.4.4. Building Characteristics

The Architect of Record or the facilities departments at the field site institution provided electronic copies of the construction documents for the six buildings in CAD and PDF format. The CAD files allowed for the accurate calculation of room and suite areas and the PDF files facilitated easy navigation through the hundreds of pages of drawings for each building.

The documents were used to examine spatial, morphological, and design characteristics common to the six field site buildings, which was a technique used in a previous residence hall study (Amole, 2009). The 13 building characteristics were:

1. Room Area: the square footage of the student room or suite. If the room shared a bathroom, the room area included half the area of the bathroom. The area of suites included all private bedrooms, common spaces, and bathrooms.
2. Room Area/Person: the square footage of the student room or suite divided by the number of occupants sharing that space. If the room shared a bathroom, the room area included half the area of the bathroom. The area of suites included all private bedrooms, common spaces, and bathrooms.
3. Room Volume: the cubic feet of the student room or suite (room area x ceiling height)
4. Room Depth: the linear feet of distance between the exterior window wall and the furthest interior wall in the room (i.e. the corridor wall where the door is located).
5. Window area: square footage of the exterior window(s).
6. Exterior wall area: the area of the exterior wall(s) in the room or suite measured in square feet.
7. Window to wall ratio: the ratio of window area to exterior wall area (i.e. 0.33 or 33%)

8. Orientation: the cardinal direction that the windows faced (i.e. north, south, east, or west).
9. Receptacles: the total number of power outlets in the student room or suite. (i.e. one duplex receptacle would equal two receptacles)
10. Building area: the overall gross square feet of building area.
11. Floor level: the floor level of the student room or suite above grade.
12. Proximity to common space: the linear feet of distance between the room or suite corridor door and the nearest lounge or common space door.
13. Room occupants: the total number of occupants sharing a room or suite.

3.4.5. Energy Model Assumptions

Energy model assumption for plug loads were not available for all of the field study buildings. However, design engineers for two of the buildings provided plug load assumptions. In addition, a State Energy Efficiency in Design (SEED) report documented the assumptions for a third building. This information included the energy model input for plug loads (the power density in w/sf), the daily schedule or profile of use (the average percentage of the power density expected hourly over the course of a typical day). In few cases, engineers shared documentation of predictions for numbers, types, and usage used to inform the model input and schedule.

3.4.6. Data Analysis

Descriptive Statistics:

Survey and meter data were downloaded and transferred to Excel spreadsheets for descriptive statistical analysis, which described and summarized characteristics of the data including: percentages, frequencies, measures of central tendency (i.e. mean, median, and mode), and measures of variability (i.e. range, variance, and standard deviation). These statistics described:

1. Demographic characteristics of the survey sample
2. Characteristics of the field study sites
3. Frequencies and distributions of responses to Likert scale questions in the survey
4. Range of plug load power and energy measurements
5. The predicted and measured plug load power on the daily profile schedules

Calculating Metrics:

Plug load data collected from the electrical panels, spot measurements in rooms, and self-audit portions of the student surveys were downloaded and transferred to Excel spreadsheets. In the spreadsheets, the data was organized, labeled, and used to calculate plug load metrics, which illustrated the range of plug loads found in specific rooms or groups of rooms, to compare the results from the three types of plug load measurements taken, and to compare with the energy model assumptions provided by the design team.

The electrical panel data and spot meter data consisted of tens of thousands of measurement points over the measurement periods. The formula functions in the spreadsheet calculated the average, minimum, and maximum wattages and kilowatt hours of energy used for overall, daily, weekends, and weekday conditions. These numbers were divided by the square footage of the student rooms or suites and further subdivided by the number of occupants in the room to determine plug load power density (w/sf), annual energy usage (kWh/yr), kWh/sf/yr, and plug load EUI (kbtu/sf/yr). Graphics illustrated the range of values for each room or group of rooms measured to facilitate comparisons across rooms, students, or buildings.

The self-audit data provided by students consisted of the numbers of different types of electronic devices listed, the amount of usage on a typical day, and the number of uses each week. Using the formula functions in the spreadsheet, each device was multiplied by an estimated wattage for the device and divided by the square footage of the student rooms or suites, then further subdivided by the number of occupants in the room to determine plug load power density (w/sf), annual energy usage (kWh/yr), kWh/sf/yr, and plug load EUI (kbtu/sf/yr).

Bivariate Correlations:

Bivariate correlations tested the strength and direction of the relationship between a dependent variable (plug load power or energy) and an independent variable (building characteristics). There are two types of correlation coefficient tests: the Pearson product-moment correlation and the Spearman Rho rank correlation coefficient. The primary differences between these two tests is that the Pearson product-moment correlation is a parametric test (it makes assumptions about the population from the study sample) and the Spearman Rho correlation is a non-parametric test (it does not make assumptions about the population from the study sample). In order to use the parametric test, a series of assumptions must be satisfied (i.e. interval level measurement or above, normal distribution, sufficient sample size, etc.). This analysis used the Spearman Rho correlation test for the following reasons: plug load data collected from a non-randomized sample at the study sites and several independent variables taken at the ordinal level of measurement (i.e. floor level).

SPSS software tested correlations between the variables. Each test generated two statistics: a correlation coefficient and a coefficient of determination. The correlation coefficient (*r*) ranges from -1.0 to +1.0 (+ indicates a positive relationship and – indicates a negative relationship). An *r* of +1 or -1 indicates a perfect correlation and an *r* of 0 indicates no correlation. This study used Kaska-Miller's interpretation criteria for correlation coefficients for nonparametric social and behavioral science results (2013, p. 81): $r = \leq 0.30$ indicated a weak correlation; $r = 0.30\text{-}0.80$ indicated a moderate correlation; and $r = \geq 0.80$ indicated a strong correlation. The coefficient of determination (r^2) measured the proportion of the variance in the dependent variable explained by the independent variable expressed as a percentage. The results of each test were documented using a Venn diagram and a scatterplot (Abu-Bader, Pryce, Shackelford, & Pryce, 2006).

3.5. Phase II: Interviews

Phase II involved interviews with three groups of residence hall stakeholders: designers (architects and engineers), housing facilities managers/administrators, and student residents answered questions regarding their experiences and impressions related to plug load energy usage in student housing. The interview data analysis used a Constructivist Grounded Theory approach to reveal salient themes and to construct a theory that describes these themes.

3.5.1. Constructivist Grounded Theory

Glaser and Strauss introduced the idea of Grounded Theory in the late 1960s and outlined an approach to qualitative research whereby theory is "grounded" in the data (1967). They describe analytic procedures such as coding and memoing, which are now widely used techniques in qualitative analysis. Grounded Theory evolved overtime as Glazer and Strauss moved in different philosophical directions. Charmaz and Bryant developed Constructivist Grounded Theory (CGT) in the early 2000s to move Grounded Theory in a social constructivist direction. It shares methodological strategies with classic Grounded Theory, but rejects its epistemological perspectives that relied on generalization, objective observation, and variables. CGT is predicated on multiple realities, dualities in the external world, sees data as incomplete, and positions the researcher as a participant in the process (Charmaz, 2000, 2006a).

3.5.2. Interview Participant Selection

The method used to select interview participants varied depending on the stakeholder group. The selection criteria were as follows:

1. Design practitioners interested in the dissertation topic and/or who were connected to the Phase I study sites
2. Campus operations and/or facilities managers who were connected to the Phase I study sites
3. Students who participated in the Phase I student survey and indicated interest in participating in the interview process at a later date
4. Design practitioners and/or facilities managers chosen through "snowball sampling," which involved asking study participants connected to Phase I of the study to recommend or refer potential interviewees

3.5.3. Interview Logistics

The data collection took place over 8 weeks (July 23 until September 26, 2014). The preferred method was to conduct interviews in-person, but participants had the option to do a phone interview instead. Interview scheduling took place several weeks to a month in advance primarily through e-mail. Participants understood that the interviews would last approximately 40 minutes. Interview locations varied, but included the researcher's office and participants' offices.

Participants read and signed a consent form prior to the beginning of an in-person interview. For phone interviews, participants returned the signed consent form prior to the scheduled phone call. (See Appendix C)

3.5.4. Conducting the Interviews

Questions:

Grounded Theorists often begin their studies with a general set of research interests. Blumer suggests that these ideas "sensitize" the researcher to ask certain kinds of questions about the research topic (Blumer, 1969). Charmaz suggests that these "sensitizing concepts" can act as points of departure that help frame the interview questions and the analysis (2006a, p. 17). In responsive interviewing, these "sensitizing concepts" can help form the basis for a number of "main questions" that address the research concerns, but act as a flexible structure allowing for follow-up questions based on interview responses (Rubin & Rubin, 2012).

Responsive Interviewing:

The goal of responsive interviewing is to obtain greater depth from respondents by allowing them to take the conversation in directions that reveal how they feel about the issues they are being asked about (2012, pp. 116-122). Therefore, interview questions acted as a guide with only 4-5 main questions. In the event that an interviewee went on a lengthy tangent unrelated to the research topic, the researcher would lightly steer the conversation back on-course using these main questions. (See Appendix D)

Number of Participants:

Two considerations guided the number of interviews conducted: Charmaz suggests that around 30 interviews provides "a solid foundation for a detailed analysis" (2011, p. 171) and the concept of "saturation" in qualitative analysis suggests that researchers may have sufficient interview data when they begin hearing similar responses or themes in subsequent interviews (Charmaz, 2000, p. 520). The final interview data set totaled 24 interviews.

Voice Recording:

Two voice recording devices recorded each interview, one primary and one back-up. The audio files were downloaded to a personal computer after each interview. Notes taken during the interviews document aspects of the setting and/or participant facial expressions/demeanor not easily captured with the voice recordings (Patton, 2002, pp. 383-384).

3.5.5. Transcribing the Interviews

The voice recordings were transcribed into text documents for analysis. The freeware *Listen N Write* showed the playback speed of the recording to facilitate accurate transcriptions. The transcriptions commenced before the completion of the interviews, which allowed the revision of interview questions for subsequent interviews based on ideas and concepts that emerged in the transcription narratives. The text was transcribed verbatim in a question and answer format excluding only distracting words or sounds common in the spoken word recordings (i.e. "like" or "um"). Inaudible words or phrases were documented as such.

On average, it took approximately four hours to transcribe a 40-50 minute recorded interview. The 24 interviews totaled approximately 88 hours of transcription. Transcripts were approximately 8-12 pages in length. The transcripts did not identify participants by name. In order to keep their actual names confidential, interviewees received a code based on their stakeholder group (i.e. OP1). Participants received an electronic copy of the transcript to review and return with any clarifications or text that they preferred to be omitted from the transcript. Only two participants requested that omitting minor elements of the text from the transcripts, particularly where they had named someone in the narrative.

3.5.6. Data Analysis

The interview analysis followed a Constructivist Grounded Theory approach and relied on a variety of qualitative analysis procedures as outlined by Charmaz(2006b), Miles and Huberman (1994), Patton (2002) Richards (2005), and Saldana (2009). Interview transcripts were uploaded into Atlas.ti, a computer-assisted qualitative data analysis software (CAQDAS) program to navigate, organize, sort, and code the data. CAQDAS programs can assist researchers to examine relationships among the data in more fluid and dynamic ways than are possible using a traditional manual coding and analysis method (Bringer et al., 2006). They allow the researcher to work with and close to the data, but they do not perform the analysis itself.

Coding:

The analysis began with coding, the process by which transcribed narrative data are organized and assigned meaning in qualitative analysis. Miles and Huberman describe codes as "tags or labels" assigned to segments, or "chunks," of text (1994, p. 56). The code categories were emergent rather than resulting from preconceived ideas applied to the data. Thus, the "sensitizing concepts" framed the study, but they were not used to get the data to fit specific topics, ideas, or categories. Coding allowed the data to be taken apart and compared at a line-by-line level. The codes took the form of short phrases beginning with verbs ending in *ing*, which Charmaz suggests helps to capture the processes in the narratives and facilitates comparisons (Charmaz, 2006a, p. 49). An example of a coded line is: "don't force students to do certain things. There are a few pieces of equipment we don't allow, but… received the code: "resisting restriction"

Coding facilitated the interpretation of the data where by repeating ideas, significance, and frequency helped define analytic focus areas. As such, some codes rose above others and became tentative analytic categories.

Memos:

During coding, written memos described or analyze the codes. Memos linked codes or sections of text across transcripts as a way of better understanding and revealing repeating ideas, categories, and themes. Memoing began early during transcription and continued throughout the analysis process. In essence, the memos helped to make sense of the codes (Charmaz, 2011, pp. 72-95). An example of a memo is "proximity of amenities:"

> When students can't have a certain device in their rooms, but there is one in a common area, then the proximity becomes very important. If the amenity is far from the room, then student may resist going to use it, which can cause frustration. So, prohibited items in rooms and proximity in the building to places where those items can be used is important

Analytic Categories & Coherent Processes:

The data analysis was iterative in nature, but gradually move from the actual words of the participants to more abstract ideas that helped to illuminate connections and linkages in the data set. Ultimately, two analytic categories brought together salient themes across the interviews and formed the basis for a single coherent process.

CHAPTER IV

QUANTITATIVE ANALYSIS

4.1. Introduction

This chapter describes the results and analysis of four sets of data collected through: plug load monitoring in electrical panel boxes, plug load spot metering in student rooms/suites, student self-audit surveys, and residence hall design documents. First, the results of the plug load measurements and metrics are presented, which include: monitoring, metering, self-audit energy estimates, comparisons of the measurement methods, and comparisons with plug load predictions used in the design process. Second, the results of the survey are presented, which include: sample demographics; student devices/usage; and student attitudes and actions. Lastly, the results of correlations between plug load power/energy and building characteristics are presented.

4.2. Plug Load Measurements & Metrics

Residence hall plug load metrics were created using three different methods: power quality meter measurements in electrical panels containing primarily or exclusively receptacle circuits, plug load meter measurements in student rooms, and estimates of electronic devices and usage from student self-audit surveys.

4.2.1. Electrical Panels

Power quality meters were used to measure receptacle circuits in electrical panel boxes in four of the six field site buildings. Altogether, the five panels measured plug loads in 13,177 ft^2 of resident rooms/suites housing 90 students. See Table 4.1 for the area and number of occupants included in the measurements.

Table 4.1: Electrical panel measurement sample

	Building1	Building 2	Building 3	Building 4 (A)	Building 4 (B)	Total
Building Area Measured (sf)	3,238	1,624	3,004	2,751	2,560	13,177
Occupants (#)	14	10	28	19	19	90

Plug Load Measurements & Metrics:

The results of the plug load measurements from electrical panels and the subsequent plug load metrics calculations are shown in Table 4.2. The average values of the data collected across the buildings were as follows: the measurement period was slightly more than one week (7.75 days), the peak plug load power was 2,542.4 watts (range of 1,939-3,248 watts), average plug load power was 657 watts (range from 481-1,067 watts), the minimum plug load power was 208.6 watts (range from 48-549 watts), the plug load power density was 1.03 w/sf (range of 0.71-1.61 w/sf), the daily plug load energy use was 16.48 kWh/dy (range of 7.81-29.05 kWh/dy), the annual plug load energy use per square foot estimate was 1.608 kWh/sf/yr (range of 0.90-2.42 kWh/sf/yr), and the plug load energy use intensity was 5.05 kbtus/sf/yr (range of 2.84-7.61 kbtus/sf/yr). See Figure 4.1 for the relationships between peak, average, and minimum plug load power and Figure 4.2 for the annual plug load energy use.

Table 4.2: Measurements & metrics for electrical panel measurements

	Building 1**	Building 2***	Building 3	Building 4 (A)	Building 4 (B)	Average
Days of Meas.	7.02	6.89	6.96	8.94	8.94	7.75
Peak watts	2,481.00	2,619.00	2,425.00	1,939.00	3,248.00	2542.4
Average watts	778.00	330.00	1,067.00	481.00	633.00	657.8
Min. watts	549.00	50.00	313.00	48.00	83.00	208.6
w/sf	0.77	1.61	0.81	0.71	1.27	1.034
kWh/dy	29.05	7.81	25.43	11.54	8.57	16.48
kWh/sf/yr*	2.42	1.30	2.29	1.13	0.90	1.608
Kbuts/sf/yr* (EUI)	7.61	4.08	7.18	3.56	2.84	5.054

* A year is assumed to be 270 days or the 9 mo. academic year when residence halls are fully-occupied

** Adjustments made for: 200 watt fan and an estimated 0.5 w/sf for hard-wired lighting

*** Adjustments made for: 73-175 watt fan coil units and an estimated 0.5 w/sf for hard wired lighting

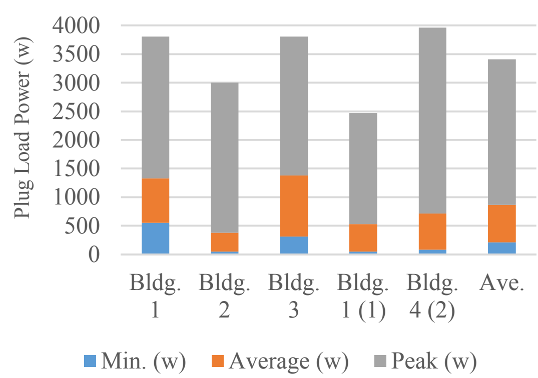


Figure 4.1: Plug load wattages showing the percentages of max (peak) load

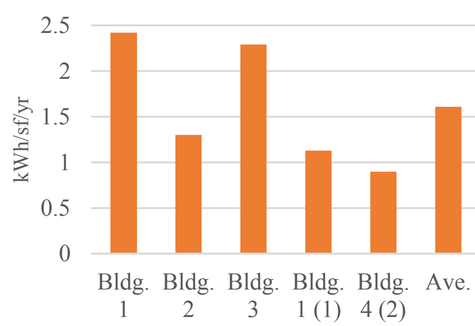


Figure 4.2: Estimated annual plug load energy

Patterns of Usage:

Across a series of rooms or suites, the patterns of plug load power appear similar among the buildings measured. Peak wattage tends to occur in the mornings from 6:00-9:00AM and in the evenings after 4:00PM. Peaks tend to occur 2-3 times daily. Slight variations in usage occur on certain days or on weekends vs. weekends. For example, one building had lower peak usage on a Friday and Sunday night, perhaps indicating differences in occupancy at those times. Some buildings show similar peak plug loads each day while others show similar peak plug loads on most days with higher or lower peaks interspersed. Likewise the patterns of daily plug load energy use are similar across the buildings measured and show a linear relationship between energy use and time, which indicates consistent energy use throughout the measurement period. (See Figure 4.3, typical)

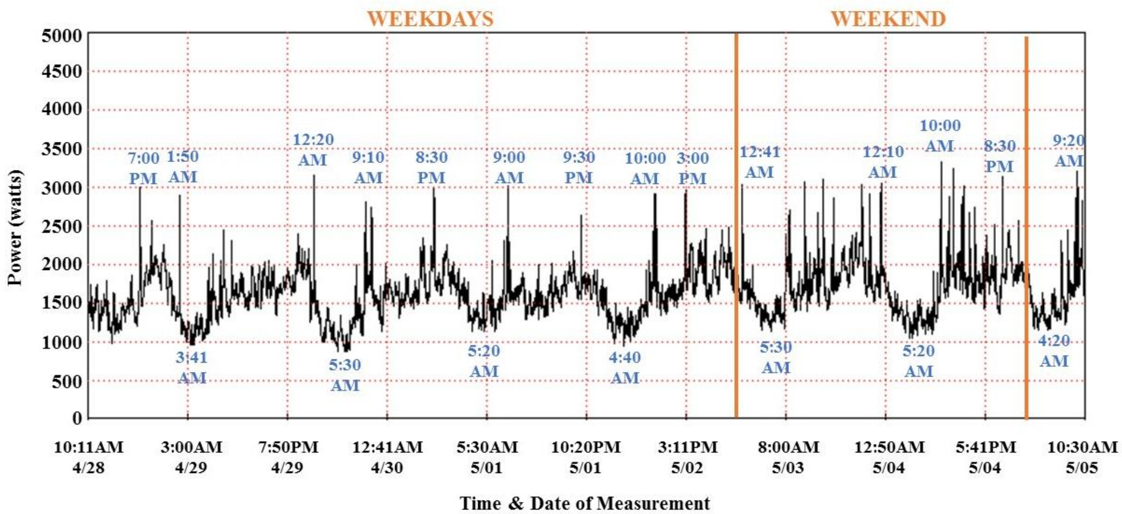


Figure 4.3: Typical pattern of usage over the measurement period (shown for Building 1)

Table 4.3 shows average and minimum plug load power expressed as a percentage of the peak plug load power. Overall, the average plug load power across the buildings was 26% (range of 12-44%) and the minimum plug load power was just 8% (range of 0.3-0.22) of the peak plug load power.

Table 4.3: Percentages of peak loads for electrical panel measurements

	Building 1	Building 2	Building 3	Building 4 (A)	Building 4 (B)	Average
Average watts: peak watts (%)	0.31	0.12	0.44	0.24	0.19	0.26
Min. watts: peak watts (%)	0.22	0.02	0.13	0.02	0.03	0.08

Logistical Limitations:

Overall, the preparations for the electrical panel measurements described in Chapter III facilitated straightforward equipment set-up, measuring, and equipment removal at each study site building. However, there were unexpected challenges at two of the sites that required modifications to the methods.

At one site, all electrical panels were located in the corridors. It was not possible to leave the equipment in a public corridor or hanging out of a panel box in these locations. The researcher attempted to connect a larger distribution panel, but there was insufficient room in the panel to connect the current transformers and voltage leads. At another site, there was no electrical outlet in the electrical room to power the data logger, which necessitated an extension cord to the attic above. At the conclusion of the measurement period, the researcher discovered that the meter lost power after only 12 hours of logging data due to interference with the extension cord. As a result of these challenges, it was not possible to measure one panel in each of the six field site buildings. The researcher devised an alternate plan to measure two panels in one of the other buildings for a total of five panels measured. In Tables 4.1-4.3 these measurements are "Building 4(A)" and "Building 4(B)."

Additionally, two of the electrical panels included several non-receptacle circuits for lighting, fans, or fan coil heating/cooling units. The researcher consulted with the design engineers for the buildings to estimate the non-receptacle loads in the electrical panels and subtracted the estimates from the measured data.

Even with the adjustments for Building 1, it appears that Buildings 1 and 3 have relatively high base plug load (min. watts) at unoccupied or under-occupied times (313-549 watts) when compared with 50-80 watts in the other buildings. These differences may be attributable to more energy intensive devices left on or plugged-in more of the time, but determining the exact cause would require further investigation.

4.2.2. Spot Room Measurements

Plug load meters measured plug loads in student rooms in each of the six field site buildings. Altogether, the spot meters measured plug loads in 6,977 ft^2 of resident rooms/suites housing 34 students.

Plug Load Measurements & Metrics:

Table 4.4 shows the results of the plug load spot meter measurements and the subsequent plug load metrics calculations. The average of the data collected were as

Table 4.4: Measurements & metrics for spot meter measurements

	Building 1	Building 2	Building 3	Building 4	Building 5	Building 6	Ave.
Building Area (sf)	2,325	1,258	553	1,253	588	1,000	1,163
Occupants (#)	9	7	4	8	2	4	5.7
Days of Meas.	4.89	4.63	8.32	6.37	4.29	4.17	5.45
Peak watts	286.97	460.17	119.24	109.72	105.34	184.46	210.98
Average watts	23.03	9.88	21.68	9.26	9.12	13.75	14.45
Min. watts	4.13	0	2.16	2.52	0.42	2.65	1.98
w/sf	1.12	2.53	0.72	0.70	0.68	1.06	1.14
kWh/dy	0.55	0.23	0.55	0.21	0.12	0.33	0.33
kWh/sf/yr*	0.68	0.34	1.23	0.23	0.23	0.41	0.52
Kbuts/sf/yr (EUI)	1.80	1.07	3.14	0.74	0.65	1.27	1.45

* A year was assumed to be 270 days or the 9 mo. academic year when residence halls are fully-occupied

follows: the measurement period was less than one week (5.45 days), the peak plug load power was 210.98 watts (range of 105.34-286.97 watts), the average plug load power was 14.45 watts (range from 9.12-23.03 watts), the minimum plug load power was 1.98 watts (range from 0-4.13 watts), the plug load power density was 1.14 w/sf (range of 0.68-2.53 w/sf), the daily plug load energy use was 0.33 kWh/dy (range of 0.12-0.55 kWh/dy), the average annual plug load energy use per square foot estimate was 0.52 kWh/sf/yr (range of 0.23-0.68 kWh/sf/yr), and the plug load energy use intensity was 1.45 kbtus/sf/yr (range of 0.65-3.14 kbtus/sf/yr).

Patterns of Usage:

In contrast with the electrical panel measurements, the patterns of use differ quite dramatically in the spot meter data both between rooms and buildings. Nevertheless, there were several trends in the data. Peak plug loads tend to occur in the late afternoons and evenings with smaller peaks and valleys occurring from late mornings to mid-afternoons. Also, some data sets show low wattage power being drawn continuously throughout the day between peaks (i.e. 1-8 watts) while others show no power being drawn between peaks. This pattern may be an indication that some students are using phantom power and others are unplugging or powering down devices when not in use. As with the electric panel data, the spot meters show fairly consistent patterns of power usage from day-to-day with peaks and valleys occurring at similar times. However, since the spot meter data was at the individual student level vs. groups of students, it showed that weekends may have higher power usage than weekdays. (See Figure 4.4)

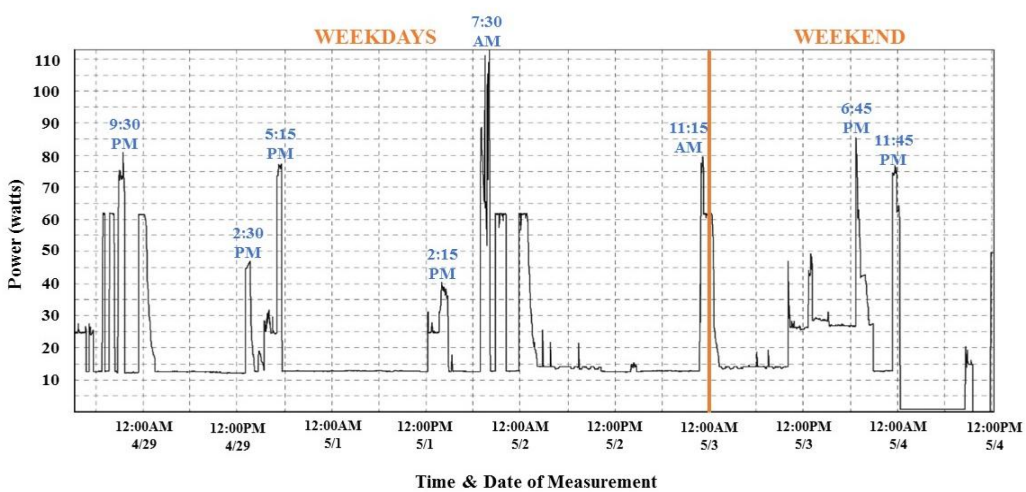


Figure 4.4: Typical pattern of usage (shown for Building 1)

Logistical Limitations:

Residence life staff distributed the plug load meters to student resident volunteers in each building and the researcher had no direct contact with the participants. The researcher attached an instruction tag to each meter. The majority of participants appeared to follow the instructions properly. However, in several cases there is evidence that participants did not follow the instructions, which compromised the data collected by the meter. For example, the researcher asked participants to write the time and date that they plugged the meter into the outlet as well as their room number. Volunteers returned some meters without the time, date, and/or room number information. Follow-up e-mails were successful in obtaining this information for some but not all of these meters.

Also, in an effort to attract participants, the researcher designed the metering procedure to be simple and not redundant with the self-audit surveys happening simultaneously. Therefore, the researcher did not ask participants to document exactly what devices they plugged into the meter. The instructions were to plug all of the devices that they ordinarily would have plugged-in all the time into the power strip/plug load meter set-up. However, a power strip only contains six outlets and the pattern of devices always plugged-in or plugged-in as necessary may have differed from how students would ordinarily use devices in their rooms.

4.2.3. Self-audit Inventory Estimates

Student self-audit surveys were used to estimate plug loads in student rooms in each of the six field site buildings. Altogether, the self-audits represented plug loads in 26,278 ft^2 of resident rooms/suites housing 163 students.

Plug Load Estimates & Metrics:

Table 4.5 shows the results of the student plug load self-audit survey and the subsequent plug load metrics calculations. The average estimated peak plug load power was 2,720.02 watts (range of 1,805.14-3,706.90 watts). The average estimated plug load power density was 15.01 w/sf (range of 13.53-16.92 w/sf). The average estimated daily plug load energy use was 2.34 kWh/dy (range of 1.64-3.63 kWh/dy). The average estimated annual plug load energy use per square foot was 3.60 kWh/sf/yr (range of 2.38-4.53 kWh/sf/yr). Finally, the average estimated plug load energy use intensity was 11.31 kbtus/sf/yr (range of 7.49-14.19 kbtus/sf/yr).

Table 4.5: Estimates & metrics for student self-audits

	Building 1	**Building 2**	**Building 3**	**Building 4**	**Building 5**	**Building 6**	**Ave.**
Building Area (sf)	3,238	4,585	2,988	7,263	3,323	4,881	
Occupants (#)	14	28	26	60	15	22	
Peak watts	3,600.08	2,223.80	1,848.90	1,805.14	3,706.90	3,135.32	2,720.02
w/sf	13.53	13.71	16.18	15.22	16.92	14.47	15.01
kWh/dy	2.18	1.64	1.68	2.04	3.63	2.86	2.34
kWh/sf/yr*	2.38	2.69	3.95	4.53	4.52	3.53	3.60
Kbuts/sf/yr (EUI)	7.49	8.46	12.43	14.23	14.19	11.08	11.31

Patterns of Usage:

Although plug load data were directly measured or logged overtime as part of the self-audit, students were asked to provide daily and weekly usage patterns for specific devices. Thus, self-audits resulted in more fine-grained, device-specific data than was possible with either the panel or spot metering. For example, a mini-fridge was estimated to draw 175 watts of power. However, the compressor of the unit may only run for 8 hours per day. Therefore, the wattage may be low compared with high wattage devices such as a hairdryer, which runs for 10-15 minutes.

Logistical Limitations:

In an effort to maximize the number of self-audit survey responses, participants were only asked how many of a certain type of electronic device they owned, whether they shared it with roommates, and how often each day and week they used it. This method enabled students to quickly move through four categories of devices and provide a general sense of usage. The researcher then assigned typical wattages to each device. However, device power ratings and usage vary (i.e. brands of laptop computer) and the calculations make no attempt to distinguish between different device brands/models. Additionally, plug load data was not logged over time as it was with the electrical panel and spot meter measurements and therefore it was not possible to examine usage patterns over the study period.

4.2.4. Methods Comparison

Table 4.6 shows a side-by-side comparison of the three plug load measurement and metrics methods. The results show significantly different values. However, as expected, each method was capable of describing plug loads in residence hall rooms its own unique way.

Table 4.6: Comparison of plug load measure & metrics

	Self-audits	**Elec. Panels**	**Spot Meters**
Peak watts	2,720.02	2,542.4	210.98
w/sf	15.01	1.03	1.14
kWh/dy	2.34	16.8	0.33
kWh/sf/yr*	3.60	1.61	0.52
Kbuts/sf/yr (EUI)	11.31	5.05	1.45

The self-audits described the specific electronic devices that students have in their living spaces and the "potential" peak plug load power that may result from this equipment. This information may prove useful for right-sizing electrical system or to identify electrical demand load shedding opportunities (i.e. restricting devices or providing efficient ones). The data is particularly fine-grained, but it is self-reported and power and energy metrics are estimated rather than measured directly.

The metered data is less-fine grained than the self-report data, but it was directly measured over time. It shows the actual vs. potential power and energy use since it is unlikely that all devices in a student room are used simultaneously. The measurements describe groups of devices plugged into a meter or groups of devices plugged into outlets fed by a common electrical panel. It is not possible to distinguish specific devices from the spot metered data or even specific students or rooms from the panel data. However, the data illustrates the patterns of usage over time (i.e. peaks, valleys, phantom loads, etc.).

Spot meters required that all devices being measured be plugged into the unit. If devices are scattered around a resident room and cords cannot practically reach or connect to the meter, the resulting data may be compromised by these missing loads. This may explain the lower power and energy measurements from the spot meters. However, the meters are easily dispatched to student volunteers and inexpensive. The power quality meters required working with electricians to install and remove the expensive equipment. It was also difficult to find “ideal” panels to measure. Nevertheless, larger areas of buildings can be metered efficiently without recruiting volunteers and without access to private rooms. In the absence of more sophisticated metering or monitoring in residence hall buildings, the three measurement/estimating methods, despite inherent strengths and weaknesses, were effective in providing plug load data.

4.2.5. Comparisons with Plug Load Predictions

As discussed in Chapters I and II, architects and engineers designing residence hall buildings routinely use plug load assumptions in energy models to predict building performance before the facilities are built. The design teams for four of the six field site buildings provided specific plug load assumptions used during the design process for comparison with in-use plug load measurements taken in this research. These assumptions included: plug load power density (peak power) in w/sf and the daily schedule or profile of use, which shows the percentage of the plug load power density expected at different times.

Table 4.7 compares the predicted and actual plug load power densities in w/sf. Overall, the actual measured plug load power densities were higher than predicted in design. The one exception to this was for Building 5 where the average spot meter plug load power density of 0.68 w/sf was almost exactly the predicted value of 0.625 w/sf. The electric panel measurements ranged from 1.6-3.2 times higher than the predicted values, the spot meters ranged from 1-5 times the predicted values, and the self-audits (which represent potential plug load power density as discussed in Section 4.2.4) were 24-54 times the predicted value.

Table 4.7: Plug load power density predicted vs. calculated from in-use

	Building 1	**Building 2**	**Building 3**	**Building 4**	**Building 5**	**Building 6**
w/sf design energy model assumption	0.25	0.50	NA	0.625	NA	0.50
w/sf electric panel monitoring	0.77 (3X)	1.61 (3.2X)	0.81	0.99 (1.6X)	NA	NA
w/sf spot meters	1.12 (4.5X)	2.53 (5X)	0.72	0.68	1.06	1.14 (2.3X)
w/sf self-audits	13.53 (54X)	13.71 (27.4X)	16.18	15.22 (24X)	16.92	14.47 (28.9X)

Figures 4.5-4.7 compare the predicted and actual plug load profiles of use as a percentage of the peak plug load power density. For Buildings 1, 2, and 4, the actual profile does not show the pronounced peaks in the early morning and early evening that the predicted profiles show. In general, the actual profiles are less dynamic over the course of the day than the predicted profile. This may indicate less power use at the expected peak times and more at the off-peak times, for example sleeping hours or midday hours when occupants use of devices should be minimal.

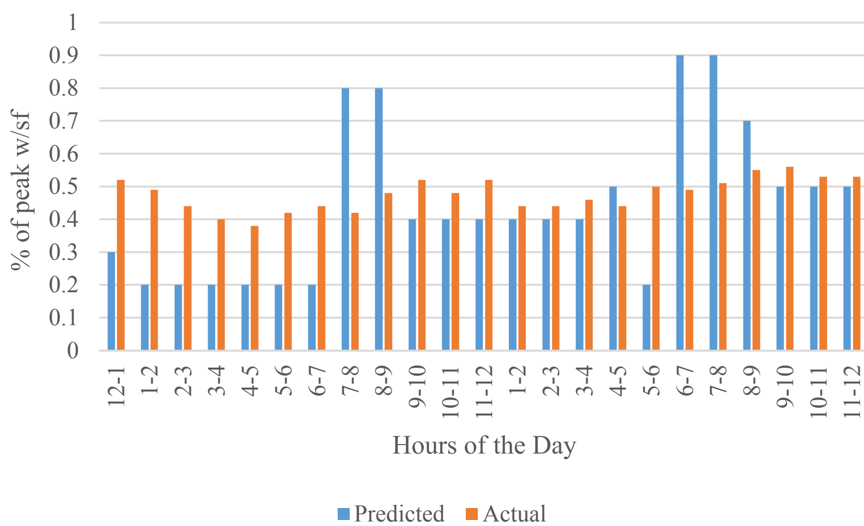


Figure 4.5: Predicted vs. actual profile of use (Building 1)

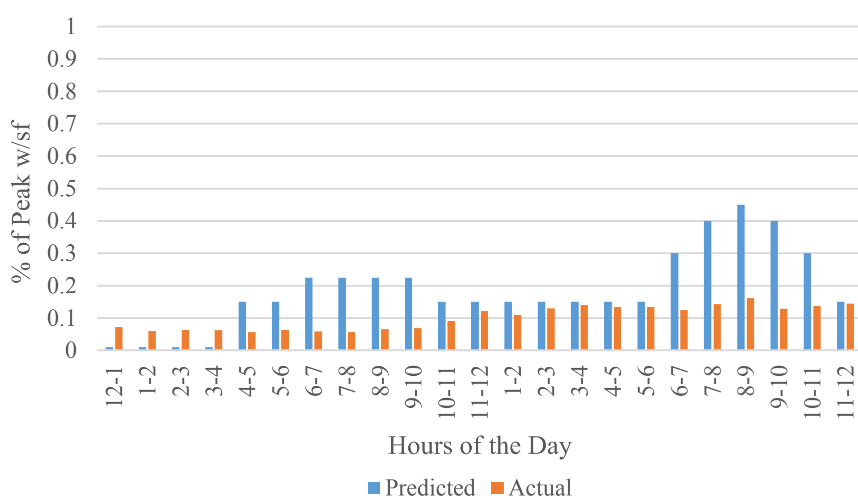


Figure 4.6: Predicted vs. actual profile of use (Building 2)

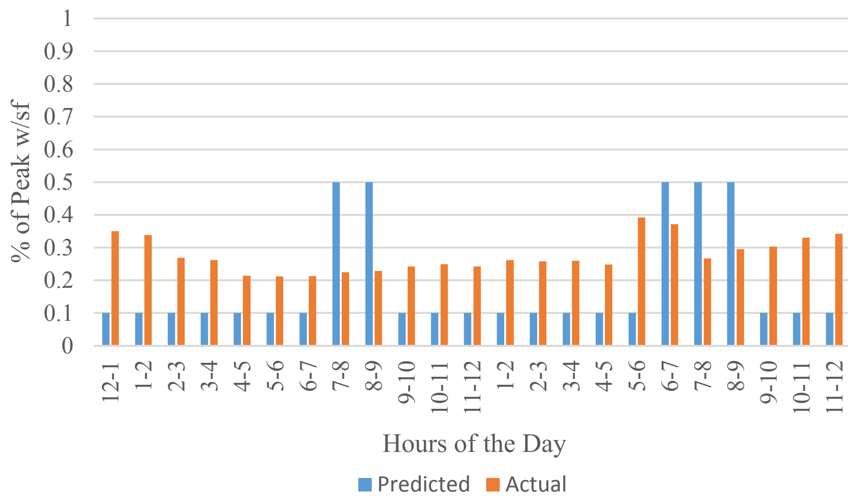


Figure 4.7: Predicted vs. actual profile of use (Building 4)

4.3. Self-audit Surveys

4.3.1. Survey Demographics

All survey participants (n=183) were undergraduate students. Of the respondents, 24% (n=44) identify their gender as male and 66% (n=137) as female. Three respondents did not identify a gender. Respondent ages ranged from 18-25 years with the majority (50%, n=91) at 19 years. (See Figure 4.9) The number of years respondents lived in residence halls ranged from 1-4 years with the majority (64%, n=117) having lived in the halls for only that academic school year. (See Figure 4.8)

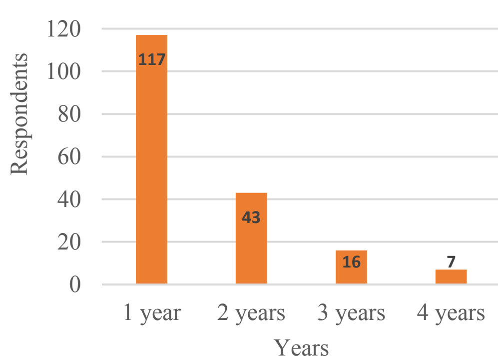


Figure 4.8: Years in residence halls

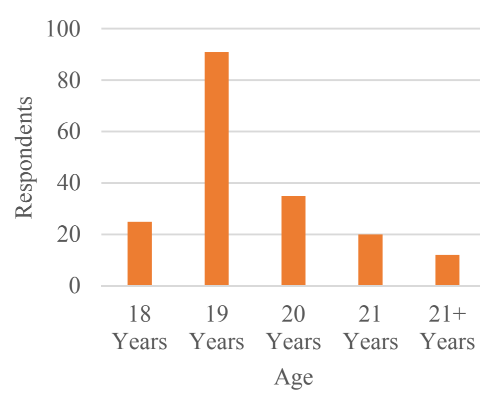


Figure 4.9: Age of respondents

Respondents came from nine countries including: The UK, Vietnam, Japan, China, Singapore, Russia, Brazil, Mexico, and the US. However, the majority (93%, n=103) came from the US. Respondents came from 16 US states, but the majority (61%, n=170) came from Oregon. One hundred and seventy students provided their e-mail addresses to for the prize drawing. Thirty eight students provided their e-mail addresses to for interview participation.

4.3.2. Student Devices

The self-audit portion of the survey asked students to document the devices they own and/or brought with them to school. These devices were divided into four general categories: computer-related devices, kitchen devices, entertainment devices, and other devices. Figure 4.10 shows the percentage of respondents who have one or more of a range of specific devices.

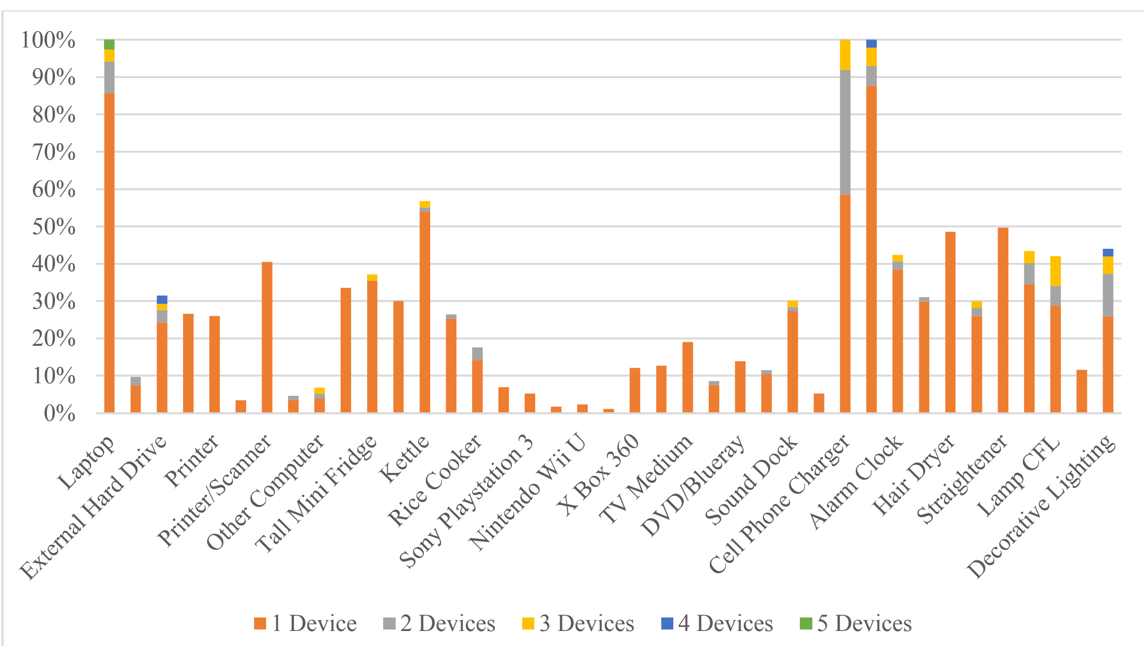


Figure 4.10: Numbers of devices students own

Without doubt, the kitchen devices draw and use the most power. However, there is an interesting difference to between the device wattage and usage. Computer-related devices draw very little power (a laptop computer draws only 25 watts when charging), but these devices are heavily used. The overall daily energy usage shows the computer equipment as a larger slice of the energy pie. Findings indicate that very few students now bring desktop computers, which use can use 10 times more power than laptops. See Figure 4.11 for the relationship between device wattage and time used in minutes per day.

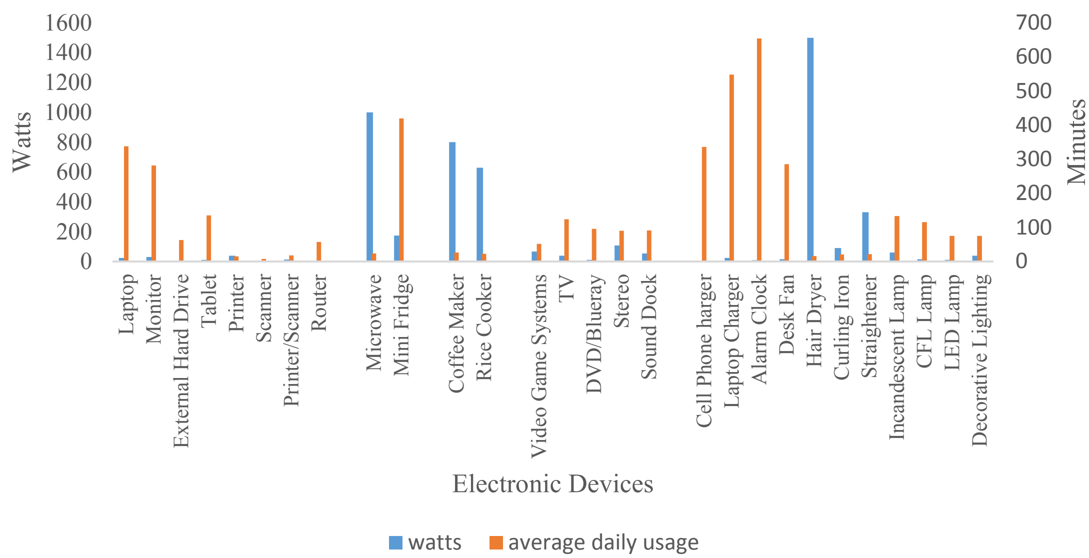


Figure 4.11: Peak plug load power (watts) and daily energy usage (minutes)

Sharing With Roommates

Most residence hall students share their room or suite with roommates. It seems logical that in a relatively small shared living space students would share electronic devices with one another. The self-audit results indicate that sharing devices varies according to the type of device. For example, residents appear to share kitchen-related devices such as mini-refrigerators and other small appliances to a much greater extent than other types of devices. Computers, personal care devices, and task lighting were among the least shared electronics. Overall, the self-audit responses suggest that sharing most electronic devices was uncommon. (See Figs. 4.12-4.15)

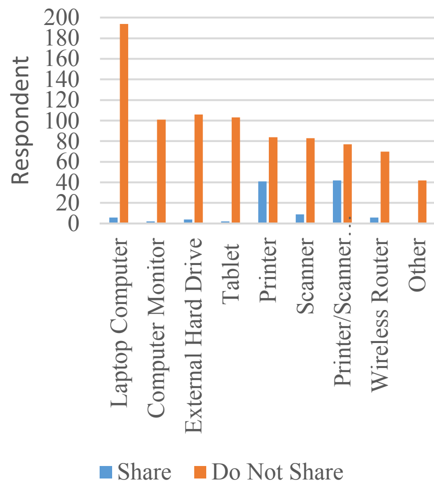


Figure 4.12: Sharing computing devices

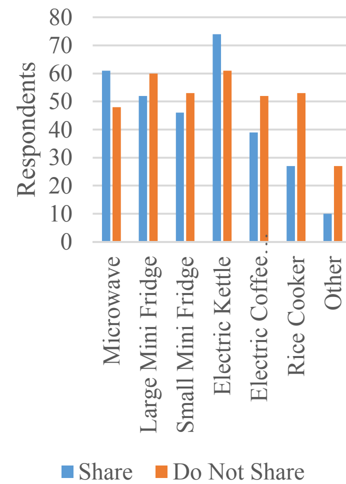


Figure 4.13: Sharing kitchen devices

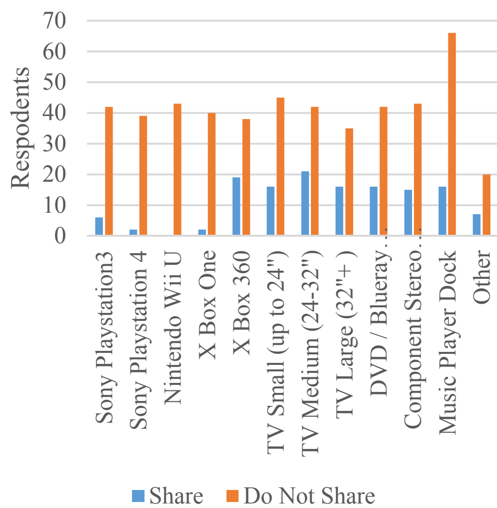


Figure 4.14: Sharing entertainment devices

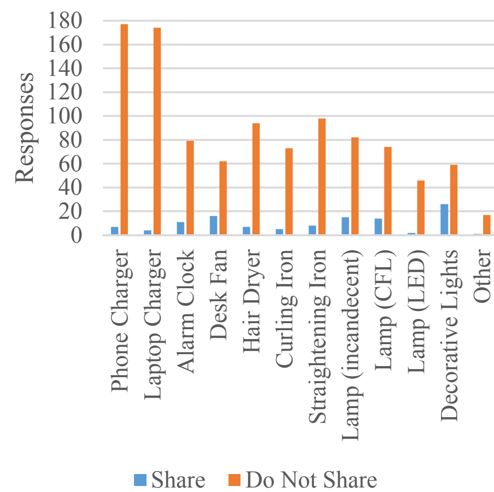


Figure 4.15: Sharing other devices

4.3.3. Weekly Device Usage

Computers, cell phones, and chargers appear to be the electronic devices that students used most frequently each week. Other computer-related equipment (i.e. printers) is less-used each week, which may explain the popularity in recent years for “business center” common spaces where residents can copy or print on a shared device.

Many students bring kitchen-related equipment (i.e. an electric kettle), but these devices seem less frequently used by some residents. Entertainment devices appear less frequently used with the exception of a music player. More than half the respondents use task or accessory lighting daily. Overall, there is a staggering array of devices that students bring with them to college. However, it appears that certain devices (i.e. laptops) are used far more often than other devices (i.e. game systems), which may have implications on the potential vs. actual plug loads in student rooms. (See Figs. 4.16-4.19)

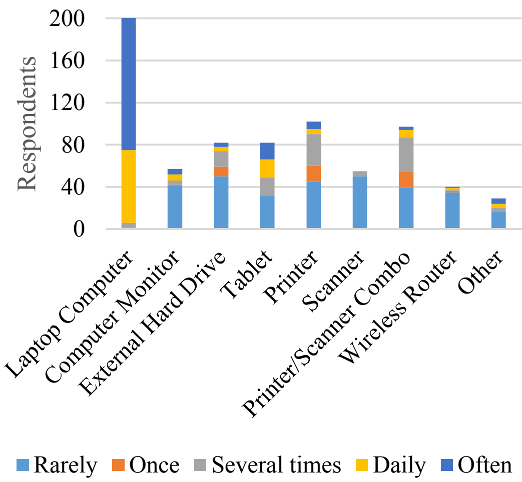


Figure 4.16 Weekly usage of computer devices

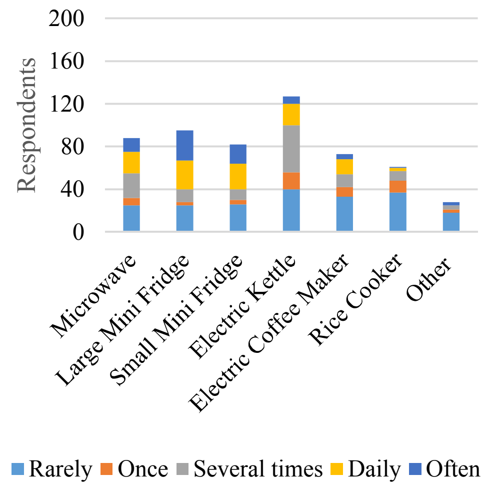


Figure 4.17: Weekly usage of kitchen devices

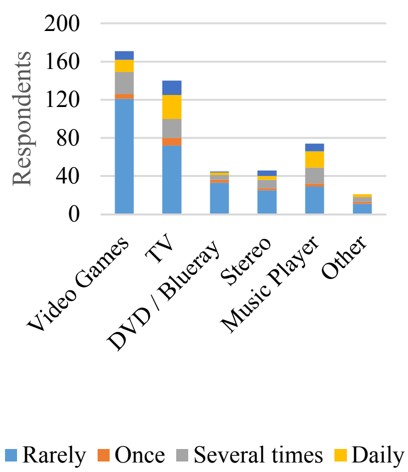


Figure 4.18 Weekly usage of entertainment devices

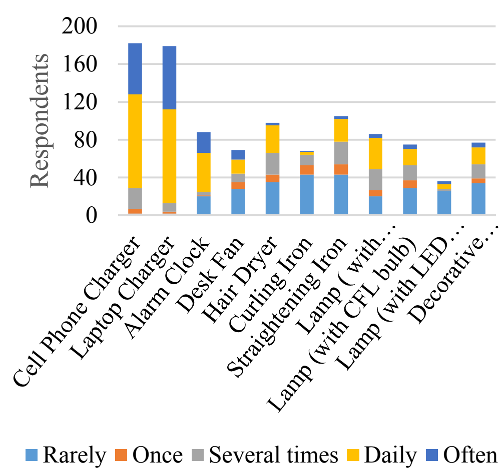


Figure 4.19: Weekly usage of other devices

4.3.4. Student Perceptions & Actions

When asked how important conserving electricity was in their household growing up, the majority of students responded “moderately important.” The responses show a normal distribution skewed slightly toward “more important.” (See Figure 4.20) When asked how important it is to save electricity in their residence halls, the responses were similar. (See Figure 4.21) Taken together, these results suggest that student attitudes about conservation in residence halls do not differ markedly from the attitudes about conservation that they experienced prior to moving to college. In addition, it appears that students recognize the importance of conserving electricity even if conserving is not a top priority for them.

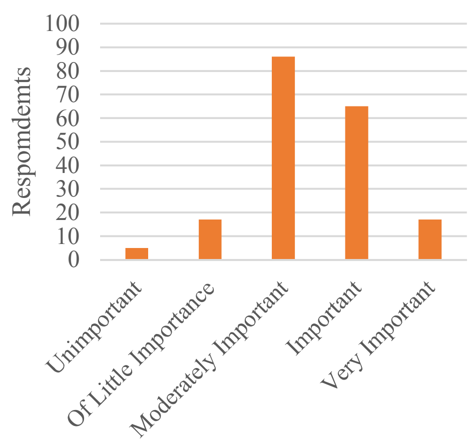


Figure 4.20: Importance of conserving electricity growing up

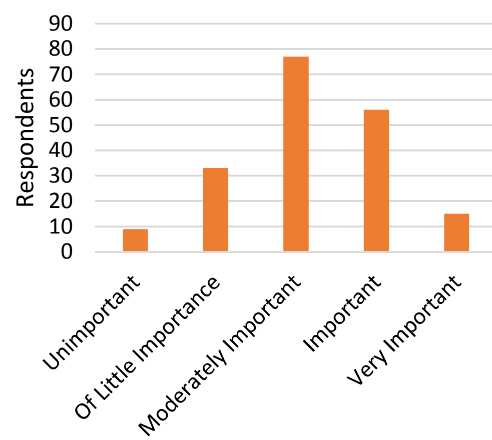


Figure 4.21: Importance of conserving electricity in residence halls

Lighting

When asked to rank a list of reasons for choosing to use task lighting over overhead hard-wired building lighting in their rooms, the most popular primary reasons appear to be “not enough light in the room” and “as a courtesy to their roommate(s).” The quality of lighting appears important to students, but not the most important criterion. Interestingly, a large number of respondents also ranked "not enough light" last, which suggests that students may be split in terms of whether or not they feel the room lighting is sufficient for their needs. (See Figure 4.22) However, it is clear from the responses that students do use task lighting to enhance the quality of the lighting and the mood or atmosphere in their rooms. Overhead lighting in residence halls is intended as ambient lighting for general tasks. Task lighting allows students another layer of lighting control.

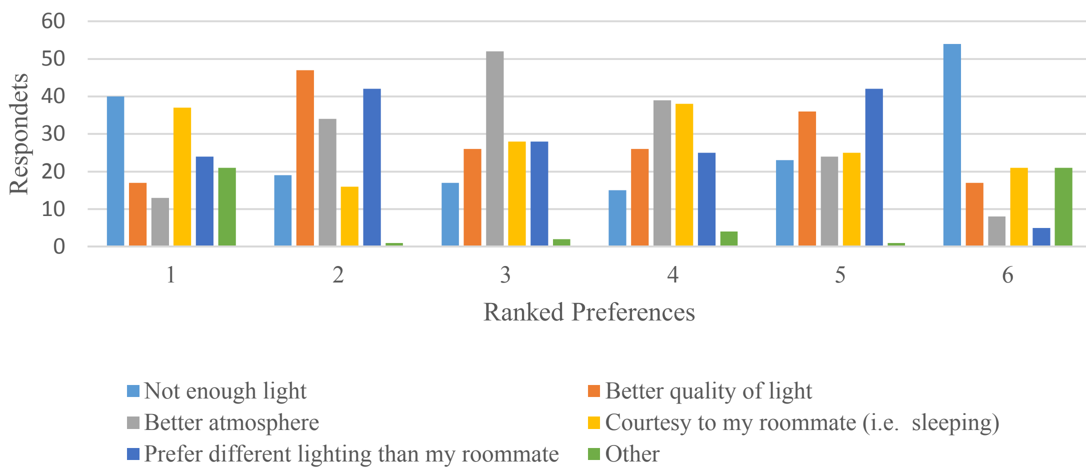


Figure 4.22: Ranking reasons for using task lighting over ceiling lighting

When asked to rank a list of reasons for closing window blinds or shades in their rooms, the most popular primary reasons appear to be "for privacy" and "I don't think much about it." This suggests that closing blinds or shades for reasons other than the amount of light coming into the room may interfere with the energy saving potential of daylighting. (See Fig. 4.23)

Plugging-in

Laptop computers are ubiquitous among students living in residence halls. Laptop battery technology is constantly improving to give users longer battery life without the need for charging. However, when asked how often students charge their laptop batteries while in their rooms, 90% of respondents claim to "always" or "often" charge their batteries. (See Figure 4.24) This suggests that laptops contribute to the plug loads in residence hall rooms despite having batteries that allow them to be used while unplugged from a wall outlet.

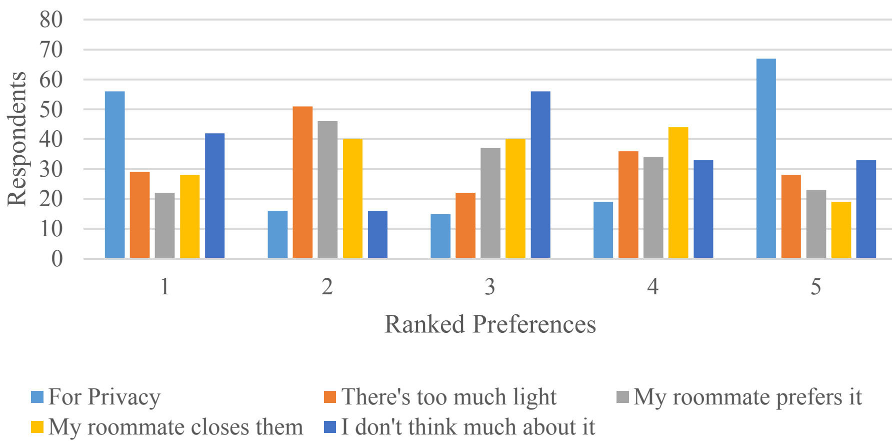


Figure 4.23: Ranking reasons for closing window shades/blinds

When asked how often electronic devices are unplugged when not in use, the majority students responded "sometimes." The responses show a normal distribution skewed slightly toward "more often." This suggests that students are conscious of unplugging devices, but that it may not be a priority for them, or something that that remember to do often. (See Figure 4.25)

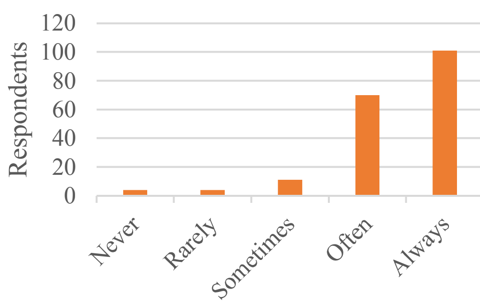


Figure 4.24: How often laptops are charged in the student room

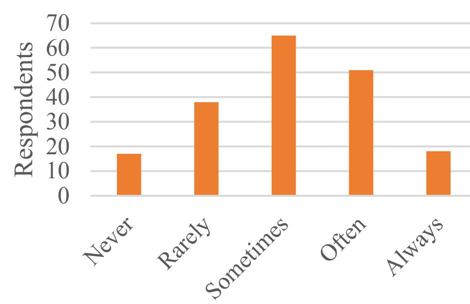


Figure 4.25: How often electronic devices are unplugged when not in use

It appears from the survey data that power strips are widespread in residence halls. 88% of respondents claim to plug electronics into power strips. (See Figure 4.26) This result is unsurprising given the easy access power strips provide to power, particularly when outlets are behind furniture, are in hard to reach places, or do not provide enough outlets for the devices being used. Housing offices also advocate the use of power strips as a safe alternative to extension cords. What is surprising is that 65% of respondents also claim to rarely or never turn off their power strips. (See Figure 4.27) Turning off a power strip is one of the easiest ways to reduce phantom or standby plug loads that result from devices drawing power when not in use by providing a single switch for all devices plugged-in to the strip. It remains unclear why students do not turn power strips off. Possible reasons may include: inconvenience, lack of awareness of conservation potential, or simply that it is not something that they think about often. However, since such a large percentage of students use power strips, but underuse them for conservation functions, smart power strips may be an effective alternative.

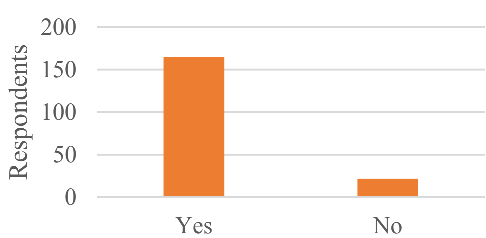


Figure 4.26: Plugging devices into power strips

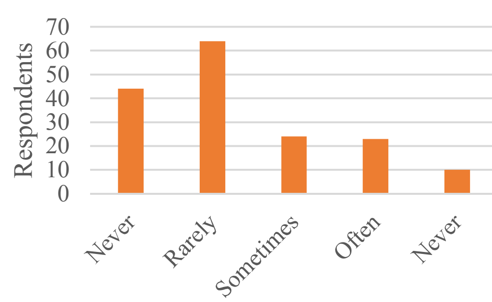


Figure 4.27: How often are power strips turned off

4.3.5. Additional Student Comments

At the conclusion of the survey, 41 students provided additional comments in an open-ended format. Topics included outlets, lighting, heating, building observation:

Elelctrical Outlets:

The electrical outlets are not placed well on my floor.

I am dissatisfied with the placement of outlets in the rooms, because there is not an outlet by all the desk spaces.

Outlets are blocked by furniture that cannot be moved other places.

The placements of the electrical outlets are very inconvenient. They are all under the beds, under the desks, or behind the closet. The only one not under something is by the sink. This makes it hard to not use power strips because the outlets are so far under other objects.

I wish there was another outlet in our rooms. One near our beds against the wall would be great. Also, the halls are terrible at muffling sound. When talking at a normal inside voice level, people can hear you in their rooms a few doors away. It makes it a bit difficult in the mornings and at nights.

There [are] a good number of outlets, just in the wrong places.

Lighting:

The two lights available in the room do not give enough light. They are extremely dim.

All additional lighting in our room is out of courtesy to our different sleeping schedules.

If I only need a little bit of light, I use [decorative string] lights that are strung around my room for light.

The overhead light looks terrible and I hate it. It's too bright.

You should make all of the lights motion sensored like in the bathrooms (same with the TVs in the lounges).

I wish some of the lights would not stay on all day and all night. The hall lights do not need to be on during the day. Also the laundry room lights do not need to be on the whole twenty-four hours a day.

Building Observations:

The light in the [laundry] room is constantly left on. It should automatically shut off to conserve energy.

I think the electricity competition that was posted in the GSH lobby should have been more publicized so that we could more avidly work toward reducing electricity!

This school lacks being effective in telling the importance of energy conservation.

Heating:

The heating system is unsatisfactory. I feel I am wasting energy because I cannot turn my heat down below the 70s.

4.4. Architectural Characteristics

Construction documents were used to examine a range of architectural characteristics across the six study sites. In general, the buildings contained two types of bedroom units: traditional bedrooms (singles, doubles, and triples) with or without private bathrooms and suites of bedrooms with private bathroom(s)—often with a common lounge space, and sometimes a kitchenette or full kitchen. Traditional rooms were an average of 233ft^2 and housed 1 to 3 occupants. Suites were an average of 975 ft^2 and housed 3-6 occupants. The average amount of unit area per occupant was 164 ft^2. Average ceiling heights across the rooms/suites was 9’-0” and the average depth of units measured from the exterior wall to the corridor wall was 19’-0”. All rooms/suites contained ample exterior windows. The average window area was 62 ft^2 and the height of windows was 5’-8”.

The average number of electrical outlets in rooms/suites tends to vary depending on the number of separate rooms and occupants. Overall, the average number of electrical outlets in rooms/suites ranged from 6 to 72 and were most often in groups of two outlets (duplex receptacles). The average number of outlets was 22 and the average number of outlets per occupant was 7.6. The more amenities included in a student unit (i.e. sinks, bathrooms, kitchens, etc.), the more electrical outlets. For example, a simple single student bedroom may contain as few as three duplex receptacles.

The size of the buildings ranged from 59,000 to 185,000 ft^2 with an average area of 127,000 ft^2. The average amount of building area per student resident was 366 ft^2. All buildings were 4-5 storeys. It was most common for the majority of rooms/suites to be located above the ground level. However, all of the buildings contained units located at grade.

4.5. Correlations

Correlations were used to test the relationships between two dependent variables (peak plug load power in watts and daily plug load energy use in kWh) and 13 independent variables (building design characteristics or factors). The range of building characteristics included: room/suite area, volume, depth, numbers of outlets, numbers of outlets per occupant, orientation, and numbers of occupants; building area, area per occupant, and level; and distance between rooms/suites and common spaces.

4.5.1. Plug Loads & Design Characteristics

Correlations for the data revealed that overall plugs loads were not significantly related to building design characteristics. The average values for the plug load variables change only slightly in response to changes in the design characteristic variables. The correlation coefficients (r) ranged from 0.009 to 0.378, weak to moderate relationships between design characteristics (IV) and plug loads (DV). The coefficients of determination (r^2) ranged from 0.00008 to 0.143, the design characteristics (IV) explain less no more than 14% of the variance in the plug loads (DV). (See Table 4.8 and Appendix E) These results suggest that design characteristics play a minor role in plug loads power and energy in residence halls and that other independent variables likely play more significant roles.

Table 4.8: Correlation Results

IV	DV	Sig (*p*)	*r*	Strength	r^2	% Variance
Area	Watts	0.010*	0.331	moderate	0.110	11.0%
Area	kWh/Day	0.401	0.055	weak	0.003	< 1%
Area/Person	Watts	0.097	0.108	weak	0.012	1.2%
Area/Person	kWh/Day	0.030*	-0.193	weak	0.037	3.7%
Volume	Watts	0.010*	0.347	moderate	0.120	12.0%
Volume	kWh/Day	0.276	0.071	weak	0.005	< 1%
Depth	Watts	0.010*	0.378	moderate	0.143	14.3%
Depth	kWh/Day	0.851	-0.015	weak	0.0002	< 1%
Outlets	Watts	0.010*	0.278	weak	0.083	8.3%
Outlets	kWh/Day	0.194	-0.085	weak	0.007	< 1%
Outlets/Person	Watts	0.053*	0.125	weak	0.016	1.6%
Outlets/Person	kWh/Day	0.003*	-0.193	weak	0.037	3.7%
Orientation	Watts	0.341	0.062	weak	0.004	< 1%
Orientation	kWh/Day	0.890	-0.009	weak	0.000081	< 1%
Distance to Lounge	Watts	0.835	-0.032	weak	0.001	< 1%
Distance to Lounge	kWh/Day	0.803	0.039	weak	0.002	< 1%
Window Area	Watts	0.001*	0.246	weak	0.061	6.1%
Window Area	kWh/Day	0.003*	0.194	weak	0.038	3.8%
Building Area	Watts	0.004*	-0.184	weak	0.034	3.4%
Building Area	kWh/Day	0.090	0.11	weak	0.012	1.2%
Building Area /Occupant	Watts	0.069	0.118	weak	0.014	1.4%
Building Area /Occupant	kWh/Day	0.093	0.109	weak	0.012	1.2%
Floor Level	Watts	0.171	-0.089	weak	0.008	< 1%
Floor Level	kWh/Day	0.315	0.065	weak	0.004	< 1%
Room Occupants	Watts	0.010*	0.373	moderate	0.139	13.9%
Room Occupants	kWh/Day	0.016	0.156	weak	0.024	2.4%

* $P < 0.05$

4.5.2. Plug Loads & Room/Suite Level Factors

Despite the overall lack of significant correlation between plug loads and design characteristics, two intriguing patterns emerge from the analysis. Overall, the tests using peak plug load power as the dependent variable had stronger relationships with building characteristics than the tests using daily plug load energy. If peak plug load power represents the potential for power use, then this finding may suggest opportunities for addressing peak demands and the associated infrastructural and/or managerial implications.

Second, only four of the 26 tests resulted in a correlation coefficient greater than r = 0.30, Kaska-Miller's threshold for a moderate correlation for nonparametric social and behavioral science results (2013, p. 81). Furthermore, all four of these results were for room/suite level design characteristics: room area, r = 0.331; room volume, r = 0.347; room depth from the window wall, r = 0.378; and number of room occupants, r = 0.373.

It is interesting to note that whole building characteristics such as total building area or floor level show significantly weaker correlations than those at the room/suite level. Higher peak plug load power was associated with larger amounts of space and greater amounts of occupants living in that space. If one current trend in residence hall design is to reduce the size of student bedrooms and to increase the amount of shared or common space, these results suggest that the design of rooms/suites may be an important part of a more comprehensive solution to address occupant use of plug load power.

4.5.3. Borderline Factors

Several design characteristics—number of outlets in the room and window area—resulted in correlation coefficients slightly less than the r = 0.30 threshold, borderline moderately significant relationships. Although these relationships were not quite as strong as the four room/suite special characteristics, these factors may have different kinds of implications on plug loads.

Code requirements influence the number and spacing of outlets in buildings. In general, more linear footage of walls and/or more complex room geometry often results in greater numbers of outlets. If more outlets negatively impact plug loads in student rooms, there may be less opportunity for design to be part of the solution within the established industry conventions.

Modern energy code requirements also influence window glazing areas. Survey results provide evidence that occupants prefer daylight to electric lighting and that most students use secondary lighting sources within their living spaces. If larger windows result in greater plug loads, this result appears to contradict what would seem a more rational outcome, that larger windows mean occupants have less need for lighting. This would be a negative correlation and not a positive one. However, the results suggest that, perhaps, larger windows mean that occupants prefer spending more time in their rooms in close proximity to their personal electronic devices.

This research provides little clear evidence for the design implications in these few borderline correlation tests, but suggests a more nuanced approach to design characteristic variables that may take into account factors not considered in this study.

4.5.4. Correlation Summary

Table 4.8 summarizes the results from correlation tests between building characteristics and plug loads. Overall, 22 of the 26 tests show weak relationships ($r < 0.30$), four tests show moderate relationships ($r = 0.30$-0.80), and none of the tests show strong relationships ($r > 0.80$). Findings suggest that design characteristics play some role in plug loads, but that other factors merit further examination. Room/suite level characteristics as independent variables resulted in the strongest relationships compared with building level characteristics. Also, peak plug load power as dependent variables resulted in stronger relationships than did daily plug load energy use. This provides some evidence that peak plug load power in student rooms and the characteristics of those rooms are somewhat more important variables, which may inform variable selections in future studies.

4.6. Summary of Results

This chapter presents the quantitative results and analysis of a field study on plug load energy in six Oregon residence halls on three campuses. Section 4.2 presents plug load measurements and metrics from data gathered through: monitoring in electrical panels, spot metering in student rooms, and student self-audit inventories. Results suggest that: various methods of plug load measurement can be effectively combined to harness the unique benefits of each; patterns of plug load usage vary by student, but generally show several peaks per day occurring in the morning and evening; self-audits inventoried the range of student electronic devices and estimated the "potential" peak plug loads; and actual plug load power density in residence halls were more than three times higher than predicted during the process design.

Section 4.3 presents the student survey results including: sample demographics, student device inventories, and responses related to plug load and energy attitudes and actions. Results suggest that students: bring many devices with them to school, but may not use all of them often; seem dissatisfied with the number or arrangements of power outlets in their living spaces; use task lighting to enhance the quality or quantity of lighting provided by ceiling lighting; and generally feel that conserving electricity was "moderately important" both in the home they grew up in as well as in their residence hall.

Section 4.4 describes the building characteristics used as independent variables in the correlations presented in Section 4.5. Results of the correlations suggest that plug loads were not significantly correlated with building design characteristics. However, moderate relationships resulted with room/suite specific characteristics such as area, volume, depth, and numbers of occupants in a room. Several borderline moderate relationships resulted for numbers of outlets and window area. This suggests that certain building characteristics may play a more important role than other in residence hall plug loads, but that further examination is necessary.

CHAPTER V

QUALITATIVE ANALYSIS

5.1. Introduction

Constructivist grounded theory (CGT) methods were used to analyze the 24 interviews collected in Phase II of this study (Charmaz, 2000, 2006a, 2011; Mills, Bonner, & Francis, 2006). Interviewees included student residents, designers (architects and engineers), and campus personnel concerned with residence hall operations (facilities managers and housing administrators). The researcher used an emergent coding technique to analyze the interview data. The large number of codes resulted in 30 salient themes emerged from the codes, and these themes informed two analytic categories: "Doing Less With More" and "Supporting the Student Experience." These emergent categories explicated the processes in the narratives and experiences of the participants with regard to plug load energy in residence halls. The coherent process found in the data was "The Balance of Power," which describes and explains the way the various stakeholder groups influence plug loads in residence halls.

5.2. Participants

Phase II of this study included 24 responsive interviews with adults who have a personal and/or professional connection to plug loads in residence halls: student residents, campus operations personnel, and building designers. Several design participants provided reports related to predicting plug load usage during or prior to the design process. The interviews elicited detailed information about the general and specific nature of plug loads in residence halls and the supplementary documents, when available, provided additional information for checking and clarifying emerging ideas.

The respondents' characteristics varied by age, gender, and type of experience with plug loads in residence halls. Half of the total interview respondents were designers with experience designing residence halls for campuses. Of these 12 respondents, seven were architects and five were engineers or energy modelers. The designer group consisted of mostly male respondents with only one female architect interviewed.

Of the five respondents in the operations group, four were facilities or housing facilities managers and one was a housing director. The operations group consisted of mostly male respondents and one female facilities manager. The ages of the respondents in the designer and operations groups ranged from mid-30s to 60s with an average age around 45-50 years old.

The seven respondents in the student group came exclusively from survey respondents. Although students at each of the three field site universities initially expressed willingness to be interviewed in the Phase I survey and were contacted several times regarding participation, only students from two of these institutions are represented in the final interview sample. One explanation may be that the interviews occurred over the summer break when students were away from campus and may not have been checking their institutional e-mail regularly. The student group consisted of most female respondents with one male respondent and their ages were between 19-21 years old.

5.3. Interview Data

The duration of the interviews ranged from 21 to 93 minutes with an average of 42 minutes. The transcription time ranged from 30 minutes to 6 hours with an average of 3 hours and 40 minutes.

5.4. Starting Points

Constructivist Grounded Theory suggests that researchers acknowledge that their starting points influence how they see the data and what they see in the data (Charmaz, 2011, p. 170). I am aware that my experiences with designing, studying, and living in campus buildings influence my approach and perspective with respect to the interview data.

As an undergraduate college student, I lived in a residence hall for two and a half years and experienced first-hand what it is like to have all of your possessions in a small room shared with a roommate. As an architecture student, I did not spend much time in my room. However, I do not recall ever thinking about energy use or conservation. Like most students, I used power when I needed it, turned the heater up when it was cold, and opened the window when I needed fresh air. Granted, electronic devices have evolved considerably since that time and I understand that students' need for devices are different than my needs while living in student housing between 1997 and 1999.

As an architect, I designed a number of buildings for academic institutions and became aware of a different perspective on energy use in campus facilities. I learned that occupants in buildings make energy-related decisions, which impact larger campus energy conservation efforts and environmental impact goals. I did not have an appreciation for this side of the story while living in residence halls. In my professional work, I used design as a way to help campuses address their energy needs and issues, often by using green building technologies to take some of the energy-related decision making away from occupants. However, I was also aware of the importance of understanding occupant behavior and preferences so that the technology could make their lives easier in addition to saving energy or mitigating waste.

As a researcher, I have examined campus sustainability efforts, energy data, and energy efficiency measures in buildings. I collected data in buildings including residence halls and feel connected to the current state of energy use in that particular building type. I have discussed the use of technologies and behavior change initiatives aimed at energy conservation in student housing with campus personnel and administrators. In addition, the first phase of this study quantitatively examined plug load energy in residence halls to provide baseline knowledge, which the interviews seek to expand and elaborate upon. This initial research also informed the kinds of question topics included in the interview guide framework.

The data I analyze here fit within a realm of experience that encompasses the experiences of: end-users (student residents), building designers (architects/engineers), and building managers (operators). The data for this study consist of interviews about plug load energy with these three groups of participants who provide their own unique perspectives on the topic.

5.5. Initial Emergent Coding

As explained in Chapter 3, the first step in the analysis process was coding the interview data. The researcher used emergent coding to assign tags to lines of text that explicate processes in the participant narratives. Emergent coding is the term given to this process because the codes emerge directly from the text rather than from preassigned codes applied to the text. This process generated more than 471 unique codes. At the beginning, nearly every line of text had a different emergent code. As the coding progressed and the codebook grew, emergent codes applied to other chunks of text as well. At the conclusion of the initial coding, the researcher combined/merged codes with that described similar ideas or processes. (See Fig. 5.1)

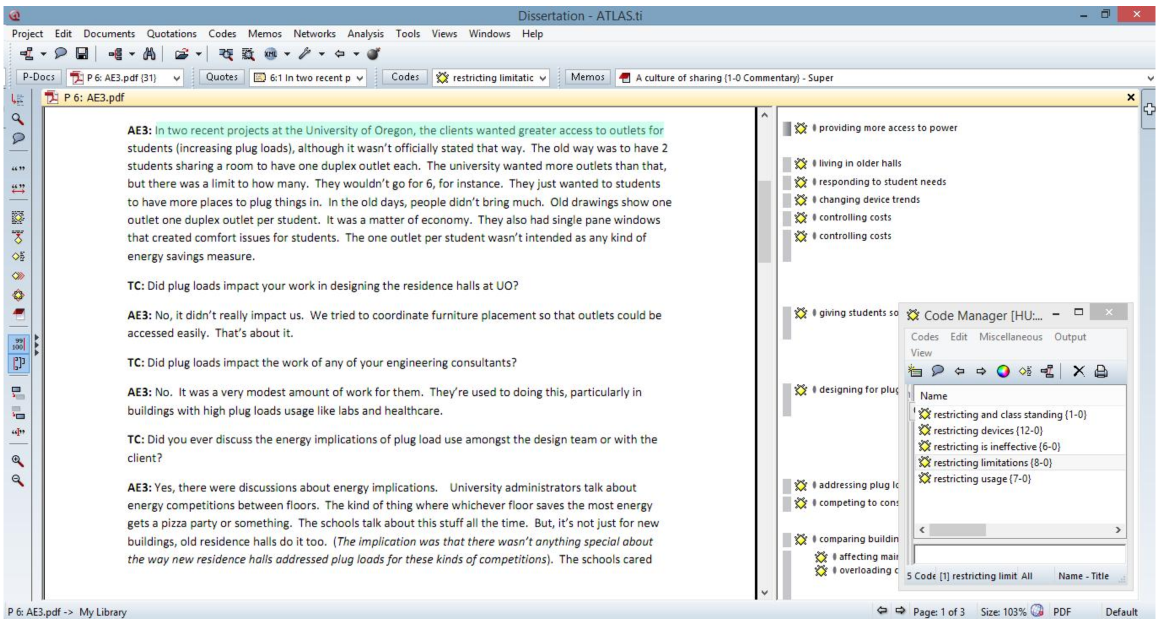


Figure 5.1: Coding process using Atlas.ti software

5.6. Emergent Themes

Following the initial emergent coding, the researcher developed 30 themes around the code topics. (See Table 5.1) For example: the theme "managing costs" brings together ideas contained within the following emergent codes: "Controlling Cost, Financing Limitations, Financing Opportunities, Misunderstanding Intent, Perpetuating the Myth of Cost, and Understanding Capital Construction and Operating Budgets." (See Table 5.1)

Table 5.1: Themes that emerged from participant narratives

Addressing Plug Loads	Providing Control
Enforcing Policies	Providing Information Fee
Connecting with Institutional Goals	Providing Information/Feedback
Designing for Efficient Operations	Pushing Clients
Designing for Student Needs	Raising Awareness
Educating Users	Recognizing Institutional Priorities
Employing Technologies	Restricting Choices
Energy Behavior	Social/Community Interactions
Engaging Students	Supporting Freedom
Evaluating Performance	Supporting the Student Experience
Finding Efficiencies	Transitioning to and from Residence Halls
Managing Costs	Understanding Conservation Attitudes
Navigating Politics	Using Power
Occupant Energy Expectations	Using Lighting
Paying for Energy	Using Electronic Devices

5.7. Analytic Categories

The 30 emergent themes encompassed a wide range of overlapping ideas and processes related to plug loads in residence halls. From these themes, analytic categories were raised that attempted to explain and untangle the ways in which the themes overlap and come together. The two analytic categories were: “doing more with less” and “supporting the student experience.” (See Fig. 5.2)

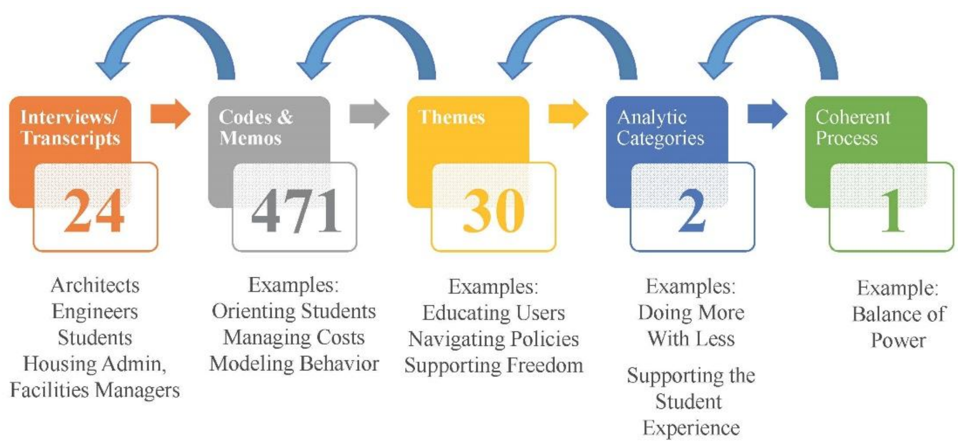


Figure 5.2: Qualitative analysis process & results.

5.7.1. Doing More With Less

Architects and engineers responded that they are motivated to do more with the design of residence halls; to push for more aggressive energy targets that respond to industry and institutional sustainability efforts; and to improve the quality of the living environment for students. One participant (AE12) described this sentiment in these terms:

> There is an acknowledgement everywhere that 'boy, we can do a lot more with these student housing projects.'

At the same time, designers appear to understand the limits or boundaries when it comes to making decisions to push residence hall designs in new directions. One participant (AE4) explained it this way:

> All we can do is make recommendations and say in our experience this has been a challenge that we've seen and something that can limit the potential energy savings or goals of the project. I've never seen it get much more forceful than that.

Another participant (AE9) described the process in terms of guiding the client:

> I feel like we usually talk about it a lot and we set budgets and we set limits and then ultimately it becomes an owner decision. So, we're there to help guide them to make that decision and understand the implications of that on the energy goals they've told us that they have.

At the institutional level, sustainability goals, targets, and commitments support the idea of doing more with residence halls. One operations participant (OP3) commented:

> When you go out and you're building a new building and you want to make it LEED Platinum or LEED Gold or Silver, there's some phenomenal things that are built into making a building LEED.

And there was also recognition within campus operations divisions that institutional green building policies guide the design outcomes. Another operations participant (OP4) put it this way:

> I'm not the only one in the room trying to make [energy efficiency] decisions and a lot of these smart functions are [part of] other mandates such as getting LEED Gold for buildings and energy conservation.

There was also recognition that a lack of institutional commitment impacts the degree to which a residence hall project can achieve even more stringent targets. One design participant (AE1) described it this way:

> I like to start with our clients to have those policy conversations because I need to know how far they're willing to go.

However, institutional cultures vary considerably, which also influences the direction of the design process. Designers are sensitive to such differences when working with institutional clients on residence hall facilities. One design participant (AE6) explained:

> The conversations depend a little bit on which entity you're working with. And when I say entity, I'm referring to specific universities; because there's a culture that influences that discussion from the get-go depending on the university.

The design process looks different lower down the institutional hierarchy where housing offices appear caught between three competing objectives: providing the best living and learning experience, controlling costs because housing relies on revenue, and meeting institutional sustainability objectives. The challenge for housing offices and designers of residence halls is how to achieve green buildings that are student-centered at a reasonable cost. One design participant (AE12) put it this way:

> We're trying to make really smart buildings simple so that they can be cost-effective.

Within the analytic category *Doing More With Less*, there are four sub-categories described below that further explicate the processes inherent in maximizing outcomes within budgetary constraints: (1) "First Cost is King," (2) "Code Implications", (3) "All-Inclusive Rates," and (4) "Accessing Plug Loads."

First Cost is King

Many design and operations participants discussed the process of designing and constructing residence halls for cost control. Participants shared what it looks like when first cost considerations (the costs associated design and construction) now impose barriers on exploring and/or implementing design solutions that have the potential to positively impact operational costs later. Designers conceptualized this idea as a structural limitation of residence halls that impacts how residents use the building, but that remain largely hidden from the end-users. One design participant (AE1) described it this way:

> Budgets are a constraint, and especially residence halls that have to show that the revenue covers the expense of the building. So, they're pretty disciplined buildings on a university campus. They're not always the Taj Mahals because they are budget conscious.

However, the underlying processes at work appear to be more complex. Although cost considerations do appear to be a strong driver in the design and construction of residence halls, cost alone is not the dominant driver. Rather, meeting institutional sustainability goals and providing for the student life experience occur within the cost-constraints. The success of the design processes appear to rest on the extent to which residence halls are able to satisfy these three objectives.

Code Implications

Codes further constrain the design process by forcing designers and clients into doing things a certain way. Codes begin to shape the design of power systems in buildings by mandating conservative solutions that include: safety factors; the number and spacing of outlets; and safety devices such as arc-fault protection and ground fault circuit interrupter receptacles (GFCIs). Some designers felt that these types of mandates potentially lead to overdesign, which eats into the already tight budgets. One design participant (AE7) expressed his concern this way:

> The code is very conservative and I think there needs to be a better way to do it. I understand the reasons behind it. It's all about life-safety and let's not start fires and all this. But, I think in some ways the code is doing owners a disservice in [that] you're spending more money that you may not actually need to.

However, as codes and standards evolve and begin to target aggressive energy saving measures, they begin to take the power of the final say about technologies out of the hands of the client. For instance, metering of end-uses becomes a requirement rather than a decision. This trend supports green design objectives and removes the cost barrier from discussions with clients.

Budget Silos and Building Performance

Designers and facilities managers acknowledge that capital construction budgets and building operations budgets are often distinct. Participants described these budgets as "silos" or "different pots," One design participant (AE1) explained it this way:

> In public higher education the pots of money are different. You go to the legislature for funding and you get blank amount to build a building. The operations of the building comes out of a different pot of money.

What this process looks like from the design standpoint is that the budgetary silos impose a barrier to exploring design strategies that have the potential to save energy and costs in the long-run when they require greater up-front first-costs. Another design participant (AE12) put it this way:

> There are sometimes things outside the budget and that sort of thing that are motivators for taking aggressive sustainability stances. The silos tend to dampen aggressive sustainability stances because they take money from the budget. The silos of any particular campus are a hindrance sometimes to using more aggressive strategies at a fraction of the cost.

However, cost-conscious institutions are sometimes willing to entertain greater upfront costs if designers can demonstrate performance benefits. If designers can show clients the money they will save, it can be a compelling argument toward breaking down the barriers of these budgetary silos, and designers appear to have the power to do this. Design participant AE1 explained:

> The only way to promote some of these great sustainable systems is to show the life-cycle analysis, but the [monies] are different and they don't mix politically. So, you should be able to siphon off some of the operational costs because you're demonstrating that you're going to use less of the operational money long-term.

Another design participant (AE4) expressed similar sentiments:

> When you start talking dollars, then people listen. You start talking about operating costs, things like that, and that is what universities are also interested in. So, I think that that kind of gravity, the pull that that has, can be really powerful too.

Design participant (AE9) discussed the value of having someone on the client-side who can act as an advocate for the design approaches and facilitate decision-making:

> I think that getting everyone on-board, for everyone to invest their time in it just to set that up even if it is feasible. People have other priorities. It's not that important to them. Having strong champions that have the political capital to be able to push that through…

But, predicting performance outcomes is difficult and designers increasingly want and need to know how closely the predicted performance estimates during design resemble the actual performance of the building-in-use. When there is a mismatch, it tends to cast a shadow on the overall sustainable design achievements for a residence hall project. One operations participant (OP3) described it this way:

> You may get that building up in a [LEED] Platinum status, but four or five years down the road, some of those things you put into play operationally are really challenging and they cost a little bit more or aren't as energy efficient as you thought they were.

The attitude on the design side is that breaking down the institutional budgetary silos requires persuasion and confidence in savings predictions during design. There is never a guarantee that clients will accept greater first-costs in exchange for long-term savings. However, clients that do accept such trade-offs find it disappointing when the performance outcomes differ from those promised during the design process.

All-inclusive Rates

One of the most popular topics among student, operations personnel, and design participants was that of the traditional all-inclusive room rates that are common in residence halls. The most logical explanation for why housing offices use this type of rate structure is that it simplifies things from billing, management, and monitoring standpoints. However, student participants complain that never paying a utility bill or seeing a utility bill obscures energy usage. One student (ST2) described it this way:

> I think that they're very distant from the real cost of things and what their individual impact is. You don't pay an electric bill and a water bill. Everything is lumped in to what it costs to just live there for a semester. Someone who is living off campus has a very different experience most of the time.

One design participant (AE6) contrasts living in residence halls with living in places where you do pay directly for utilities by saying:

> Why do you care how much electricity you spend at your house? At the end of the day, it's the bill, right?

Another design participant (AE1) sees the solution as passing the costs on to users:

> I think that one of the most important things we could do is pass the utility bills on to student and make them accountable for the decisions they make.

Designers often blame limited metering capabilities for the reason that residence halls can't pass energy costs on to users. Participant AE12 speculated on whether accountability and awareness is possible even without being able to meter student rooms at a fine gained level:

> For instance the idea that if we can't meter everything individually, if we can't really put that cost on the students, can we at least help them understand what the implications of their lifestyle [are]?

And while limited metering may prevent passing energy costs on to users in the same way as utility customers pay for their energy, there also appears to be a recognition among housing offices that charging a flat rate alleviates the student of the burden of worrying about energy usage, a burden that institutions seem to see as a routine expense. Participant OP3 described the situation in these terms:

> There's an underlying feeling that [paying electricity bills is just] part of doing business.

Accessing Plug Loads

There is a trend on campuses to provide more access to power, which is a recognition of student needs in terms of the devices they bring and the way they use those devices in their residence hall living environments. One design participant (AE12) explained the situation this way:

> It's mostly just finding the worst-case scenario. That's what they're sort of bound to do on this.

Providing more access to power enhances the student living experience by facilitating ease of usage, but ultimately undermines sustainability and cost management objectives. Designers complain that providing greater access negatively impacts other design goals that designers and campuses are trying to meet. One design participant (AE1) described the situation this way:

> The more we invest in power and data and space to accommodate all of this, the less money we have to add beds or add academic space or add lounges or other things.

Another design participant (AE7) lamented that greater access equates in his mind with greater cost, materials usage, and systems complexity.

> I understand the idea of having more outlets and more power available, but I go back to that cost issue. That translates into more receptacles, more conduit in the wall, more copper, more panels, bigger up-front cost. And the administration or whoever is asking for this needs to weigh that against the nuisance factor.

There is also the concern that providing greater access encourages energy usage, which may complicate opportunities to design net-zero energy buildings that make as much energy as they use. Design participant (AE12) put it in these terms:

> All these added plug loads [are] just wasting the opportunity to create net-zero energy buildings.

Design participant AE4 worried that providing greater access to power works against designers seeking energy-efficient solutions and that clients need to be aware of this:

> This is kind of unregulated energy consumption and we go through this design process and we propose these high-efficiency buildings that can be swept down by just plugging in whatever you want. That can negate a lot of the savings potentially that we design to. I see it as more of an issue now, more of a hot-button topic to talk about early-on with the facilities, with the universities.

The general consensus among the design participants is that plug loads are an important part of their routine design discussions. One design participant (AE9) emphasized this point:

> We talk about [plug loads] a lot. We do a lot of net-zero type buildings and when we do the net-zero buildings suddenly plug loads are half of the energy use of the whole building. So, for something that's completely out of our scope, we talk about them disproportionately for sure because it becomes really important to the overall energy savings target we're trying to hit.

One of the classic dilemmas in the design of buildings has always been the extent to which design processionals should simply provide what their clients are asking for. In the case of plug loads, designers of residence halls appear to have their hands tied when it comes to providing more access to power. But, at the same time, they recognize that satisfying client requests impacts other important design goals such as energy efficiency and conservation.

5.7.2. Supporting the Student Experience

Facilities managers and designers appear to agree overwhelmingly that one of the primary roles of residence halls today is to support the student experience and that this differs with previous attitudes about student housing as simply a place for students to sleep. Supporting the student experience is about giving students the kind of environment that helps them learn, grow, and mature into independent adults. Increasingly, helping students to think and live more sustainably is an important aspect in supporting the student experience, and one that positively benefits the university's bottom line. One facilities manager (OP3) put it this way:

> It was really just a philosophical idea about how to allow students to develop—giving them maximum opportunity to develop as a community member and as an individual.

Within the analytic category "Supporting the Student Experience," there are seven sub-categories that further explicate the processes inherent in enhancing student-centered living environments and the ways in which energy usage and conservation factor into this objective: (1) "Sustainable Living," (2) "Student Plug Load Attitudes," (3) "Student Plug Load Usage," (4) "Changing Energy Behavior," (5) "Making it Easy," (6) "Educating Users," and (7) "Restricting Behavior." These sub-categories are described in detail below.

Sustainable Living

There is overlap between meeting institutional sustainability goals and satisfying the student living experience. A greener building contributes to the living experience and the living experience can be a model of sustainable living. So, these two things are not distinct or competing objectives. One design participant (AE11) explains this relationship:

> What we find is so much of the sustainable energy consumption strategies etcetera really don't have a negative impact on livability. In fact, they usually have a positive one. It's just [that] a lot of the energy is wasted that you're not really using it. So, you're not really going to miss anything.

The attitude appears to be that green design is not in conflict with supporting students. However, this position contradicts sub-category "Accessing Plug Loads," which seems to suggest that satisfying student needs does, in fact, have negative ramifications on sustainable design objectives.

Student Plug Load Attitudes

To support the student experience, there is widespread recognition among the participants that the buildings must cater to the users. At the same time, participants acknowledge that how students are using residence halls is changing—the devices they bring with them is changing, how they interact with peers in the facility is changing, what they expect in terms of amenities and access is changing. One operations participant (OP2) explained it this way:

> You look at these things and you're kind of going 'but, this is the way it's done.' But, you're right, it all changes. I have trouble keeping up, but I'm old enough now.

These trends suggest that designers (and institutions) need to know more about the student residents and their attitudes to fully understand their energy use.

An important aspect of the student resident experience is that, for many, this is the first time they have lived away from home and they have freedom to live in ways that they have probably never had before. One student participant (ST6) described the situation this way:

> You're a freshman in college; you probably have more freedom in most cases than you have had ever. For at least a freshman, saving power is probably very

> low on the priority list for all the other things they have to do. It's just one more thing to think about.

One aspect of residence halls that makes them different than other living environments is that students are essentially living in one or a few rooms with all of their stuff. One student participant (ST4) elaborated on this experience:

> You spend so much time in only one room and in only one place and there's so much you can do in that singular room and most things that you need are there that you approach how you use electricity different than if you were living in a house or if you were living in an apartment.

However, student populations in residence halls experience high turn-over from year to year. Unlike a single family house designed for a specific client, residence halls need to support the experience of different kinds of students who are always coming and going, which is a difficult challenge for designers. One design participant (AE6) explained why designing for student residents can be so challenging:

> Students are [a] harder [group]. Coming back to residence halls, you've got a group of students for a year. Next year, you've got a brand new group of students. You've got to train them from day-one. It's kind of like society in general; you're only two generations away from barbarism at any time. A new crop of kids are coming along, you have to teach them manners and respect just like they've never known it before, because they haven't!

Student attitudes about energy vary considerably. There are students who feel entitled to use energy however they want. One student participant (ST7) explained this attitude:

> That seems to be what people say: ‘well, we’ve already paid for it so it just doesn’t matter if we leave it on.’

Then, there are those who consciously conserve energy amidst other peers who do not. Participant ST3 described this attitude:

> I would say most of the people weren’t as electricity conscious and they would leave lights on all the time and stuff like that. And, I was usually the one who was like, “Okay [we‘ve] got to turn lights off [if] we’re leaving” and stuff like that.

Student Plug Load Usage

Design and operations participants note that it can be difficult to learn about how residence hall occupants use plug load energy. However, what they do know appears to come through limited direct interactions with students. And, surprising things emerge from these interactions. One design participant (AE10) explains how he gets useful information from student residents:

> We did a few student forums. So, not only were able to capture students that are within that program and are committed to the university and institution, but we also drew from students that were just in general interested or that were in their freshman year and they knew that by the time they were in third year, they could get a room in this building.

There appears to be no comparable substitute for seeing first-hand how residents configure their living spaces, what devices they bring with them to school, and what their energy use patterns are. While it can be difficult to gain access to student rooms, one design participant (AE4) describes the rare experiences this way:

> It was a real educational process walking through and surveying a few of these rooms and just seeing what people have in these dorm rooms. It's like a house that they just compacted into 200 square feet.

Designers commonly use power density metrics as a way of estimating how much energy from lighting, plug loads, etc. to expect from buildings that are different sizes. The problem in residence halls is that students bring a large number of personal electronic devices with them, which describes the potential for energy usage, but they never actually use all of these devices at the same time. This relates to the sub-category "Accessing Plug Loads" in the sense that providing for the peak (potential) plug load power density may lead to overdesigning and higher materials/systems costs. One design participant (AE9) explains it this way:

> If you turn everything on, you're dealing with 3 w/sf [or] whatever it is, but you never have everything on all at once.

The information that students share with designers and institutions can inform designs and policies, and participants appear to agree that policies based on building observations are superior to a top-down means of imposing policies. Design participant AE7 explains what this might look like:

> I'm just taking a shot in the dark and making sure that people aren't tripping breakers everywhere? But, are we overbuilding? I don't think we're under-

> building, I think we typically overbuild. So, a lot of it is ferreting out information from the users.

Changing Energy Behavior

There appears to be a consensus among the design and operations participants that occupant behavior is a significant aspect of electricity consumption in residence halls and that it must be an integral component of the solution. However, these participants suggest that they do not have sufficient tools at their disposal to influence this occupant behavior.

One participant (AE12) commented on the problem this way:

> That behavioral issue has been one that's a stickler for me, the Achilles heel or whatever over the years that realizing our best made plans are really contingent on those kids.

He went on to say:

> But, on all these things, that last percentage is about behavior and I equate that with plug loads, you know? You have to rely on the inhabitants of that building to work with the building.

At the heart of the behavior discussion is the question: what role should schools take in the way students use energy in the building? One way that appears less intrusive is community engagement through activities and programs. Many institutions have embraced energy competitions as a way of engaging students living in residence halls. In general, participants like the idea behind the competitions, but often say that they are not well organized or advertised and that this interferes with students feeling motivated to participate. One student (ST2) put it this way:

> Competition can be a good thing. A lot of students like to be competitive, but it depends on how you frame the motivation.

Another student (ST2) had this to say:

> The RAs didn't talk about it, we just kind of knew it was happening. So, if they had pushed that a little more I think people would have cared more.

Overall, student residents sense room for energy competition improvements, but appear to struggle to identify exactly how. One student participant (ST2) commented:

> On the hall, yes, we were a small community, but we never really saw more than just our hall as the whole building. And, it was building-by-building. So, if they'd done it maybe on a smaller scale, that could have been better.

Although residence halls increasingly use technologies such as occupancy sensors to conserve energy, many student struggle with how to appropriately use them. The result is often that student energy behavior interferes with the functioning of the technologies. One student participant (ST4) complained:

> I actually don't think that anyone knows how to use [occupancy sensors] and how the system works. I think that becomes a big problem.

Another student participant (ST6) put it this way:

> Well, if people don't like something, they're going to get around it. If you have one outlet that is, of course, for a fridge, you're going to plug your power strip into that outlet if you don't like the fact that your power is turning off.

One of the dilemmas for residence hall designers is that building layouts or configurations can work against the idea of letting occupants share amenities or appliances. Design participant AE10 described the problem this way:

> If you're working within the constraints of a residential hall that it's based on the more traditional residential life experience with single rooms or double rooms off of a double-loaded corridor, you [don't] have the benefit of sharing a kitchenette with friends.

Some design participants discussed ways in which design can influence student behavior. One example is the idea of creating common or shared kitchens and lounge spaces. One design participant (AE5) explained the creative use of design to solve the problem in this way:

> Some of it is just encouraging good behavior and the best they can do that is to design these common spaces and shared/communal spaces that are nice and are handy and students want to use.

Making it Easy

Related to changing energy behavior is the idea of making energy conservation easy for students. Design and operations participants suggested that student residents may be more likely or willing to save energy when saving is easy. One operations participant (OP3) explained it this way:

> It seems as though the more convenient you make it, the more likely it is to happen.

One design participant (AE12) suggested that convenience may play an important role in student conservation:

> I think it reflects the attitude of our culture…that we're all aware of green issues, but when it really comes down to it I feel that we're not really willing to be too inconvenienced to solve green energy problems.

Making saving electricity easier for residents suggests a move away from restricting behavior and toward educating users about buildings and energy conservation, and using technologies that do the saving for residents. One student resident (ST6) described this approach:

> You can beat people with the stick as much as you want. But, I think the best approach is to educate, but more to make the technology such that it does it by itself.

Nevertheless, technologies designed to save energy such as outlets tied to occupancy sensors do not operate independently of the users, and can interfere with the idea of making conservation easier for students. One operations participant (OP2) recounted an experience he had on his campus:

> What we found was the biggest complaint the kids had was that they would end up plugging something in that they didn't want to conserve energy on—like a microwave—but they'd also find not only did it shut off and turn off their clock

> on it, but when they roll over in bed, the microwave would activate, turn on, go beep, and wake them up. So, they've switched some of the plug loads stuff around. We found out those switching plug loads—at least from our perspective—didn't seem to do quite what we were hoping they were doing.

What may seem during the design process to facilitate student energy conservation can have consequences that are very different from the design-intent. Therefore, design and operations personnel must pay careful attention to facilitate energy savings in occupied residence halls.

Educating Users

A common theme among participants in all stakeholder groups is the value and necessity of educating users to be more energy conscious. There appear to be at least three reasons for this: it's a softer approach that engages students in the process of saving energy, it is less expensive than designing buildings with systems and technologies that do the savings for students, and it connects with the primary mission of higher education institutions. One design participant (AE10) described it this way:

> [The] short story is that with the university, we figured out that it's not so much about spending the money and putting all of these fancy controls for the plug loads, but making them aware of what's the goal and telling them 'you can buy your own green energy strip for your computer and cell phone and all that.' We decided then to make an entire campaign around education of the user.

One operations participant (OP3) suggested that educating the user in addition to safety is perhaps the most suitable way to regulate student behavior:

> [If] the institutional goal has an educational component to it and it provides some additional safety or helps the community be stronger, then those are the types of regulations you put in there.

Restricting Behavior

There is a widespread consensus among the participants that more policies regulating student use of power would be unpopular and would undermine the student experience. One student participant (ST6) explained it this way:

> I think a heavy-handed approach like that wouldn't be so helpful. It would make maybe a backlash and, to be honest, people are going to bring stuff.

Students appear to understand the need for safety checks, but do not necessarily accept them. This situation provides further validation that dictating behavior with regard to power may, at best, be counterproductive and may, at worst, backfire.

Restricting students appears to contradict the concept that giving students the freedom to do as they please supports the residential experience. One design participant (AE4) explained this risk:

> That's one of the really big challenges I see with dorms having restrictions with energy usage or what they can bring in. Especially in this country, there's this idea of this freedom, we can use all the power we need and bring in all the equipment we need. And, you're going to face some resistance on that front.

Residence hall policies primarily target safety violations such as having an unapproved extension cord. Fewer institutions regulate some energy-hog electronic devices are regulated (i.e. mini-fridges and microwaves). In these cases, students must buy or rent specific devices or devices that meet specific performance requirements, the usage of devices is unaffected. Students still run their mini-fridge all the time and still use the microwave how and when they wish. What the device policies do is to guarantee that students are using the most energy efficient appliances available. One design participant (AE10) suggests that:

> Maybe [regulating appliances is] not so much of a policy change, but maybe more of an awareness for students of what they can bring and cannot bring.

5.8. The Balance of Power

The coherent process in this phase of the research appears to be the "Balance of Power," which deals with the relationship between construction and operational costs; energy and sustainability goals; and the student experience with regard to residence halls. Students, designers, and operations stakeholders are involved in shaping that relationship because each of these groups have power. Students have the power to bring and use electronic devices and use them as they choose; campus facilities managers and housing offices have the power to create, change, or impose policies that impact student energy use and are the final decision makers on how energy is managed within the buildings; and designers have the power to influence which energy efficiency strategies, technologies, and capabilities are considered as part of the design process.

Because campuses avoid restricting what students can bring and do with regard to plug load energy, the balance of power shifts toward the end user. (See Fig. 5.3) However, since institutions and entities within institutions, such as housing offices, fund residence hall construction, they retain the power to accept or reject energy-related design decisions. However, designers recommend the energy-related design possibilities to those responsible for operating the completed facilities. These professionals have the power to justify their recommendations based on their experience and analysis and to guide their clients toward efficient building solutions that satisfy energy goals.

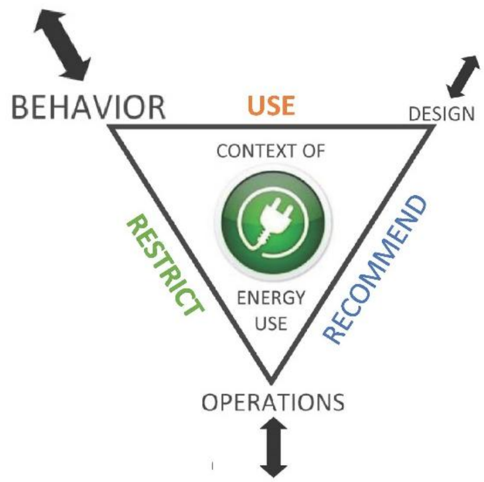


Figure 5.3: Qualitative findings in relation to
the initial conceptual model.

In residence halls, the specific end-users are unknown, but the type of end-user (students) and their general needs are relatively well known. In addition, institutional clients tend to own and operate the building perhaps for the lifespan of the facility and are intimately involved not only in maintaining the physical infrastructure of the building, but also in supporting the student resident experience. Residence hall designers appear to see their role as providing designs that support clients' and users' needs and goals. It is the negotiation between the stakeholder groups which appears to give residence halls their unique character with respect to plug load energy.

5.9. Summary of Results

This chapter presented the qualitative analysis of interviews with students, designers, and campus operations personnel related to plug loads in residence halls: Section 5.2 described the interview participants: seven students, twelve designers, and five facilities managers. Section 5.3 described the interviewing and transcription processes. Section 5.4 presented the starting points for the study including the experiences that the researcher has had with issues related to occupying and using energy in residence halls and the design of green institutional buildings to achieve sustainability goals.

Section 5.5 explained how an emergent coding technique was used to assign short, descriptive tags to lines of data. The process generated a large number of codes that captured the range of ideas expressed in the interview narratives. Section 5.6 synthesized the large number of emergent codes into 30 salient themes that emerged across the codes.

Section 5.7 elevated two analytic categories from the salient themes that explicated the processes and experiences of the participants with regard to plug load energy in residence halls. Within the category "Doing Less With More," sub-categories addressed issues related to: first-cost vs. operational costs; code implications; institutional budget silos; all-inclusive room rates; and accessing power. Within the category "Supporting the Student Experience," sub-categories addressed issues related to: sustainable living; student energy attitudes and usage; energy behavior change; making conservation easy; user education; and restricting behavior.

Section 5.9 introduced a coherent process the "Balance of Power," which described and explained the ways in which the three stakeholder groups have power and share power when it comes to plug load energy related decisions. This process drives the way that the various stakeholder groups influence plug load energy in residence halls and reveals the multiplicity of perspectives on the topic and the interconnectedness of these perspectives in plug load energy outcomes in student housing.

CHAPTER VI

DISCUSSION

6.1. Introduction

This chapter presents a discussion of the research findings in relation to questions asked and hypotheses posed in Chapter I. The discussion addresses: plug load metrics developed from study data, results of correlation tests, student behaviors with respect to device usage, the culture of plug loads in residence halls, and a comparison of predicted and in-use plug load power density.

6.2. Results in Relation to Research Questions

6.2.1. What Are the Baseline Metrics for Plug Load Energy in Residence Halls?

An analysis of self-audit survey and plug load measurement data suggests the following baseline metrics for residence halls:

Peak Power:

The average peak plug load power across the study sites was as follows: the student self-audit was 2,720 watts, the electrical panel measurements were 2,542 watts, and the spot metering in the student rooms was 211 watts.

Plug Load Power Density:

The average plug load power density metrics across the study sites were as follows: the student self-audit was 15.01 w/sf, the electrical panel measurements were 1.03 w/sf, and the spot metering in the student rooms was 1.14 w/sf.

Daily Plug Load Energy Usage:

The average daily plug load energy usage metrics across the study sites were as follows: the student self-audit was 2.34 kWh/dy, the electrical panel measurements were 16.8 kWh/dy, and the spot metering in the student rooms was 0.33 kWh/dy.

Annual Plug Load Energy Usage Per Area:

The average annual plug load energy usage per square foot of building area metrics across the study sites were as follows: the student self-audit was 3.6 kWh/sf/yr, the electrical panel measurements were 1.61 kWh/sf/yr, and the spot metering in the student rooms was 0.52 kWh/sf/yr.

Plug Load Energy Use Intensity (EUI):

The average plug load EUI metrics across the study sites were as follows: the student self-audit was 11.31 kbtus/sf/yr, the electrical panel measurements were 5.05 kbtus/sf/yr, and the spot metering in the student rooms was 1.45 kbtus/sf/yr. The average Site EUI for the residence hall building type is estimated at 73.9 kbtus/sf/yr (USDOE, 2014). Therefore, the EUI metrics presented in this study suggest that plug loads may account for approximately 2-14% of the overall Site EUI.

Variance in Measurements/Metrics:

The measurements and metrics presented above reveal considerable variance across the data collection methods. A possible explanation for the variance between the self-audits and the other measurement methods may be that the audits provide estimates based on all reported student devices and usage while the spot and panel metering provide measurements of real-time usage. It is certainly possible that self-audit participants overestimated their usage of devices and it appears that students use relatively few of the devices they bring with them to school. Therefore, self-audits may provide an inflated sense of power draw and energy usage (a worst-case scenario).

A possible explanation for the variance between the spot metering and the panel metering may be that the spot meters did not capture the full range of power draw and energy usage for each volunteer due to the fact that only one spot meter and associated power strip were provided for each room. If the participant had devices located in other parts of the room or in other spaces within a suite, those devices may not have been accounted for in the data collected and may have resulted in the lower measurements and metrics seen in the analysis.

6.2.2. How Important Are Building Design Characteristics or Factors on Plug Load Energy Usage in Residence Halls?

The results from correlations do not indicate strong relationships between building design characteristics and plug loads in residence halls. Findings indicate weak correlations ($r < 0.30$) in 22 of 26 tests, moderate correlations (r 0.30-0.80) in 4 of the 26 tests, and no strong correlations ($r > 0.80$). Moderate correlations for room/suite level building characteristics explain approximately 11-15% of the variance in plug loads, which suggests that design plays a role in plug load use, but that future research should consider a wider range of design and non-design independent variables in correlation tests.

6.2.3. What Are the Specific Target Occupant Behaviors That Could Influence or Inform Future Design and Energy Conservation Efforts in Residence Halls?

Students living in residence halls exhibit a diverse range of energy use behaviors. However, results from the quantitative and qualitative data analyses suggest four primary behaviors to target for low-cost and low-tech energy behavior change efforts:

Charging:

Every student survey respondent reported having a laptop, cell phone, and associated chargers. Estimating plug load use for devices with chargeable batteries can be challenging because the times of day that the devices are plugged-in to charge and the duration of the charge vary considerably among respondents. Also, students appear to routinely charge devices even when their devices have battery power as a precaution against the inconvenience of having a battery die at a later time. Laptop computers, cell phones, and tablets are relatively low-wattage devices (i.e. 10-25 watts), but many students appear to leave them charging for long periods of the day (i.e. 8-10 hours per day). Often, this charging occurs overnight and at least one interviewee reported that she knew she was wasting energy because her phone battery took only 2-3 hours to fully charge. However, the extent of the wasted plug loads in this scenario remain unclear.

Findings suggest that battery charging is one of the most common plug load uses in residence halls and that savings may be possible with little impact on occupant use of the chargeable devices. Hardwired technologies such as switchable outlets and aftermarket technologies such as smart power strips have the potential to disrupt power to chargers when the room is unoccupied or when occupants are sleeping. Furthermore, the consumer electronics industry appears to be developing longer charge batteries that may obviate the frequency and/or necessity of charging devices in the future.

Sharing:

The majority of student survey respondents shared a room or suite with roommates. There are some devices that roommates tend to share (i.e. kitchen-related appliances) and others that are rarely shared (i.e. personal care devices such as hairdryers and personal computers). Expensive or space-intensive appliances such as mini-refrigerators would present obvious sharing opportunities for roommates, but the data suggests exceptions to this. One student interviewee reported that she lived in a suite that had a shared refrigerator and she still brought her own personal mini-fridge so that she could keep her food separate from her roommates. This suggests that there may be barriers to sharing a communal refrigerator that may interfere with student preferences. Some institutions, including Southern Oregon University, now require students to rent energy efficient appliances from vendors and/or place a limit on how many of a certain appliance students in a room or suite can have. However, this research indicates that there may be opportunities to rethink the way students share appliances like refrigerators, how those appliances are designed and configured (i.e. separate compartments), and how many students share them. The data also suggests that there are many devices that students do not commonly share and it remains unclear whether better methods of communication and/or coordination prior to the school year may eliminate the need for duplicate or redundant devices and facilitate sharing among roommates.

Using Power Strips:

A large percentage of student survey respondents (88%) reported that they have and use a power strip in their residence hall room or suite. However, nearly 2/3 of respondents report that they infrequently turn the power strip off. A common complaint among the respondents was that electrical outlets in their living spaces are difficult to access or reach (i.e. when they are behind beds or furniture). While design participants in the interviews report that they focus attention on the optimal location of outlets, it appears likely that student residents have a need for power strips despite efforts to improve outlet access. This situation suggests that smart power strips that turn off when not in use and/or power strips tied to occupancy sensors may be a simple, low-tech way to save plug load energy in the absence of more sophisticated switchable outlets tied to room occupancy sensors.

Lighting:

The majority of student survey respondents have supplementary lighting in addition to the hard-wired ambient ceiling lighting in their rooms or suits. More than 80% of respondent report having a task lamp and more than 40% report having decorative lighting (i.e. holiday lights). The survey data suggests that occupants use supplementary lighting over room lighting for a variety of reasons including, but not limited to, needing more light. However, supplementary lighting also appears to play a role in allowing roommates to coexist in the same space with different lighting preferences and needs. Fewer than 20% of respondents report using LED task lighting, while nearly 45% report using CFL and incandescent lighting. However, it appears likely that LEDs will become a more popular choice over time as the technology improves and the costs decrease.

These findings suggest several possibilities for addressing plug load usage from supplementary lighting. One approach may be to explore hard-wired lighting in rooms or suites that allows for differential lighting within the same room (i.e. replacing one overhead luminaire with several). Another approach may be to accept that ambient ceiling lighting will never allow for the level of differentiation that students want or need and to focus efforts on requiring students to have energy efficient supplemental fixtures provide alternative lighting to students, a solution that some campuses have already embraced or considered. Perhaps the lowest-cost solution may be to educate residents about the energy implications of different types of lamps and guide them in purchasing devices to outfit their rooms prior to moving into the residence hall.

6.2.4. How Can the Culture of Plug Load Usage in Residence Halls Be Better Understood in Terms of the Influence and Interactions Between Design, Building Operations, and Occupant Behaviors?

Extensive analysis of quantitative and qualitative data collected in this study demonstrated that plug loads in residence halls are influenced by the building design processes, facilities management activities, and student resident behaviors. Designers influence plug loads in residence halls principally by providing access to power in buildings. However, designers are increasingly finding creative ways to reduce plug loads through: technologies (i.e. switchable outlets), policy recommendations (i.e. mini-fridge vendor contracts), and using common space to get students out of their rooms. Facilities managers influence plug loads in residence halls through restrictions/lack of restrictions on which devices students can bring, all-inclusive room rates that include electricity, oversight of student plug load use patterns, and making decisions about which energy saving design features to provide. Students influence plug loads in residence halls by using electronic devices in their rooms/suites, engaging in plug load conservation efforts, and sometimes by using social pressure to motivate peers to mitigate waste.

However, this research finds evidence that design, operations, and occupancy do not operate independently and that these three realms of influence shape the culture of usage in residence halls in complex ways. For example, students interact directly with designers in focus groups that solicit resident feedback during the design process for new facilities. Designers propose solutions to address plug loads to operations personnel who evaluate the implications of these solutions on project budgets and long-term maintenance of the facilities. Operations personnel interact directly with students during scheduled room safety and extended vacation checks which often include plug load related items (i.e. extension cords and power strips).

Nevertheless, the interaction between these three realms of influence is less one of collaboration and more one of power sharing. Designers have the power to make recommendations to clients, and operations personnel have the power to accept or reject these recommendations. Students have the power to use plug load energy or to conserve plug load energy, and operations personnel have the power to allow students to use energy or to restrict their usage. Therefore, the culture of plug loads in residence halls involves a give and take between groups to optimize building performance and to enhance the student experience.

6.3. Results in Relation to Hypotheses Posed

6.3.1. The Assumptions Used to Predict Plug Load Electricity Usage in Residence Halls During Design Energy Modeling Are Lower Than Plug Load Electricity Measurements and Estimates Taken in Occupied Residence Halls

Calculations from plug load measurement and survey data suggest that plug load power densities are higher than those predicted during the design process, which validates the hypothesis. Energy model plug load assumptions were available for four of the six study site buildings and ranged from 0.25-0.625 w/sf. By comparison, the in-use calculated plug load power densities in those same buildings ranged from 0.68-16.18 w/sf Metrics calculated from the self-audit surveys were 24-54 times higher than model assumptions, while metrics calculated from electrical panel measurements were only 1.6-3.2 times higher. These findings suggest that plug load assumptions used in energy modeling are too low to accurately predict the power draw and energy use in residence halls and that adjustments to plug load predictions are necessary.

6.3.2. There Are Significant Correlations Between Building Design Characteristics and Plug Load Energy Use in Residence Halls

As noted in Section 6.2.2, the results from correlation tests do not indicate strong relationships between design characteristics and plug loads in residence halls. Thus, the hypothesis is invalidated. Although design characteristics correlate with plug loads, at best they explain only a small percentage (11-15%) of the variance. It is clear that other factors may play a greater role in residence hall plug loads.

6.4. Summary

This chapter presented a discussion of the study findings in relation to the research questions and hypotheses that framed this investigation of plug loads in residence halls. In response to the research questions raised in the study, the discussion: summarized plug load metrics and the variance between these metrics across the data collection methods; summarized test results that did not find strong correlations between building design characteristics and plug loads; presented charging, sharing, and lighting as four target behaviors to address ways of reducing plug loads; and explained how the study data supports the roles that students, designers, and operators play in influencing the culture of plug loads in residence halls. In response to the hypotheses posed in the study, the data: validated the idea that plug load assumptions used during design inaccurately represent the plug load usage of the occupied buildings and invalidated the idea that design characteristics play a significant role in residence hall plug loads.

CHAPTER VII

CONCLUSION

7.1. Conclusion

7.1.1. Research Design Overview

This research used a sequential mixed methods design to examine the influence of design, operations, and occupancy on plug loads in residence halls. Phase I involved a field study in six residence halls on three campuses in the Pacific Northwest. Plug load usage was assessed using student self-audit surveys and physical measurements in student rooms and in building electrical panels. The field study data then established a baseline that included plug load metrics, device inventories, and energy usage patterns. Phase II elaborated on the Phase I baseline through 24 responsive interviews with student residents, campus housing facilities managers, and residence hall designers. The study had three primary objectives to:

1. Develop a field-based method for measuring, examining, and understanding plug loads in residence halls with limited metering or monitoring capabilities
2. Establish baseline plug load metrics for residence halls that inform design and energy model predictions, and facilitate comparisons across building types
3. Explore the ways in which design processes, building operations, and behavior influence the culture of plug load use in residence halls through the words and perspectives of: architects and engineers; housing administrators and facilities managers; and student residents

Four research questions addressed these objectives. To answer questions related to plug load metrics, electricity measurements taken over a one week at each field site and occupant self-audits of their devices and usage patterns were compared with building design characteristics and energy use assumptions used during the design process. To answer the questions related to the influence of design, operations, and occupancy on plug loads, interviews were conducted and analyzed for repeating ideas and emergent themes that formed the basis for two analytic categories and one overall coherent process that describe and explicate the processes occurring in and across the participant narratives.

7.1.2. Notable Research Outcomes

There are four notable outcomes of this dissertation. First, architects and engineers consider plug loads in the design of residence halls, despite the traditional view that plug loads unregulated energy beyond the scope of designers' control. Design participants indicated that attitudes related to the role of plug loads in residence hall design have changed. The data suggests that designers are increasingly addressing the implications of plug loads on a variety of outcomes including: building performance, compliance with codes/standards, energy targets/goals, campus sustainability efforts, and occupant engagement/education. While the challenge of addressing electricity used by building users is undeniable, designers appear to be engaged in finding effective and creative solutions to the problem. While operations participants are aware of the challenges associated with plug loads in residence halls, they appear less engaged in finding ways to address them than do designers, which may relate to: institutional policies and conditions predicated on cost-control, minimizing maintenance; all-inclusive room rates for residents; attitudes about enhancing the student experience; and giving students freedom and privacy. The findings suggest that residence hall designers face barriers to exploring and implementing solutions to address plug loads in their design processes.

Second, results of the field site data collection indicated that the actual in-use plug load metrics were higher than those predicted during design energy modeling. The magnitude of the difference between design assumption and actual plug load metrics varied considerably depending on the method of measuring or estimating plug loads in the buildings. For example, physical measurements resulted in metrics up to 1.6-3.2 times higher while self-audits resulted in metrics 24-54 times higher. Many design participants were not surprised by the higher actual plug load metrics. However, the variance highlights the importance of understanding the difference between the potential for plug load power density based solely upon student devices and the power needs of those devices, and the actual plug load usage from those devices over time. Intuitively, designers know that students do not use all of their devices at the same time and they adjust their assumptions according to schedules of use. The plug load data analyzed in this study provided validation of this phenomenon. However, buildings designed for efficient operations still need to address the issue of potential peak power usage since there are limited mechanisms in place to control or prevent student electricity usage. Failure to address this “potential use” may have significant maintenance implications should electrical systems become overloaded. Therefore, the implications for design appear to be that a distinction must be made between systems designed to support potential peak plug loads and realistic, though not excessive, energy use assumptions used to evaluate building performance during the design process.

Third, results of the student self-audit survey provided a useful understanding of the types and range of devices that students have and use in residence halls. Perhaps the most surprising finding in this area was that the devices that all or most students have and use frequently tend to have lower-power needs. For example, all respondents have a laptop and a cell phone. The proliferation of smart electronics (i.e. tablets, smart phones, etc.) combined with the information provided by student interview participants suggests fewer devices used for a wider variety of uses. The data certainly suggests a trend in this direction and may signal the obsolescence of traditional single use devices (i.e. DVD players, TVs, etc.). Doing more with fewer smart devices that have lower-power needs and can be charged elsewhere (outside the room) seems to suggest a downward trend in terms of plug load energy in residence halls.

Lastly, the results of this research do not suggest strong relationships between plug loads and residence hall design characteristics. A small number of room/suite level characteristics show moderate correlations with plug loads. The relative weakness of the correlation tests indicated that other factors are involved. The implication for future research is to examine a broader range of characteristics to better understand the combinations of design and other factors that tend to result in the lowest resident plug loads. This information could further inform the way designers address plug loads and configure spaces in future residence hall facilities.

7.2. Suggestions for Future Research

This research appears to represent the first comprehensive mixed-methods study of plug loads in residence halls. More research is needed in this area. The following are suggestions for future research on plug loads in residence halls.

The field work phase of this study was limited to six residence hall buildings on three institutional campuses in the Pacific Northwest. It may be useful for future residence hall plug load studies to consider: field sites within or across other geographic regions of the United States; field sites on a larger number of institutional campuses; and/or more field site buildings on the same campus (i.e. all residence halls in an institution's portfolio).

None of the field site buildings chosen for this study had metering or monitoring capabilities for plug load energy end-use. Choosing field site buildings with metering and monitoring capabilities would greatly simplify data collection activities and may allow plug loads to be directly compared with other building energy loads (i.e. heating, cooling, lighting, etc.). This study was unable to provide data related to the percentage of overall building energy is attributable to plug loads, which is currently a gap in the available data for residence halls that future research should address.

This study used a three-pronged approach to measuring plug loads at the field sites, which attempted to address the fact that there was no single point to measure fine-grained data at the room level or aggregate data at the building level. The data suggested that each of the three methods (self-audits, spot metering, and panel metering) described different aspects of plug load power and energy use in residence halls. However, there was considerable variation in the metrics calculated from each method. Future studies using similar data collection procedures may consider employing one method only at a larger scale. For example, metering all receptacle panel boxes or spot metering all residents on a floor or for an entire building. This approach would require greater amounts of monitoring equipment, but would increase the sample size and facilitate easier comparisons. In addition, obtaining more specific data on student devices (i.e. an inventory of specific devices and their power needs rather than generic types of devices could improve the accuracy of room audit.

The field study phase occurred over a six week period with data collection lasting one week at each study site building. Since students live in residence halls for an entire academic year, there is certainly great potential for longitudinal studies that track plug loads over time and simultaneously with other buildings. Such studies may provide insight regarding the role of season, weather, climate, academic schedules, breaks, etc. have on energy use in student housing.

This study used a sequential mixed methods design with a less-dominant quantitative data analysis followed by a more dominant qualitative data analysis (quant-QUAL). The idea was to use the Phase I data collection to establish baseline plug load metrics and then to expand upon these metrics through a series of responsive interviews. However, the three-pronged plug load data collection generated a very large quantitative data set. Future mixed methods research in this area should carefully consider the balance of quantitative and qualitative data. Nonetheless, the inclusion of interviews added an illuminating narrative focus to the investigation and should be considered in future building energy studies. This research was limited to 24 interviews, but future studies may explore the benefits of including more participants in the interview sample.

There appears to be considerable interest in emerging technologies such as smart electronics and plug load monitoring/controls. Future research might explore market penetration for emerging devices and controls technologies that could impact the experience and lead to reductions in plug load energy usage in residence halls. Such research has the potential to: highlight changing energy use patterns; inform design strategies to address plug loads; and influence operations policies and procedures.

Finally, presently there is no central repository of building design or energy performance information for residence halls. Setting-up a broad-based database would allow this information to be shared in a standardized format and could inform the design, renovation, and maintenance of residence halls in the future.

APPENDIX A

SURVEY

This questionnaire concerns your energy consumption in your residence hall. You will be asked questions about your electronic devices and energy usage in your room and shared spaces. The questionnaire will only take 10-15 minutes of your time. The purpose of this study is to collect information for a research dissertation project. The information you will be asked presents minimal risk and will remain confidential. However, you have the option of withdrawing at any time by simply closing the website window or tab.

The results of this questionnaire will help researchers to better understand student electricity consumption in residence halls and may assist campuses in improving the design and operation of student housing. The feedback you provide is very important to us. At the conclusion of the study, you will have an opportunity to enter your e-mail address in a drawing for one of four $25.00 school bookstore prizes.

Please Note: Your response to this questionnaire is voluntary. By clicking the "next" arrow, you are indicating that you are giving your consent to participate in this study. All information provided will be kept confidential. If you have questions, please contact Tom Collins, the Principal Investigator of this study, at 617-721-8713 or at thomasc@uoregon.edu. If you have any questions about your rights as a research participant, please contact Research Compliance Services at researchcompliance@uoregon.edu or 541-346-2510.

>>

0% 100%

We would like to know specifically about your electronic equipment and patterns of usage in your residence hall. Please indicate how many of each device you OWN, whether you you SHARE usage or ownership with a roommate, and how much you use it. If you DON'T OWN or SHARE a device, leave the item blank or enter a zero for the number of devices.

Computer Equipment

	How many do you own?	Do you share this with roommates?		How often do you use it each week? (It's fine to approximate)					How often do you use it on a typical day? (It's fine to approximate)	
	Type a number	Yes	No	Rarely	Once	Several times	Daily	Often	Minutes	Hours
Laptop Computer										
Computer Monitor										
External Hard Drive										
Tablet (i.e. iPad)										
Printer										
Scanner										
Printer/Scanner Combo										
Wireless Router										
Other (please type)										

Kitchen Equipment

	How many do you own?	Do you share this with roommates?		How often do you use it each week? (It's fine to approximate)					How often do you use it on a typical day? (It's fine to approximate)	
	Type a number	Yes	No	Rarely	Once	Several times	Daily	Often	Minutes	Hours
Microwave										
Tall Mini Fridge										
Small Cube Mini Fridge										
Electric Hot Water/Tea Kettle										
Electric Coffee Maker										
Rice Cooker										
Other (please type)										

Entertainment Equipment

	How many do you own?	Do you share this with roommates?		How often do you use it each week? (It's fine to approximate)					How often do you use it on a typical day? (It's fine to approximate)	
	Type a number	Yes	No	Rarely	Once	Several times	Daily	Often	Minutes	Hours
Sony Playstation3										
Sony Playstation 4										
Nintendo Wii U										
X Box One										
X Box 360										
TV Small (up to 24")										
TV Medium (24-32")										
TV Large (32" or larger)										
DVD / Blueray Player										
Component Stereo System										
Music Player Dock										
Other (please type)										

<< >>

0% 100%

Other Equipment

	How many do you own?	Do you share this with roommates?		How often do you use it each week? (It's fine to approximate)					How often do you use it on a typical day? (It's fine to approximate)	
	Type a number	Yes	No	Rarely	Once	Several times	Daily	Often	Minutes	Hours
Cell Phone Charger										
Laptop Charger										
Alarm Clock										
Desk Fan										
Hair Dryer										
Curling Iron										
Straightening Iron										
Lamp (with incandecent bulb)										
Lamp (with CFL bulb)										
Lamp (with LED Bulb)										
Decorative String/Christmas Lights										
Other (please type)										

How important was conserving electricity in your household growing up?

Unimportant	Of Little Importance	Moderately Important	Important	Very Important

How important is conserving electricity to you in your residence hall?

Unimportant	Of Little Importance	Moderately Important	Important	Very Important

How often do you unplug electronics when you're not using them?

Never	Rarely	Sometimes	Often	Always

Do you plug your electronics into plug or power strips?

- Yes
- No

<< >>

How often do you charge your laptop battery in your room?

Never	Rarely	Sometimes	Often	Always
○	○	○	○	○

How often do you spend time in your room at the following times of day?

	Never	Rarely	Sometimes	Often	Always
Early Morning (12-9 AM)	○	○	○	○	○
Late Morning (9 AM-noon)	○	○	○	○	○
Afternoon (noon-4 PM)	○	○	○	○	○
Early Evening (4-8 PM)	○	○	○	○	○
Late Evening (8 PM-midnight)	○	○	○	○	○

How often do you use electronic devices in the following residence hall spaces?

	Never	Rarely	Sometimes	Often	Always
Your Room/Suite	○	○	○	○	○
Friends' Rooms/Suites	○	○	○	○	○
Bathroom	○	○	○	○	○
Floor Kitchen	○	○	○	○	○
Laundry Room	○	○	○	○	○
Floor Common Space/Lounge	○	○	○	○	○
Lobby or Other Common Spaces	○	○	○	○	○

<< >>

0% 100%

What type of lighting do you prefer for the following activities in your room?

	Click to write Column 1		
	Daylight from Window	Overhead Electric Lighting	Electric Task Lighting or Lamp
Working	○	○	○
Relaxing	○	○	○
Socializing	○	○	○
Other	○	○	○

Please rank the following reasons for closing the blinds, shades, or curtains in your room:

	1	2	3	4	5
For Privacy	○	○	○	○	○
There's too much light	○	○	○	○	○
My roommate prefers it	○	○	○	○	○
My roommate closes them	○	○	○	○	○
I don't think much about it	○	○	○	○	○

Please rank the following reasons for using a task or desk lamp over the overhead lighting or daylight from the window:

	1	2	3	4	5	6
Not enough light	○	○	○	○	○	○
Better quality of light	○	○	○	○	○	○
Better atmosphere	○	○	○	○	○	○
Courtesy to my roommate (i.e. sleeping)	○	○	○	○	○	○
Prefer different lighting than my roommate	○	○	○	○	○	○
Other	○	○	○	○	○	○

<< >>

0% 100%

Which residence hall do you live in?

Burlingham Hall	Gilbert Hall	Global Scholars Hall	Living-Learning Center	Shasta Hall	McLoughlin Hall

What is your room number? *(This will help us to understand where you live within the building complex for analysis purposes only)*

How often are you encouraged by the university or housing staff to conserve electricity or energy in your room or suite?

Never	Rarely	Sometimes	Often	Always

How satisfied are you with the number of electrical outlets in your room?

Very Dissatisfied	Dissatisfied	Neutral	Satisfied	Very Satisfied

<< >>

0% 100%

What is your age?

18	19	20	21	Other (Please Type)

I identify my gender as:

- Male
- Female

What level are you in school?

Undergraduate	Graduate

How many years have you lived in a residence hall (including this school year)?

1 year	2 years	3 years	4 years	More than 4 years

<< >>

0% 100%

Where do you consider yourself to be originally from?

United States	Outside the U.S.

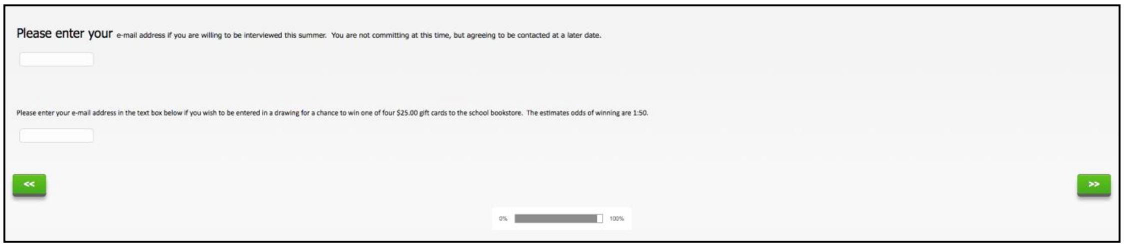
<< >>

0% 100%

Is there anything else that you would like to tell us about?

<< >>

0% 100%



Please enter your e-mail address if you are willing to be interviewed this summer. You are not committing at this time, but agreeing to be contacted at a later date.

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 $25.00 gift cards to the school bookstore. The estimates odds of winning are 1:50.

<<

>>

0% 100%

We thank you for your time spent taking this survey.
Your response has been recorded.

0% 100%

APPENDIX B

SURVEY RECUITMENT

Hello **[Insert Name of Residence Hall]** !

Plugged-in

http://tinyurl.com/plugsurvey

[Insert Residence Hall Name] has been selected to participate in a research study about student electricity use in residence halls

Please Spread The Word To Your Friends & Neighbors

The online questionnaire will ask you to tell us about your electronic devices & usage patterns in your residence hall environment

It Will Only Take 10-15 Minutes

Your feedback is very important to our study

The last day to take the questionnaire is [Insert Day & Date]

ENTER TO WIN

A $25.00 Gift Card to the **[Insert Name of School Bookstore]**

4 prizes will be awarded & the odds of winning are approximately 1:50

Hello **[Insert Name of Residence Hall]** !

Plugged-in

http://tinyurl.com/plugsurvey

[Insert Residence Hall Name] has been selected to participate in a research study about student electricity use in residence halls

Please Spread The Word To Your Friends & Neighbors

The online questionnaire will ask you to tell us about your electronic devices & usage patterns in your residence hall environment

It Will Only Take 10-15 Minutes

Your feedback is very important to our study

The last day to take the questionnaire is [Insert Day & Date]

ENTER TO WIN

A $25.00 Gift Card to the **[Insert Name of School Bookstore]**

4 prizes will be awarded & the odds of winning are approximately 1:50

Plugged-in Questionnaire
http://tinyurl.com/plugsurvey

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http://tinyurl.com/plugsurvey

Plugged-in Questionnaire
http://tinyurl.com/plugsurvey

Dear [Insert Residence Hall Name] Residents,

You are invited to participate in a research study about student electricity use in residence halls. If you choose to participate, you will be asked to complete an online questionnaire about the electronic devices you have in your room and how you use them. The brief questionnaire should take approximately 10-15 minutes. At the conclusion of the questionnaire, you will have an opportunity to enter your name in a prize drawing for one of four $25 gift cards to the [Insert Name of University Bookstore]

Access the questionnaire at: [insert URL link]

Please feel free to share this link with other [Insert Names of Residence Halls] residents. You must complete the questionnaire by [Insert Date]. Your feedback is very important to the study. Participation is completely voluntary. If you have any questions about the study, please email or call Tom Collins at [insert e-mail] or [insert phone number]. Thank you very much!

APPENDIX C

INTERVIEW CONSENT FORMS

Consent Document

My name is Tom Collins. I am a doctoral candidate in Architecture at the University of Oregon. You are invited to participate in a research study conducted by me related to energy use in student housing. I am interested in knowing how design, facilities management, and student occupancy influence plug load electricity usage in campus residence halls. You were selected to participate in this study because you manage campus facilities that include residence halls.

I will be conducting interviews (30-60 minutes in length). You are being asked to participate. I am willing to provide you with a copy of my interview transcripts. The interview data will be analyzed as part of a research dissertation project and may be used in presentations, publications, and/or the dissertation manuscript.

Any information that is obtained in connection with this study and that can, in any way, be identified with you will remain confidential and will be disclosed only with your permission. I will keep subject identities in the interviews confidential through the use of pseudonyms. Your name will not appear anywhere in the transcripts.

Any information obtained from this site will not be available to your employer, supervisors, nor any of your coworkers. I will use a pseudonym in all discussions about our interviews and in all written products about those interviews.

Your participation in this study is voluntary. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions about the study, please feel free to contact Tom Collins, principle investigator at [e-mail] or [phone number]. The department contact is the Department of Architecture, University of Oregon, Eugene, Oregon 97403. You have been given a copy of this form to keep.

If you have any questions about your rights as a research participant, please contact Research Compliance Services at researchcompliance@uoregon.edu or 541-346-2510.

Your signature below indicates that you have read and understood the information that I have provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you have received a copy of this form, and that you are not waiving any legal claims, rights, or remedies.

Print Name ____

Signature ____

Date ____________________

You have my permission to audio record the interview

Yes ___ No ___

Consent Document

My name is Tom Collins. I am a doctoral candidate in Architecture at the University of Oregon. You are invited to participate in a research study conducted by me related to energy use in student housing. I am interested in knowing how design, facilities management, and student occupancy influence plug load electricity usage in campus residence halls. You were selected to participate in this study because you are a design professional who has worked on residence hall projects

I will be conducting interviews (30-60 minutes in length). You are being asked to participate. I am willing to provide you with a copy of my interview transcripts. The interview data will be analyzed as part of a research dissertation project and may be used in presentations, publications, and/or the dissertation manuscript.

Any information that is obtained in connection with this study and that can, in any way, be identified with you will remain confidential and will be disclosed only with your permission. I will keep subject identities in the interviews confidential through the use of pseudonyms. Your name will not appear anywhere in the transcripts.

Any information obtained from this site will not be available to your employer, supervisors, nor any of your coworkers. I will use a pseudonym in all discussions about our interviews and in all written products about those interviews.

Your participation in this study is voluntary. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions about the study, please feel free to contact Tom Collins, principle investigator at [e-mail] or [phone number]. The department contact is the Department of Architecture, University of Oregon, Eugene, Oregon 97403. You have been given a copy of this form to keep.

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Your signature below indicates that you have read and understood the information that I have provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you have received a copy of this form, and that you are not waiving any legal claims, rights, or remedies.

Print Name ____________________________________

Signature ____________________________________

Date __________________

You have my permission to audio record the interview

Yes __ No __

Consent Document

My name is Tom Collins. I am a doctoral candidate in Architecture at the University of Oregon. You are invited to participate in a research study conducted by me related to energy use in student housing. I am interested in knowing how design, facilities management, and student occupancy influence plug load electricity usage in campus residence halls. You were selected to participate in this study because you are a student who lives/has lived in a residence hall..

I will be conducting interviews (30-60 minutes in length). You are being asked to participate. I am willing to provide you with a copy of my interview transcripts. The interview data will be analyzed as part of a research dissertation project and may be used in presentations, publications, and/or the dissertation manuscript.

Any information that is obtained in connection with this study and that can, in any way, be identified with you will remain confidential and will be disclosed only with your permission. I will keep subject identities in the interviews confidential through the use of pseudonyms. Your name will not appear anywhere in the transcripts.

Any information obtained from this site will not be available to the housing office, your RAs, or your peers. I will use a pseudonym in all discussions about our interviews and in all written products about those interviews.

Your participation in this study is voluntary. If you decide to participate, you are free to withdraw your consent and discontinue participation at any time without penalty.

If you have any questions about the study, please feel free to contact Tom Collins, principle investigator at [e-mail] or [phone number]. The department contact is the Department of Architecture, University of Oregon, Eugene, Oregon 97403. You have been given a copy of this form to keep.

If you have any questions about your rights as a research participant, please contact Research Compliance Services at researchcompliance@uoregon.edu or 541-346-2510.

Your signature below indicates that you have read and understood the information that I have provided above, that you willingly agree to participate, that you may withdraw your consent at any time and discontinue participation without penalty, that you have received a copy of this form, and that you are not waiving any legal claims, rights, or remedies.

Print Name ______________________________

Signature ______________________________

Date ______________

You have my permission to audio record the interview

Yes ___ No ___

APPENDIX D

INTERVIEW GUIDES

Interview Questions

The Interviews will use responsive interviewing techniques as described by Rubin and Rubin, whereby a limited number of "main questions" were used to address the main points of my research questions, but acted as a flexible structure that also allows for follow-up questions based on interviewee responses as well as probes to keep the conversation going (2012). The goal of responsive interviewing is to obtain greater depth from interviewee responses by allowing them to take the conversation in directions that reveal how they feel about the issues they are being asked about.

Main Questions:

- A limited number of questions, 4-6 max.
- These may change in subsequent interviews based upon previous participant responses
- The idea is to use the main questions as a loose framework to address the research concerns and to employ follow-up and probing techniques to steer the conversation and obtain greater depth.

Follow-up Questions:

- Reflecting back on what people have said in the interview using their words to redirect, direct, or get better depth. (A gentle approach)
- What are the words/concepts the interviewee uses often? Pick-up on some of these and use them to learn more about that topic.
- What came before or what set the stage for some event the interviewee is talking about?
- Themes are statements that sum-up what is going on. If central to the research questions, follow-up on them by seeking a more detailed explanation.

Probes: *should be short, simple, and independent of interview content*

- Go on...
- Can you give me an example?
- Could you clarify what you just said about...
- That's interesting, can you tell me more? (only use a few times max.)
- Gestures, like nodding, are good

Rubin, H. J., & Rubin, I. (2012). *Qualitative interviewing the art of hearing data* (3rd ed. ed.). Los Angeles [Calif.]: SAGE.

Operations: (facilities managers, housing staff, sustainability staff)

1. **How do plug loads influence the operations and maintenance of residence halls?**
    a. Follow-up: How important are they?
    b. Follow-up: Where do they fall in the priority list?

2. **Are plug loads more of a problem for facilities managers now than they were in the past?**
    a. Follow-up: What has changed?
    b. Follow-up: What are the drivers?
    c. Follow-up: Has demand increased necessitating rewiring, etc.?

3. **What are the barriers to reducing plug loads reductions in residence halls?**
    a. Follow-up: How can these be overcome?
    b. Follow-up: Are there signs of progress?

4. **What strategies or technologies have you explored to address plug loads in residence halls?**
    a. Follow-up: Are there any policies or plans in place to verify or encourage the use of power management settings on electronic devices?
    b. Follow-up: What feedback have you received about the effectiveness?
    c. Follow-up: What would you like to do, but haven't been able to so far?

5. **How have your personal experiences with electricity usage informed your understanding of plug loads in residence halls?**
    a. Follow-up: Was saving electricity important in your household growing-up?

6. **That covers the things I wanted to ask. Is there anything you would like to add?**

Designers: (architects & engineers)

1. **How do plug loads influence the design of residence halls?**
   b. Follow-up: How important are they?
   c. Follow-up: Where do they fall in the priority list?
   d. Follow-up: What about plug load assumptions in energy modeling?

2. **Are plug loads more of a problem for designers now than they were in the past?**
   e. Follow-up: What has changed?
   f. Follow-up: What are the drivers?

3. **What are the barriers to reducing plug loads in residence halls?**
   g. Follow-up: How can these be overcome?
   h. Follow-up: Are there signs of progress?

4. **What strategies or technologies have you explored to address plug loads in residence hall projects?**
   i. Follow-up: What feedback have you received about the effectiveness?
   j. Follow-up: What would you like to do, but haven't been able to so far?

5. **How have your personal experiences with electricity usage informed your understanding of plug loads in residence halls?**
   k. Follow-up: Was saving electricity important in your household growing-up?

6. **That covers the things I wanted to ask. Is there anything you would like to add?**

Students:

1. **How much do/did you think about electricity usage while living in your residence hall?**
   a. Follow-up: Has changed this over time?
   b. Follow-up: Have peers, RAs, or others influenced your thinking?

2. **How did the household you grew up in influence the way you use of electricity in your residence hall?**
   a. Follow-up: Was your household strict about saving energy?
   b. Follow-up: Did you develop any good or bad habits?

3. **Tell me about some of your electricity use habits?**
   a. Follow-up: What devices/appliances do always leave on or rarely turn off?
   b. Follow-up: Compare your usage with others in your hall?

4. **What keeps students from saving electricity in residence halls?**
   a. Follow-up: What kinds of habits are the hardest to change?

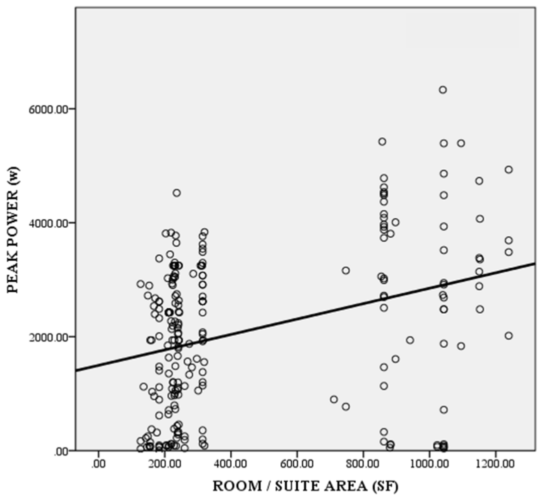
5. **What lessons have you learned about electricity use since living in a residence hall?**
   a. Follow-up: Do you think these will be useful to you when you move off-campus or graduate?

6. **That covers the things I wanted to ask. Is there anything you would like to add?**

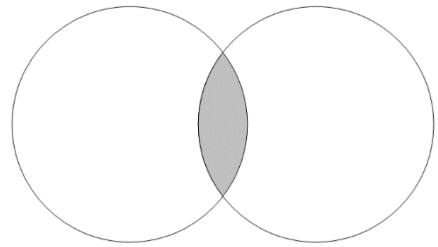
APPENDIX E

CORRELATIONS

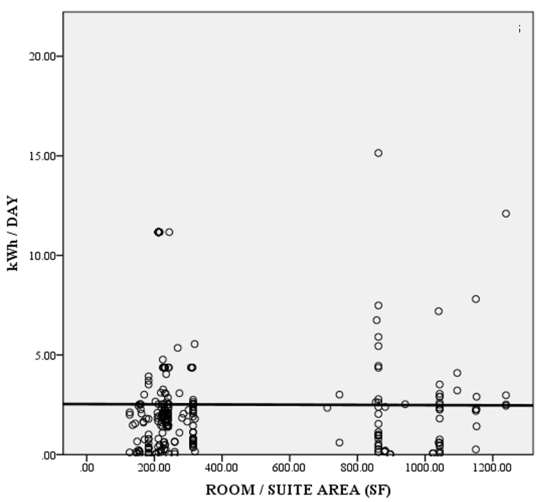
Room/Suite Area



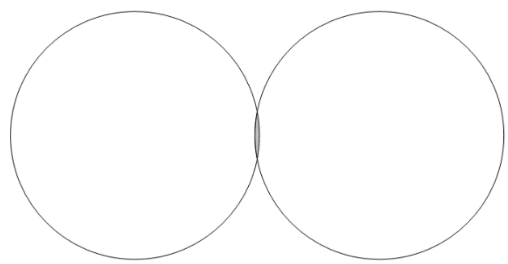
$r^2 = 0.110$, 11.1%



IV: Room/suite area (ft^2), DV: Peak plug load power (watts), n=235, scatter plot with fit line (left), Venn diagram showing the variance in peak plug load power explained by the room/suite area (right)

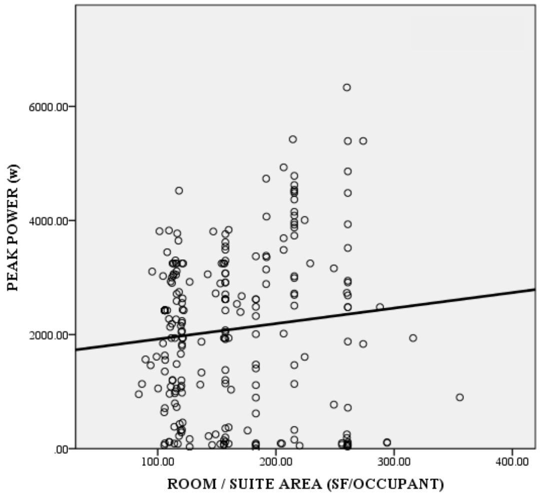


$r^2 = 0.003$, 0.3%

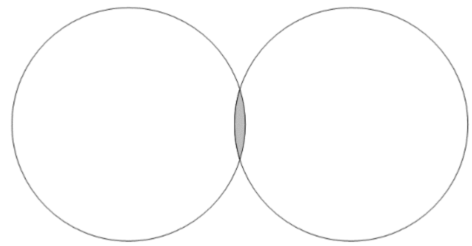


IV: Room/suite area (ft2), DV: Daily energy usage (kWh/Day), n=235, scatter plot with fit line (left), Venn diagram showing the variance in daily plug load energy use explained by the room/suite area (right)

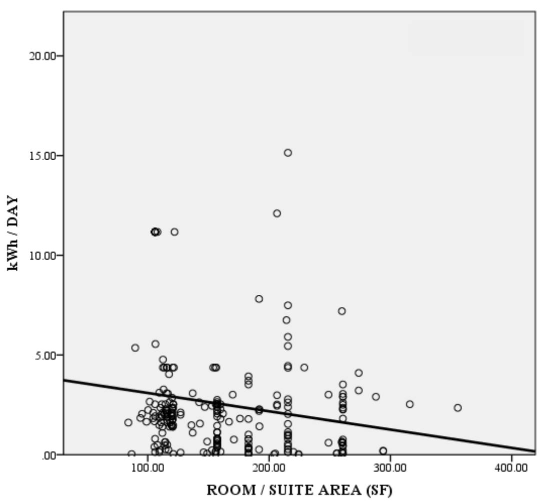
Room/Suite Area Per Occupant



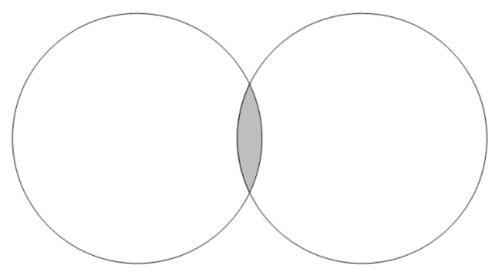
$r^2 = 0.012$, 1.2%



IV: Room/suite area (ft^2/occupant), DV: Peak plug load power (watts), n=235, scatter plot with fit line (left), Venn diagram showing the variance in peak power explained by rooms/suite area per occupant (right)

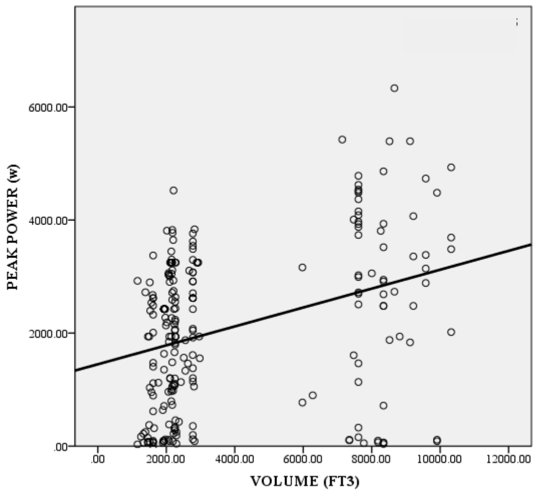


$r^2 = 0.037$, 3.7%

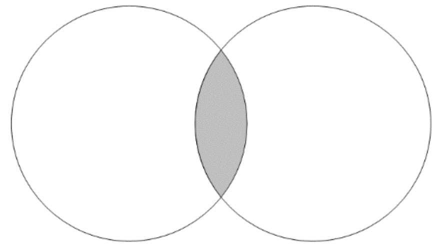


IV: Room/suite area (ft^2/occupant), DV: Daily energy use (kWh/Day), n=235, scatter plot with fit line (left), Venn diagram showing the variance in daily energy use explained by rooms/suites area per occupant (right)

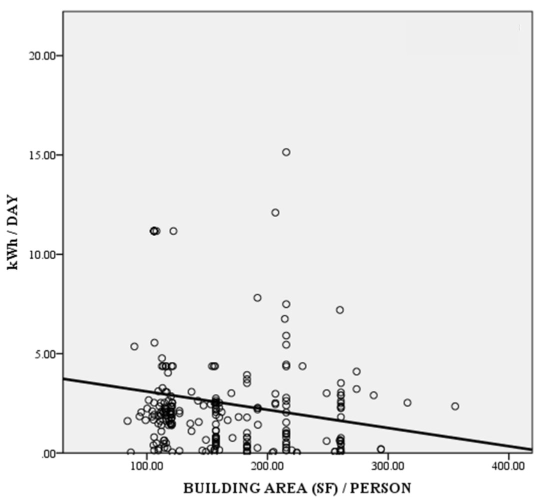
Room/Suite Volume



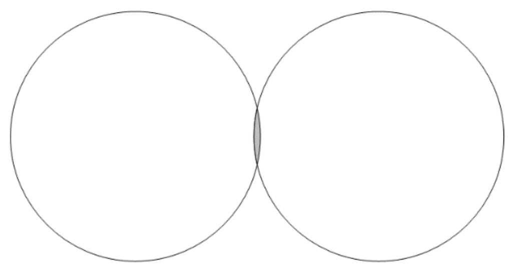
$r^2 = 0.120$, 12%



IV: Room/suite volume (ft^3), DV: Peak plug load power (watts), n=234, scatter plot with fit line (left), Venn diagram showing the variance in peak power explained by volume of the rooms/suites (right)

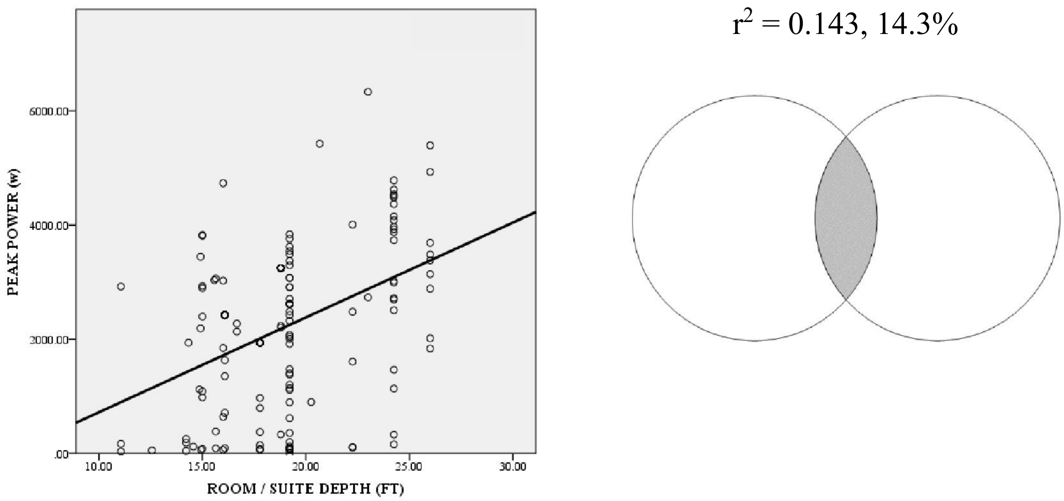


$r^2 = 0.005$, 0.5%

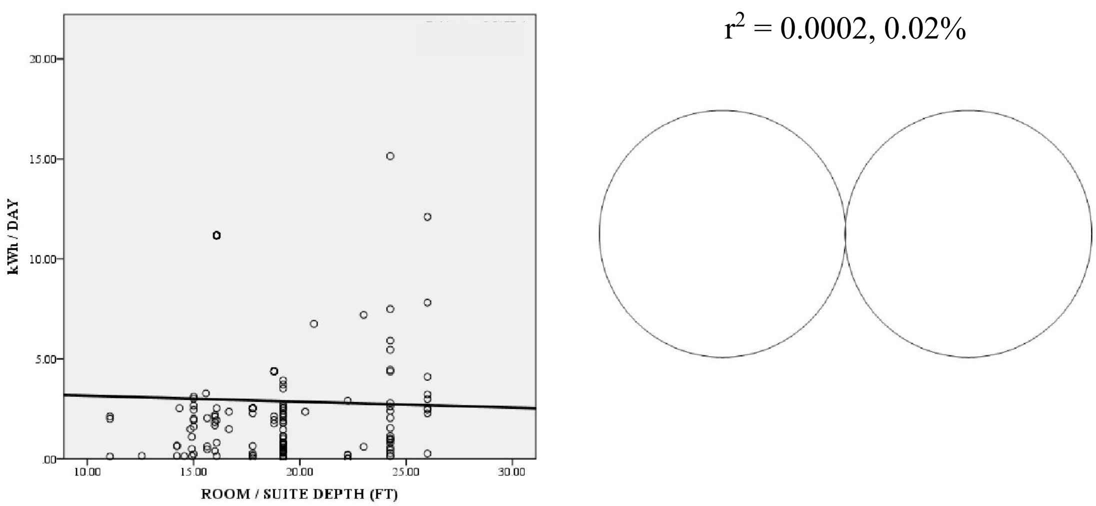


IV: Room/suite volume (ft^3), DV: Daily energy use (kWh/Day), n=234, scatter plot with fit line (left), Venn diagram showing the variance in daily energy use explained by volume of the rooms/suites (right)

Room/Suite Depth

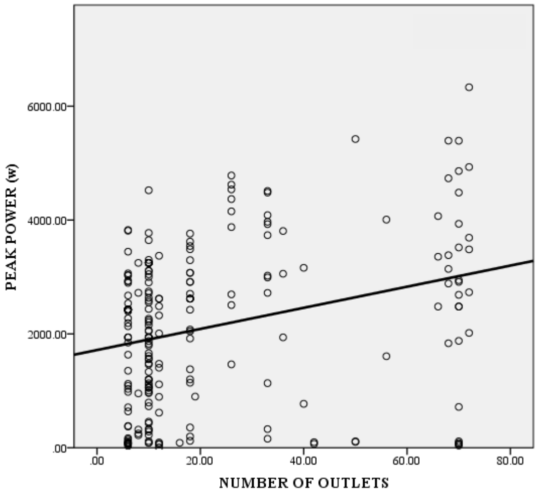


IV: Room/suite depth (ft), DV: Peak plug load power (watts), n=157, scatter plot with fit line (left), Venn diagram showing the variance in peak power explained by the depth of the rooms/suites (right)

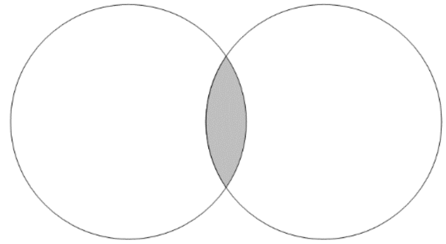


IV: Room/suite depth (ft), DV: Daily energy use (kWh/Day), n=157 scatter plot with fit line (left), Venn diagram showing the variance in daily energy use explained by the depth of the rooms/suites (right)

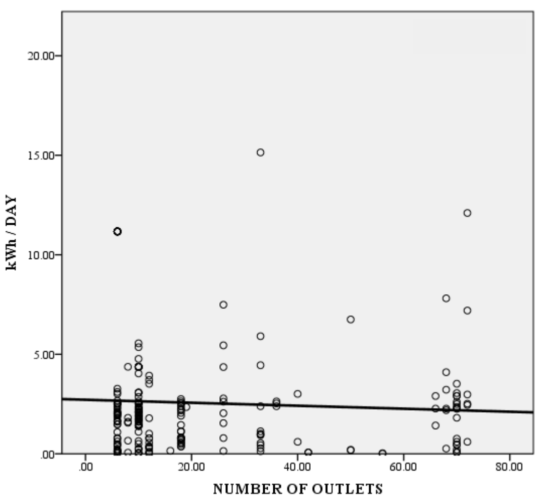
Room/Suite Electrical Outlets



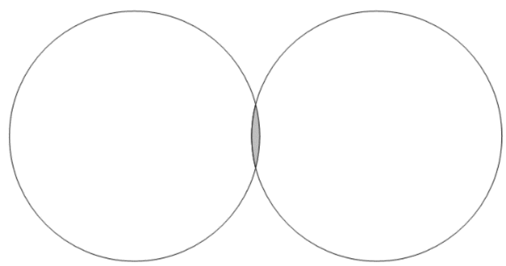
$r^2 = 0.083$, 8.3%



IV: Number of electrical outlets in the student room/suite, DV: peak plug load power (watts), n=234, scatter plot with fit line (left), Venn diagram showing the variance in peak power explained by the number of electrical outlets (right)

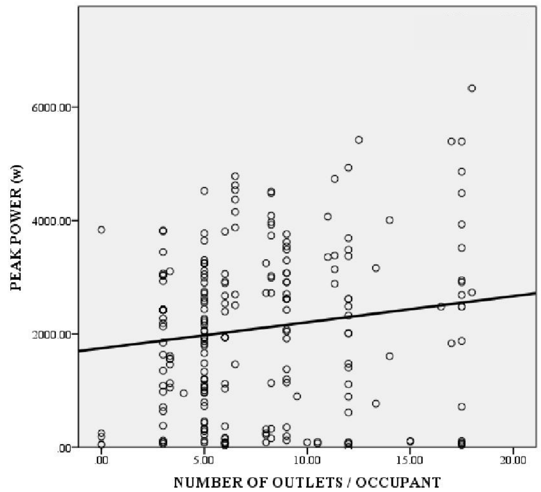


$r^2 = 0.007$, 0.7%

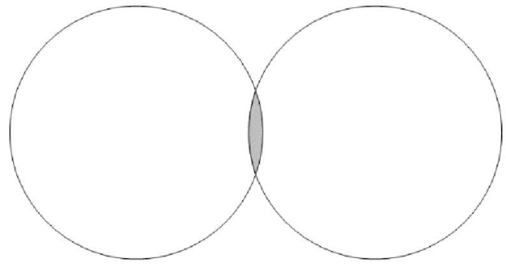


IV: Number of electrical outlets in the student room/suite, DV: Daily energy usage (kwh/day), n=234, scatter plot with fit line (left), Venn diagram showing the variance in daily energy use explained by the number of electrical outlets (right)

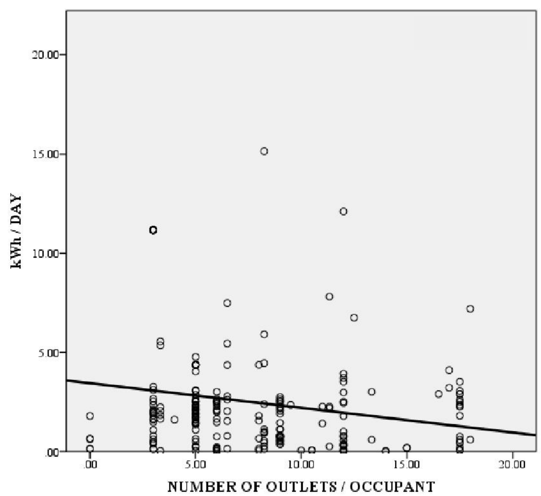
Room/Suite Electrical Outlets Per Occupant



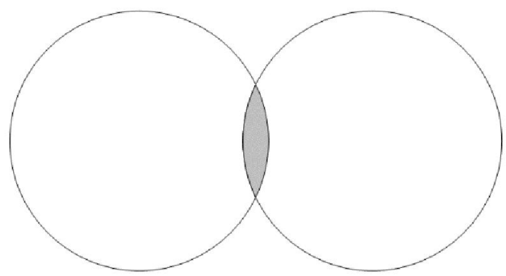
$r^2 = 0.016$, 1.6%



IV: Number of electrical outlets in the student room/suite per occupant, DV: peak plug load power (watts), n=234, scatter plot with fit line (left), Venn diagram showing the variance in peak power explained by the number of electrical outlets per occupant (right)

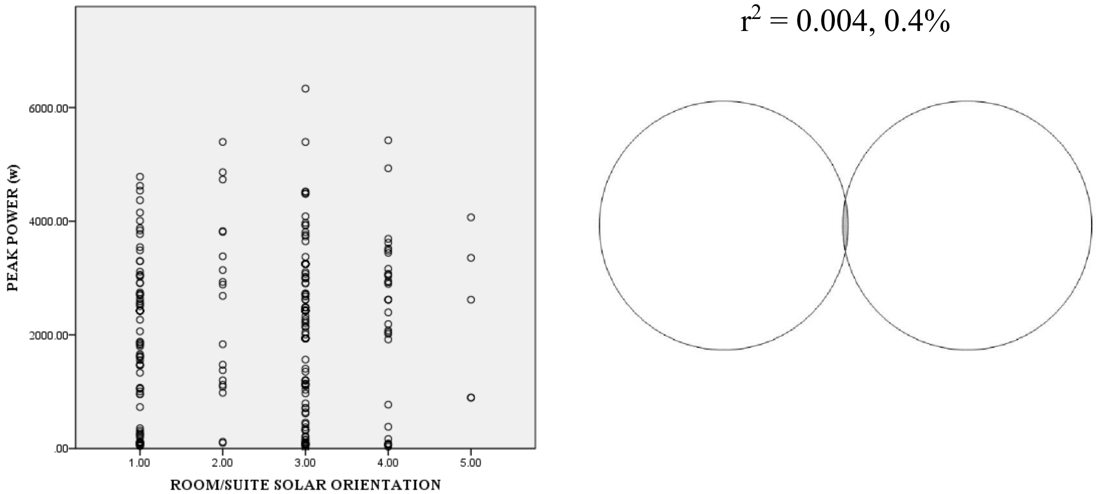


$r^2 = 0.037$, 3.7%

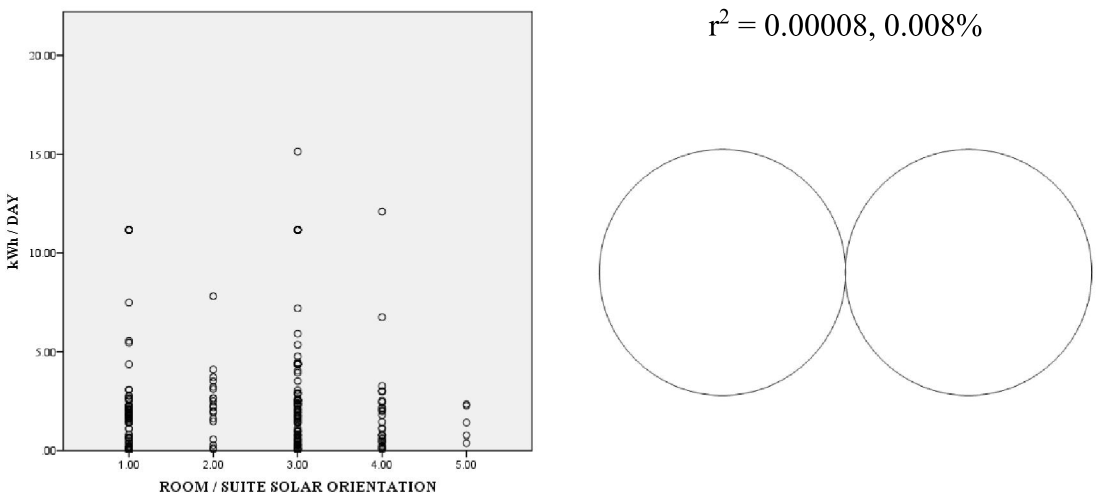


IV: Number of electrical outlets in the student room/suite per occupant, DV: Daily energy usage (kwh/day), n=234, scatter plot with fit line (left), Venn diagram showing the variance in daily energy use explained by the number of electrical outlets per occupant (right)

Room/Suite Solar Orientation

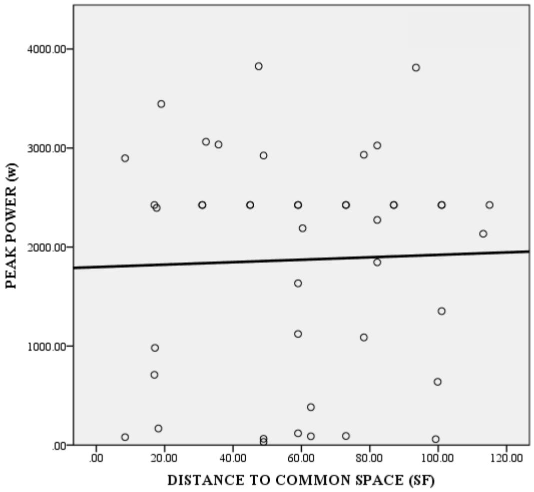


IV: Room/suite solar orientation, DV: peak plug load power (watts), n=239, scatter plot (left), Venn diagram showing the variance in peak power explained by the solar orientation of rooms/suites (right)

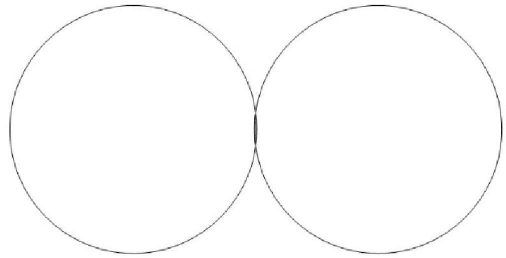


IV: Room/suite solar orientation, DV: daily plug load energy use (kWh), n=239, scatter plot (left), Venn diagram showing the variance in daily plug load energy use explained by the solar orientation of rooms/suites (right)

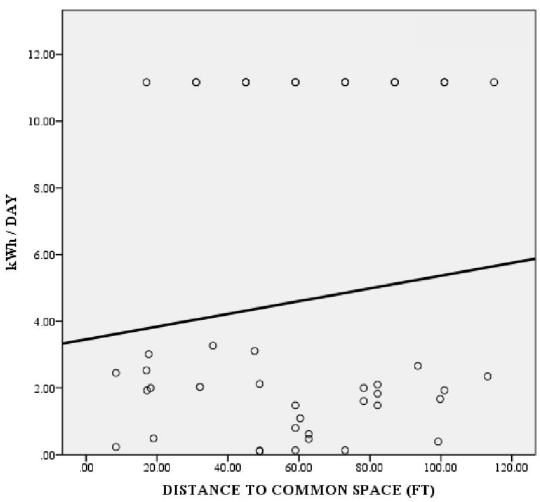
Distance from Room/Suite to Common Space



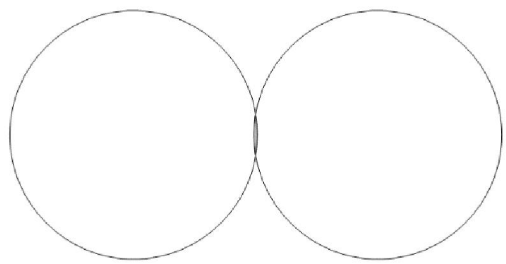
$r^2 = 0.001$, 0.1%



IV: Linear distance to common space (ft), DV: peak plug load power (watts), n=44, scatter plot with fit line (left), Venn diagram showing the variance in peak power use explained by distance to common space (right)

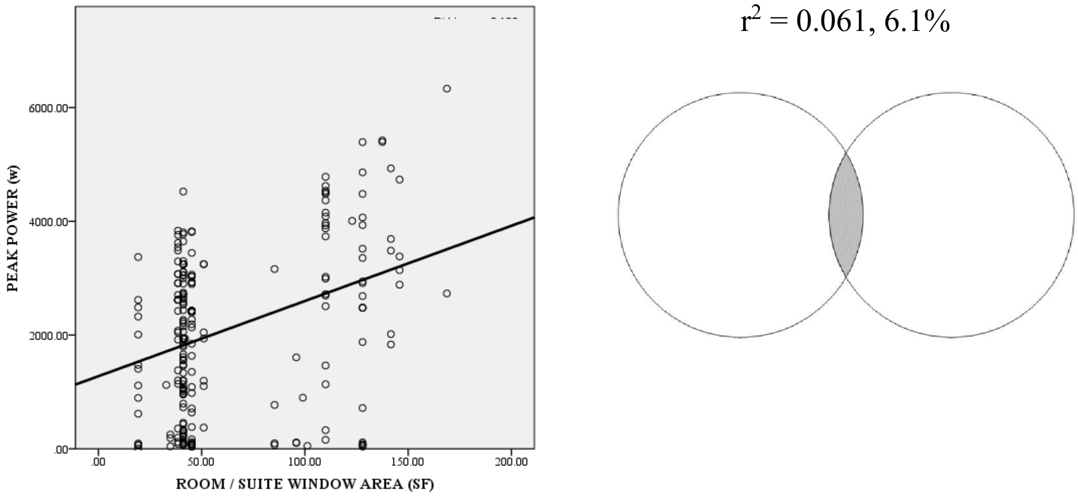


$r^2 = 0.002$, 0.2%

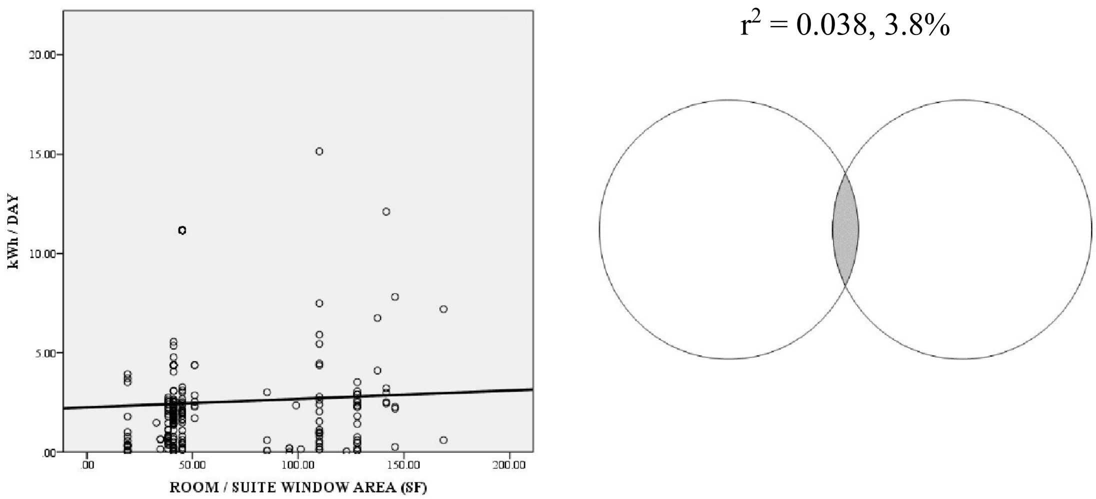


IV: Linear distance to common space (ft), DV: Daily energy usage (kwh/day), n=44, scatter plot with fit line (left), Venn diagram showing the variance in daily energy use explained by distance to common space (right)

Room/Suite Window Area

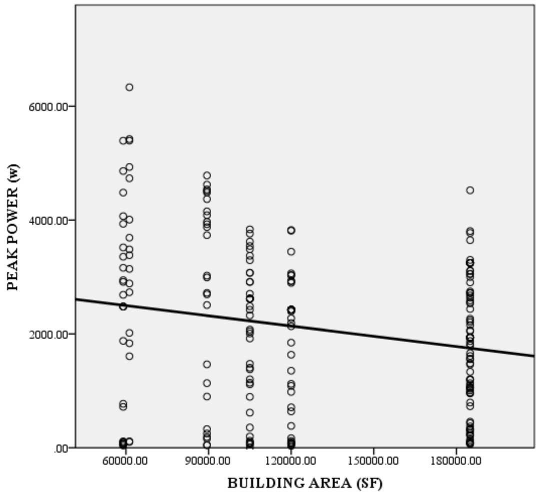


IV: Room/suite window area, DV: peak plug load power (watts), n=239, scatter plot with fit line (left), Venn diagram showing the variance in peak power explained by room/suite window area (right)

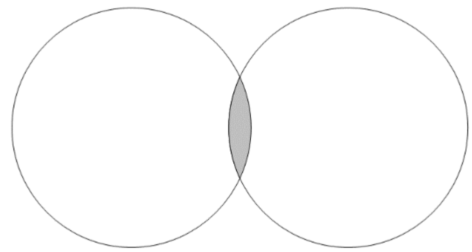


IV: Room/suite window area, DV: daily plug load energy use (kWh), n=239, scatter plot with fit line (left), Venn diagram showing the variance in daily plug load energy use explained by the room/suite window area (right)

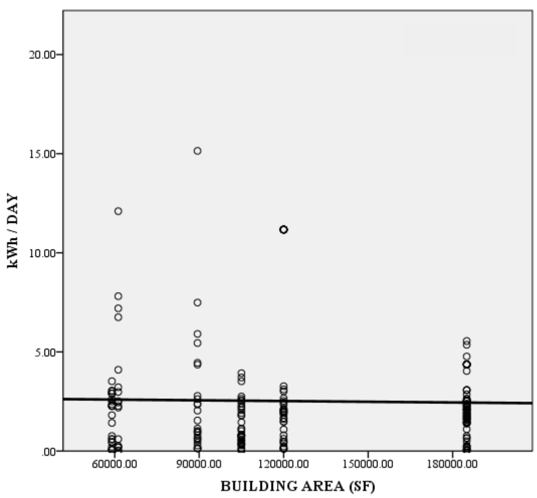
Building Area



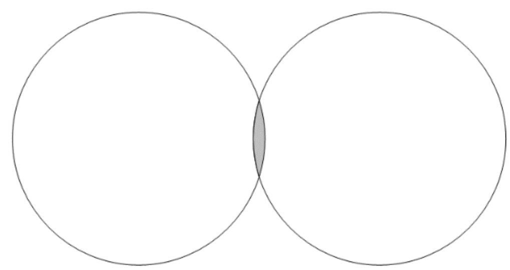
$r^2 = 0.034$, 3.4%



IV: Building area, DV: peak plug load power (watts), n=239, scatter plot with fit line (left), Venn diagram showing the variance in peak power explained by building area (right)

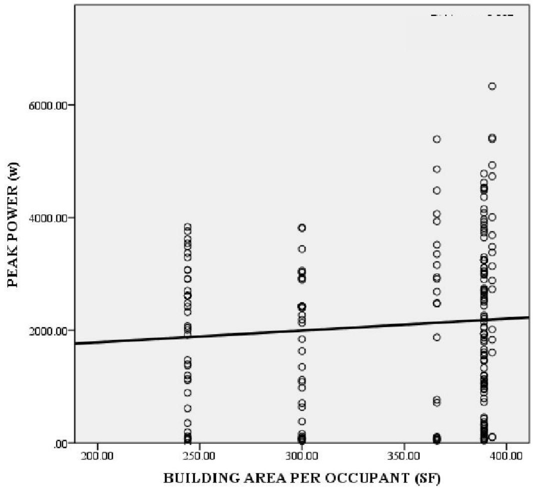


$r^2 = 0.012$, 1.2%

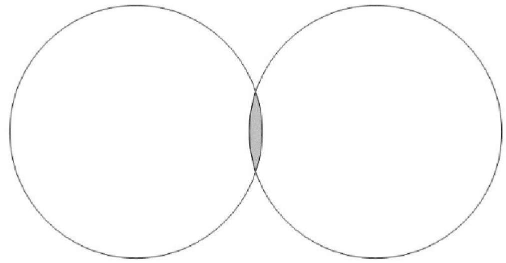


IV: Building area, DV: daily plug load energy use (kWh), n=239, scatter plot with fit line (left), Venn diagram showing the variance in daily energy use explained by building area (right)

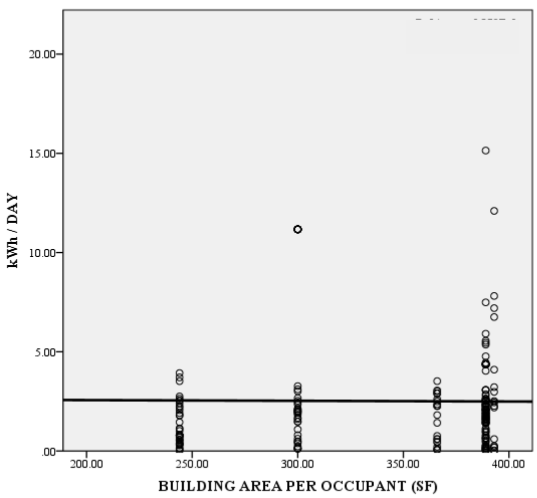
Building Area Per Occupant



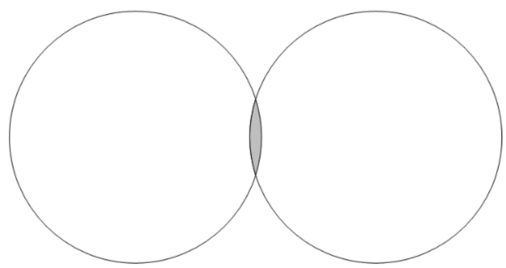
$r^2 = 0.014$, 1.4%



IV: Building area per occupant, DV: peak plug load power (watts), n=239, scatter plot with fit line (left), Venn diagram showing the variance in peak power explained by building area per occupant (right)

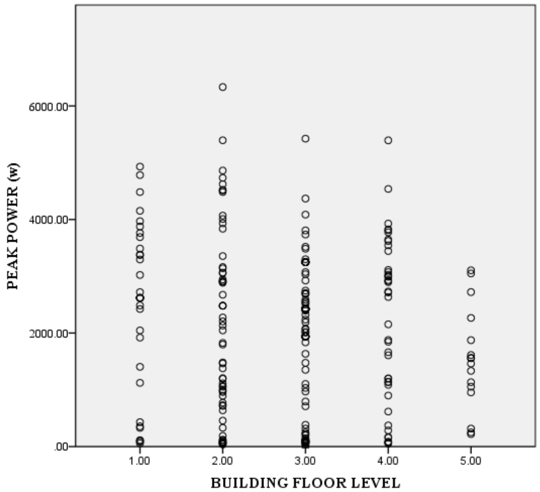


$r^2 = 0.012$, 1.2%

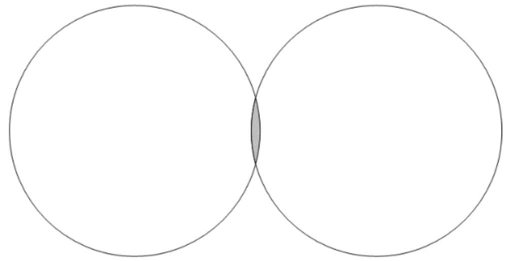


IV: Building area per occupant, DV: daily plug load power use (kWh), n=239, scatter plot with fit line (left), Venn diagram showing the variance in daily energy use explained by building area per occupant (right)

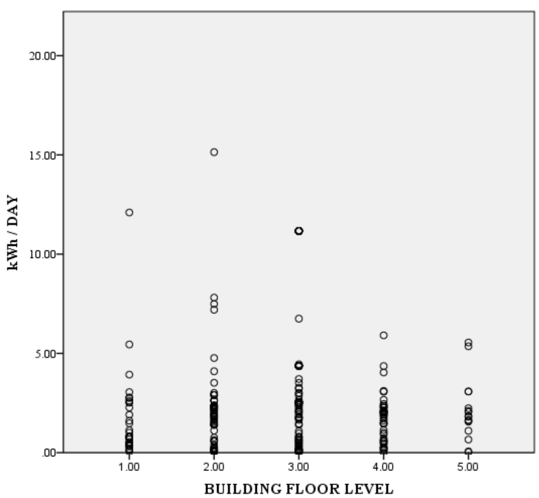
Building Floor Level



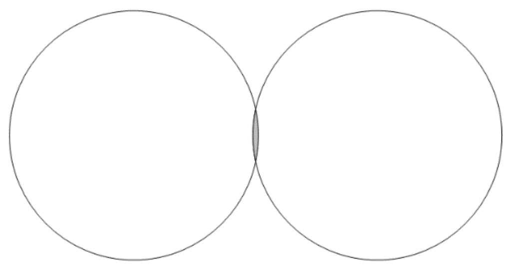
$r^2 = 0.008$, 0.8%



IV: Building floor level, DV: peak plug load power (watts), n=239, scatter plot (left), Venn diagram showing the variance in peak power explained by building floor level (right)

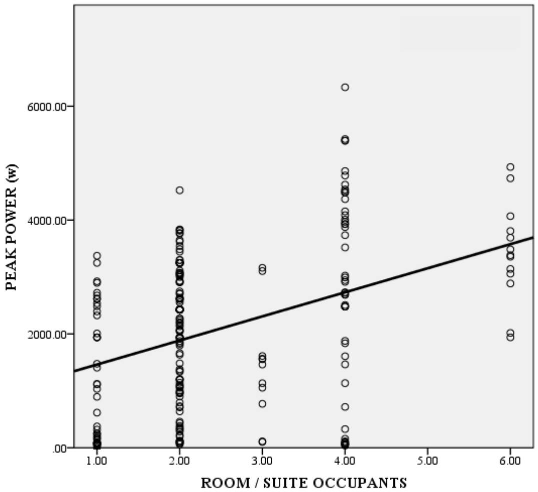


$r^2 = 0.004$, 0.4%

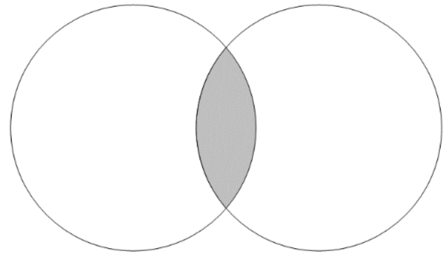


IV: Building floor level, DV: daily plug load power use (kWh), n=239, scatter plot (left), Venn diagram showing the variance in daily energy use explained by building floor level (right)

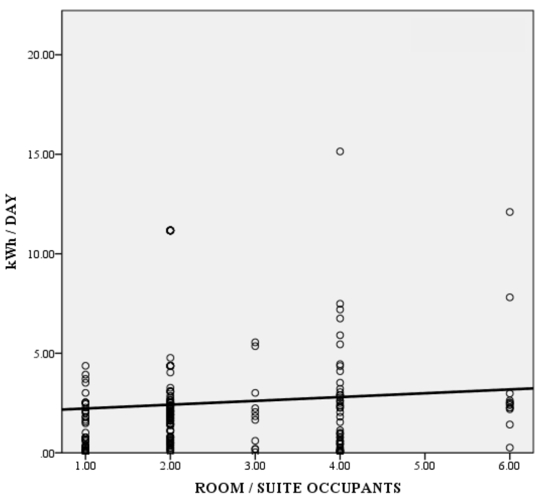
Room/Suite Occupants



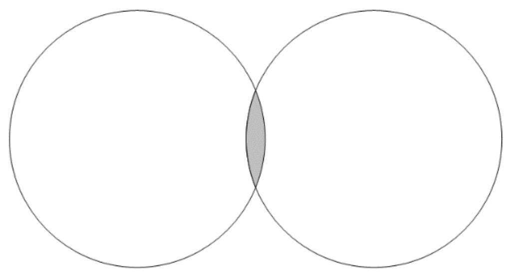
$r^2 = 0.139$, 13.9%



IV: Number of room/suite occupants, DV: peak plug load power (watts), n=239, scatter plot (left), Venn diagram showing the variance in peak power explained by the number of room/suite occupants (right)



$r^2 = 0.024$, 2.4%



IV: Number of room/suite occupants, DV: daily plug load energy use (kWh), n=239, scatter plot (left), Venn diagram showing the variance in daily plug loaf energy use explained by the number of room/suite occupants (right)

REFERENCES CITED

Abramson, P. (2012). Living on campus: 2012 college housing report. *College Planning and Management,* 1-11.

Abramson, P. (2014). 2014 Living on campus: College housing annual report. *College Planning and Management*.

Abu-Bader, S. H., Pryce, J. G., Shackelford, K. K., & Pryce, D. H. (2006). *Using statistical methods in social work practice: A complete SPSS guide*. Chicago: Lyceum Books, Incorporated.

Acupcc. (2015). Commitment text: Presidents' Climate Commitment. from http://www.presidentsclimatecommitment.org/about/commitment

Amole, D. (2009). Residential satisfaction in students' housing. *Journal of Environmental Psychology, 29*(1), 76-85.

Anderson, D., Cunningham, P., Damon, D., & de Angel, Y. (2009). A Study for Carbon Neutrality: The Impact of Decisions, Design and Energy. *Perkins + Will Research Journal, 01.02*, 7-36.

Andrews, S., Easton, E., Johnson, K., Sabo, C., & Simpson, W. (2006). *Creating energy $mart college campuses*. Paper presented at the ACEEE Summer Study on Energy Efficiency in Buildings, Monterey, CA.

Architect. (2015). Gilbert Hall, Pacific University. *Architect*.

Azari-N, R., & Peña, R. (2012). *Integrated design to achieve zero net energy in an urban office building.* Paper presented at the Solar 2011, Raleigh, NC.

Babbie, E. R. (1991). *Survey research methods* (2nd ed.). Belmont, Calif: Wadsworth Publishing.

Berger, J. B. (1997). Students' sense of community in residence halls, social integration, and first-year persistence. *Journal of College Student Development, 38*(5), 441-452.

Blumer, H. (1969). The methodological position of symbolic interactionism. *Symbolic interactionism: Perspective and method*, 1-60.

Brandon, G., & Lewis, A. (1999). Reducing household energy consumption: a qualitative and quantitative field study. *Journal of Environmental Psychology, 19*(1), 75-85.

Brewer, R. S., Lee, G. E., & Johnson, P. M. (2011). The Kukui Cup: A dorm energy competition focused on sustainable behavior change and energy literacy. *Proceedings of the Annual Hawaii International Conference on System Sciences*.

Bringer, J., Johnston, L., & Brackenridge, C. (2006). Using computer-assisted qualitative data analysis software to develop a grounded theory project. *Field Methods, 18*(3), 245-266.

Calhoun, T., & Cortese, A. (2006). We rise to play a greater part. *Planning for Higher Education, 34*(2), 62.

CEC. (2012). *Building energy efficiency standards for residential and nonresidential buildings: CCR Title 24*. CEC.

Charmaz, K. (2000). Grounded Theory: Objectivist and constructivist methods. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 509-535). Thousand Oaks Calif.: Sage Publications.

Charmaz, K. (2006a). *Constructing grounded theory : A practical guide through qualitative analysis*. Thousand Oaks Calif.: Sage Publications.

Charmaz, K. (2006b). *Constructing Grounded Theory: A practical guide through qualitative analysis (introducing qualitative methods series)*: SAGE Publications Ltd.

Charmaz, K. (2011). A Constructivist Grounded Theory analysis of losing and regaining a valued self. In F. Wertz (Ed.), *Five ways of doing qualitative analysis : Phenomenological psychology, Grounded Theory, discourse analysis, narrative research, and intuitive inquiry* (pp. 165-204). New York: Guilford Press.

Clemons, S., McKelfresh, D., & Banning, J. (2005). Importance of sense of place and sense of self in residence hall room design: A qualitative study of first-year students. *Journal of The First-Year Experience & Students in Transition, 17*(2), 73-86.

College Navigator. (2014). Retrieved February 6, 2014, from http://nces.ed.gov/collegenavigator/?s=OR&ic=1&pg=3

Collins, T. (2013). *Campus buildings & student engagement in institutional sustainability efforts.* Paper presented at the ARCC 2013 Architectural Research Conference, Charlotte, NC.

Commission, C. E. (2012). Building Energy Efficiency Standards for Residential and Nonresidential Buildings: CCR Title 24 (pp. 1-252).

Corcoran, P. B., & Wals, A. E. J. (2004). *Higher education and the challenge of sustainability: problematics, promise, and practice*. Boston: Kluwer Academic Publishers.

Cortese, A. (2003). The critical role of higher education in creating a sustainable future. *Planning for Higher Education, 31*(3), 15-22.

Creighton, S. H. (1998). *Greening the ivory tower : Improving the environmental track record of universitities, colleges and other institutions*. Cambridge, Mass: MIT Press.

Crowe, E. (2013). Case study: Analyzing plug Loads: Applying a new methodology for measuring plug load energy use: PECI.

Cupido, A., Baetz, B., Pujari, A., & Chidiac, S. (2010). Evaluating institutional green building policies: A mixed-methods approach. *Journal of Green Building, 5*(1), 115-131.

Cupido, A. F. (2011). *Development and application of policy-based tools for institutional green buildings.* McMaster University Hamilton.

Darby, S. (2001). Making It Obvious: Designing Feedback Into Energy Consumption. In P. Bertoldi & I. C. o. E. E. i. H. A. a. Lighting (Eds.), *Energy efficiency in household appliances and lighting*. Berlin ;;New York: Springer.

Darby, S. (2006). The effectiveness of feedback on energy consumption. *A Review for DEFRA of the Literature on Metering, Billing and direct Displays, 486*, 2006.

Darby, S. (2008). Energy feedback in buildings: Improving the infrastructure for demand reduction. *Building Research and Information, 36*(5), 499-508.

Devlin, A., Donovan, S., Nicolov, A., Nold, O., & Zandan, G. (2008). Residence hall architecture and sense of community: Everything old is new again. *Environment and Behavior, 40*(4), 487-521.

Dunkel, N. W. (2009). Green residence halls are here: Current trends in sustainable campus housing. *The Journal of College and University Student Housing*, 10.

Ellis, D. (2006). Dorms of the Future. *CNN Money*. http://money.cnn.com/2006/08/03/pf/college/future_dorms/

Erickson, C., & Skoglund, C. (2008). Eco-reps programs: Conducting peer outreach in residence halls. *Sustainability: The Journal of Record, 1*(1), 57-72.

Fabris, P. (2011). Major trends in university residence halls. *Building Design and Construction*. http://www.bdcnetwork.com/major-trends-university-residence-halls

Festinger, L. (1950). *Social pressures in informal groups a study of human factors in housing* ([1st ed.] ed.). New York: Harper.

Foubert, J. D., Tepper, R., & Morrison, D. (1998). Predictors of student satisfaction in university residence halls. *The Journal of College and University Student Housing, 27*(1), 41-46.

Glaser, B., & Strauss, A. (1967). The discovery of grounded theory. 1967. *Aldin, New York*.

Hales, D. (2008). Sustainability and higher education. *New England Journal of Higher Education, 23*(2), 23-24.

Harris, D., & Higgins, C. (2013). Methodology for reporting commercial office plug load energy use: NBI/PECI.

Hayes, D., Court, B., Hanford, J., & Schwer, P. (2011). Cascadia center for sustainable design: Design and construction energy performance: Bullitt Foundation; Miller Hull Partnership; PAE Engineers.

Hootman, T. (2013). *Net zero energy design a guide for commercial architecture*. Hoboken, NJ: John Wiley & Sons,.

Johnson, B., & Turner, L. A. (2003). Data collection strategies in mixed methods research. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social & behavioral research* (pp. 297-319). Thousand Oaks Calif.: SAGE Publications.

Kaneda, D., Jacobson, B., & Rumsey, P. (2010). *Plug load reduction: The next big hurdle for net zero energy building design*. Paper presented at the ACEEE Summer Study on Energy Efficiency in Buildings, Monterey, CA.

Kinsley, M. (2009). Accelerating campus climate initiatives : [Breaking through barriers]. Snowmass ,CO: Rocky Mountain Institute.

Koester, R. J., Eflin, J., & Vann, J. (2006). Greening of the campus: A whole-systems approach. *Journal of Cleaner Production, 14*(9), 769-779.

Kraska-Miller, M. (2013). *Nonparametric statistics for social and behavioral sciences*. Beaverton: Chapman and Hall/CRC.

LBL. (2015). Standby power. from http://standby.lbl.gov/docs.html

Leaman, A., & Bordass, B. (1999). Productivity in buildings: the 'killer' variables. *Building Research and Information, 27*(1), 4-19.

Lobato, C., Pless, S., Sheppy, M., & Torcellini, P. (2011). Reducing plug and process loads for a large scale, low energy office building: NREL's research support facility. *ASHRAE Transactions, 117*(1), 330.

M'Gonigle, R. M., & Starke, J. (2006). *Planet U : Sustaining the world, reinventing the university*. Gabriola Island, BC: New Society Publishers.

Mahlum. (2015). Gilbert Hall, Pacific University. from http://www.mahlum.com/projects/GilbertHall/index.asp#

Martin, R. J. (2011). STARS: A campus-wide integrated continuous planning opportunity. *Planning for Higher Education, 39*(2), 41.

McGarry, L. (2004). *Standby power challenge.* Paper presented at the Asian Green Electronics, 2004. AGEC. Proceedings of 2004 International IEEE Conference on Nanotechnology, Munich.

Mercier, C., & Moorefield, L. (2011). Commercial office plug load savings assessment *Public Interest Energy Researcg (PIER) Program: Evidence-based Design and Operations*: California Energy Commission.

Metzger, I., Kandt, A., & VanGeet, O. (2011). Plug load behavioral change demonstration project. Golden, CO: National Renewable Energy Laboratory.

MicroFridge. (2015). MicroFridge with Safe Plug.

Miles, M., & Huberman, M. (1994). *Qualitative data analysis : An expanded sourcebook* (2nd ed. ed.). Thousand Oaks: Sage Publications.

Mills, J., Bonner, A., & Francis, K. (2006). The development of Constructivist Grounded Theory. *International Journal of Qualitative Methods, 5*(1).

Moorefield, L. (2011). Plug load energy use and savings opportunities. Durango, CO: ECOS.

Moos, R. H., Van Dort, B., Smail, P., & DeYoung, A. J. (1975). A typology of university student living groups. *Journal of educational psychology, 67*(3), 359.

Murray, A., & Mills, B. (2011). Read the label! Energy Star appliance label awareness and uptake among U.S. consumers. *Energy Economics, 33*(6), 1103-1110.

Nearing, B. (2011). UAlbany wins energy award, *Times Union*.

Nelson, B. (2013, April 2, 2013). A building not just green, but practically self-sustaining, *New York Times*.

NFPA. (2013). *NEC 2014 : National Electrical Code 2014 NFPA 70.* Quincy, MA: NFPA.

Odom, W., Pierce, J., & Roedl, D. (2008). *Social incentives and eco-visual displays: toward persuading greater change in dormitory communities*. Paper presented at the OZCHI Conference, Cairns, Australia.

Orr, D. (2006). *Design on the edge the making of a high-performance building*. Cambridge, MA: MIT Press.

Pacific. (2015a). Pacific University residential areas: Gilbert Hall. from http://www.pacificu.edu/about-us/offices/housing/residential-areas/gilbert

Pacific. (2015b). Pacific Univsersity residential areas: Burlingham Hall. from http://www.pacificu.edu/about-us/offices/housing/residential-areas/burlingham#amenities

Pacific. (n.d.). *Green building handbook: Burlingham Hall* P. University (Ed.)

PAE. (2011). Building 33 SCL Report. Portland, OR.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks CA: Sage Publications.

Petersen, J., Shunturov, V., Janda, K., Platt, G., & Weinberger, K. (2007). Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. *International Journal of Sustainability in Higher Education, 8*(1), 16.

Rappaport, A. (2008). Campus greening: Behind the headlines. *Environment: Science and Policy for Sustainable Development, 50*(1), 6-17.

Rappaport, A., & Creighton, S. H. (2007). *Degrees that matter: Climate change and the university*. Cambridge, MA: MIT Press.

Richards, L. (2005). *Handling qualitative data : A practical guide*. London: SAGE Publications.

Rivas, J. (2009). *Managing plug loads.* Paper presented at the Climate leader web conference.

Rowe, D. (2007). Education for a sustainable future. *Science, 317*(5836), 323.

Rubin, H. J., & Rubin, I. (2012). *Qualitative interviewing the art of hearing data* (3rd ed.). Los Angeles, CA: SAGE.

Sagaser, D., Balogh, C. P., & Thompson, R. (2012). 2012 ACUHO-i construction and renovation findings. Tallahassee, FL: MGT of America.

Saldana, J. (2009). *The coding manual for qualitative researchers*. Los Angeles, CA: Sage.

SERA. (2015). North Campus Village, Southern Oregon University. from http://serapdx.com/projects/north-campus-village-southern-oregon-university/

Sharp, L. (2002). Green campuses: The road from little victories to systemic transformation. *International Journal of Sustainability in Higher Education, 3*(2), 128-145. doi: 10.1108/14676370210422357

Shushok, F., Scales, T. L., Sriram, R., & Kidd, V. (2011). A tale of three campuses: Unearthing theories of residential life that shape the student learning experience. *About Campus, 16*(3), 13-21.

Simpson, W. (2008). *The green campus : Meeting the challenge of environmental sustainability*. Alexandria, VA: APPA.

Sommer, R. (1969). *Personal space the behavioral basis of design.* Englewood Cliffs, N.J.: Prentice-Hall.

SOU. (2015a). Residential Complexes. from http://www.sou.edu/housing/reshall/northhall.html

SOU. (2015b). Residential Complexes: Shasta Hall. from http://www.sou.edu/housing/reshall/southhall.html

Srinivasan, R. S., Lakshmanan, J., & Santosa, E. (2011). Plug-load densities for energy analysis: K-12 schools. *Energy Buildings, 43*(11), 3289-3294.

Steingard, B. (2009). A study of in-dorm student energy use at Smith College.

Summit. (2015). PowerSight PS3500 Power Analyzer. from http://www.summittechnology.com/Power_Analyzer_PS3500.html

Tammy, E., Younos, T., Grossman, L. S., & Geller, E. S. (2013). A study of environmentally relevant behavior in university residence halls. *International Journal of Sustainability in Higher Education, 14*(4), 466-481.

Torcellini, P., Pless, S., Lobato, C., & Sheppy, M. (2011). Reducing plug and process loads for a large scale, low energy office building NREL's research support facility. Washington, D.C; : United States. Dept. of Energy; Distributed by the Office of Scientific and Technical Information, U.S. Dept. of Energy.

UO. (2015a). Camous Planning: Completed Projects. from http://uplan.uoregon.edu/projects/projects.html

UO. (2015b). Rooms and Communities: Global Scholars Hall. from http://housing.uoregon.edu/global-scholars-hall

UO. (2015c). Rooms and Communities: Living-Learning Center. from http://housing.uoregon.edu/living-learning-center

USDOE. (2013). Building Energy Data Book. from U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy buildingsdatabook.eren.doe.gov

USDOE. (2014). U.S. energy use intensity by property type *Energy Star Portfolio Manager* (pp. 1-6). Washington, D.C.: U.S. Department of Energy.

Van der Ryn, S., & Silverstein, M. (1967). *Dorms at Berkeley: An environmental analysis*. Berkeley, CA: Center for Planning and Development Research: University of California.

Watts-up? (2015). Watts-up? Pro Plug Load Data Logger. from https://www.wattsupmeters.com/secure/products.php?pn=0&wai=129&spec=5

West. (2015). Pacific University Burlingham Hall. from http://systemswestengineers.com/portfolio/higher-education/test-project-1/

Wheeler, S. (2013). SOU complex opens, earns raves, *Mail Tribune*.

Wilkins, C. K., & Hosni, M. H. (2011). Plug load design factors. *ASHRAE Journal, 53*(5), 30.

Winston, R. B., & Anchors, S. (1993). *Student housing and residential life: A handbook for professionals committed to student development goals* (1st ed. ed.). San Francisco, CA: Jossey-Bass.

Wright, T. (2002). Definitions and frameworks for environmental sustainability in higher education. *Higher Education Policy, 15*, 105-120.

Wright, T. (2004). The evolution of sustainability declarations in higher education. In P. Corcoran & A. E. J. Wals (Eds.), *Higher education and the challenge of sustainability: Problematics, promise, and practice*. Boston: Kluwer Academic Publishers.

Wright, T. (2010). University presidents' conceptualizations of sustainability in higher education. *International Journal of Sustainability in Higher Education, 11*(1), 61-73.

Zimmerman, J., & De Angel, Y. (2013). A zero net energy building pilot study. *Perkins + Will Research Journal, 05.02*, 70-91.