Comparison of Occupant Behavior in a Traditional, Green Featured, and LEED Certified Building Case

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ACADEMIC ABSTRACT

In developed nations, 20-40% of greenhouse gas emissions and more than one-third of energy consumption are attributable to buildings. Among various available strategies, the building sector has the greatest potential for carbon emission reduction. Leadership in Energy and Environmental Design (LEED) took early action to promote sustainable designs in buildings and has become the most well-known rating system in the field of building sustainability. However, little research has evaluated the effects of LEED on occupant pro-environmental behavior. To examine this, a Post Occupancy Evaluation (POE) was conducted in a traditional, green featured, and LEED certified building case to compare the similarities and differences in environmental awareness, perceptions, and perceived ease or difficulty of pro-environmental behaviors, as well as to assess the degree to which pro-environmental behaviors were exhibited by occupants. This was used to determine if the aforementioned factors influence occupant behavior in different building cases. Ease or difficulty of pro-environmental behaviors and environmental awareness were found to be significant factors in influencing pro-environmental behavior in the LEED certified and green featured building cases. In addition, being in a LEED building appears to influence occupant pro-environmental behavior in a positive way. Also, there is evidence to suggest that being in a green featured building appears to influence occupants to exhibit pro-environmental behavior as well. These findings are valuable for owners and designers that want occupants in their buildings to exhibit pro-environmental behavior.

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PUBLIC ABSTRACT

Climate change is an issue that has risen to national and global importance with the increase of rising sea levels, temperature and precipitation, and extreme weather events. To combat the issue of climate change, changes in building design through the avenue of green rating systems have been used to encourage the building sector to reduce energy consumption and thus, a building's environmental impact. LEED (Leadership in Energy and Environmental Design), is one of the most well-known green rating systems used to rate energy efficient buildings. However, the effect of LEED on occupant pro-environmental behavior has been less studied in understanding how occupant behavior impacts energy consumption in a traditional, green featured, and LEED certified building case.

This thesis aims to explore if occupying different buildings influence occupants to exhibit pro-environmental behaviors. For this study, I investigated whether occupant's environmental awareness, perceptions, perceived ease or difficulty of set behaviors and pro-environmental behavior differed between different building cases. This thesis concludes that being in a LEED certified and green featured building appear to influence occupants to exhibit pro-environmental behavior, more so than being in a traditional building.

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ATTRIBUTION

This thesis is composed of one manuscript intended for journal publication and future conference papers. This forward contains information regarding the contribution of authors of the manuscript.

There is an additional contribution summary in Appendix E as per departmental requirements.

Study #1:

Adrienne Hill – Adrienne came up with the concept behind the research, reviewed the relevant literature, developed and tested the survey instrument, collected the data, performed the analysis, and wrote all the sections of this manuscript. Adrienne incorporated comments from other authors as she saw fit.

Yilong Han – Yilong advised Adrienne on structuring the manuscript and provided periodic comments on the manuscript.

John Taylor – Dr. Taylor advised Adrienne on the structuring of the manuscript and provided periodic comments. Dr. Taylor acted as Adrienne's academic advisor and was in contact with Adrienne throughout the process of the research.

Tripp Shealy – Dr. Shealy provided input on the research and provided periodic comments on the research. When Adrienne's academic advisor moved universities, Dr. Shealy acted as Adrienne's campus advisor for Adrienne's last semester of graduate school.

Annie Pearce- Dr. Pearce provided input on the methodology and data analysis that shaped the results. Dr. Pearce also provided comments on the overall direction of the research.

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INTRODUCTION

Climate change is an issue that has risen to national and global importance with the increase of rising sea levels, temperature and precipitation, and extreme weather events. To combat the issue of climate change, changes in building design could offset carbon emissions and reduce environmental impact in the building sector.

Since the early 2000s, green rating systems have been created to encourage the building sector to design, build, and operate buildings in such a way that reduces energy consumption and environmental impact. LEED (Leadership in Energy and Environmental Design) is the most well-known rating system, and it is used extensively around the world. However, the effects of LEED on occupant pro-environmental behavior has been less studied.

This thesis aims to understand the relationship between building cases and occupant's proclivity towards exhibiting pro-environmental behavior. To achieve this aim, this thesis explores the effect of environmental awareness, perceptions, and perceived ease or difficulty of set behaviors on pro-environmental behavior in a traditional, green featured, and LEED certified building case.

Comparing Environmental Awareness, Perceptions, and Perceived Ease or Difficulty of Behaviors in a Traditional, Green Featured, and LEED Certified Building Case

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1. Introduction

Climate change is linked to rising sea levels, uncharacteristic temperature and precipitation changes, and an increase in extreme weather events (NASA 2016). The effects of climate change are increasing due to human activities from burning fossil fuels and the release of carbon dioxide into the atmosphere (NASA 2016). In developed nations, 20-40% of greenhouse gas emissions and more than one-third of energy consumption are attributed to buildings (Newsham, Mancini et al. 2009). Because of the large amount of energy that is consumed by buildings, the building sector has the greatest potential to reduce energy consumption (Solomon 2007).

Sustainability rating systems provide an incentive and framework for reducing energy use and greenhouse gas emissions during the design and construction of buildings (Ahn et al. 2013). One of the most well-known green rating systems, which has been implemented in more than 161 countries, is Leadership in Energy and Environmental Design (LEED) overseen by the United States Green Building Council (USGBC). The purpose of LEED is to guide stakeholders in the building construction, design, and operations phase to reduce energy use and environmental impacts (Shealy et al. 2016). Based on a point system, the more points a building achieves by meeting designated sustainability metrics, the higher the certification level a project can earn. These scale from certified, to silver, gold, or platinum levels of certification. Because of the recognition and popularity of the LEED rating system, an increasing number of building projects are pursuing LEED certification, (Eichholtz et al. 2010). As of October 2016, more than 82,800 buildings and 15.7 billion square feet of buildings was LEED certified. In addition, it was estimated that 1.85 million square feet were being certified by LEED daily (USGBC Statistics 2016).

2. Literature Review

The effects of LEED have been studied in multiple areas including; building design characteristics (e.g., civil, mechanical, and electrical systems), building operation (e.g., how building managers operate the building systems), energy consumption (Azar and Menessa 2014), and in terms of unrealistic energy simulation models (Azar and Menessa 2012). A less studied factor is the effects of LEED on building occupants. Building occupants are a necessary factor to consider when analyzing how energy is consumed within a space (Gyberg and Palm 2009). This would suggest that LEED buildings also need environmentally aware occupants to achieve the expected reduced energy consumption in buildings (Browne and Fame 1999).

However, current research about LEED certified buildings tends to overlook the necessity for a building's occupants to exhibit pro-environmental behavior, activities that promote sustainable actions while at the same time eliminating negative ones (Kollmuss and Agyeman 2002). Post Occupancy Evaluation (POE) studies show predicted energy use and behavior of occupants does not equate to what happens in practice. This type of feedback has been applied in evaluating occupant's overall satisfaction, indoor environmental quality, and perceived productivity (Heerwagen 2000, Kumar and Fisk 2002, Seppanen, Fisk et al. 2006, Singh, Syal et al. 2010, Wener and Carmalt 2006). For example, POEs have been used for occupant feedback to understand how occupants were using a building (Kansara and Ridley 2012, Littleford, Ryley et al. 2014, Marans and Edelstein 2010, Menadue, Soebarto et al. 2013, Menezes, Cripps et al. 2012). In these studies, the evaluations were useful to highlight the deviation of occupant behavior in buildings. In a study by Brown (2014), the POE highlighted the reasons behind the under-usage of an energy efficient heating and cooling system that was intended to reduce energy consumption. The comments section by the occupants made it clear that the system was too hard to use and was,

therefore, never turned on by occupants. In addition, POEs can also highlight disconnects between management directives and what gets accomplished within a company. In a commercial building POE, Menadue et al. (2013) reported that 85% of survey respondents in the Green Star building stated that they had not received instruction on how to operate the building, even though the company stressed occupant training. Also, in a study examining after-hours usage of office equipment done by Webber et al. (2006), results indicated that more than 50% of office equipment was left running after hours by building occupants, leading to excessive energy use by 3,700 pieces of equipment in 12 different commercial buildings in the United States. This type of feedback highlighted by POE's is critical in understanding how buildings are performing from the occupant perspective. Based on the results from POE studies, occupants do not always behave in ways that lower energy consumption in buildings. For energy efficient LEED buildings that reduce energy consumption, the latest green technology implemented or the highest level of LEED certification achieved may not be enough. Changing occupant behavior in these buildings is crucial to reducing energy consumption since buildings with green features can be compromised due to the specification or technical attributes of the building failing to adequately account for occupant's needs, expectations and behavior (Brown and Gorgolewski 2014).

Even though building occupants do not always behave in ways that lower energy consumption, they also have the potential opportunity to aid in a building's energy reduction goals with their behavioral actions. In fact, occupants exert almost as much influence over energy consumption in a building as building operators (Chong 2007). This means that occupants have just as much opportunity to reduce energy consumption in a commercial building by their decisions as a building operator. To get occupants to make better behavioral choices in terms of energy means to modify occupant behavior. To change behavior, there are numerous intervention programs that exist,

including eco-feedback systems, to motivate occupants' pro-environmental behavior (Chen et al. 2013, Gulbinas et al. 2015, Jain et al. 2013, Peschiera et al. 2012). However, intervention programs sometimes do not lead to desired effects. In an eco-feedback study, when users realized they were saving more energy than their peers, some users started consuming more energy (Gulbinas et al. 2013). In some cases, when the study was over, individuals reverted to their old habits, thus not continuing with the pro-environmental behavior (Schwartz, Fischhoff et al. 2013). Since occupants spend approximately 90% of their time indoors (Höppe 2002), it is important to understand occupant behavior in buildings to effectively reduce energy consumption (Brown and Gorgolewski2014). As a result, to achieve the energy efficiency objectives of LEED certified buildings, buildings need occupants that are exhibiting pro-environmental behaviors. Motivating individuals to exhibit pro-environmental behavior involves understanding human behavior and psychology (Zuo and Zhao 2014).

Encouraging pro-environmental behavior involves understanding what influences an individual to exhibit certain behaviors in the first place. That is why the framework of the theory of planned behavior was chosen, since it is a theory that predicts deliberate behavior. Other frameworks, including the value belief norm (VBN) theory and diffusions of innovations theory, were considered, but didn't fit within the context of trying to understand what influences building occupants to exhibit pro-environmental behavior. According to the theory of planned behavior, an individual's behavior can be influenced by their own attitudes, social norms, and perceived behavioral control (Ajzen and Madden 1986). The definition of attitude, in this case, is a settled way of thinking or feeling about something. When it comes to innovations, individuals tend to favor ideas that fit their own preconceptions and attitudes (Dennis, Soderstrom et al. 1990). One possible way that individuals change certain attitudes is through gaining more information.

According to technology adoption theory and attitude based decision making, the ability for a human to change is also based on their baseline knowledge about a certain activity (Wilson and Dowlatabadi 2007). Increasing knowledge is akin to increasing environmental awareness, being conscious of the fragility and our role in the environment (Rashid et al. 2012). Numerous studies evaluated the relationship between an individual's knowledge of green practices and an individual's behavior. This research has shown contradictory effects in residential (Brounen, Kok et al. 2013, Brown and Gorgolewski 2014, Gardner and Stern 2008, Kang, Cho et al. 2012) and commercial buildings (Marans and Edelstein 2010). In some cases, increasing an individual's environmental awareness caused positive change in pro-environmental behavior. In other cases, there was no influence or a negative effect in pro-environmental behavior (e.g., Gyberg and Palm 2009).

Prior conditions, such as social norms and perceived needs, can also motivate an individual to change a behavior (Ajzen and Madden 1986). Norms can refer to an individual perceived social pressure to implement or not implement a certain behavior. This can relate to an individual's perception on how their willingness to do certain behaviors will be approved or disapproved by others around them in society (Abrahamse and Steg 2009). A factor in understanding an individual's behavior begins with an individual's perception and how those perceptions affect their habits, which can determine the likelihood of an individual exhibiting pro-environmental behaviors (Littleford, Ryley et al. 2014, Pierce, Schiano et al. 2010).

In addition, behavior is strongly influenced by an individual's confidence in their ability to change their behavior. This is referred to as perceived behavioral control (Ajzen and Madden 1986).

Perceived behavioral control can relate to occupants' perceived ease or difficulty of adopting a set of behaviors (Abrahamse and Steg 2009). Beliefs about opportunities, resources, and technology

may be viewed as an underlying behavioral control based on past experiences with behavior and second-hand information (Ajzen and Madden 1986). This type of belief can be related to how people perceive their workplace environment and perceived individual control over their environment. Research in perceived control has been conducted in relation to indoor environmental quality, perceptions of productivity, and satisfaction in commercial and residential buildings resulting from an individual's environment (Attari et al. 2010, Kato, Too et al. 2009, Kim, Oh et al. 2013, Menadue, Soebarto et al. 2013, Pierce, Schiano et al. 2010, Schwartz, Fischhoff et al. 2013).

Despite the substantial amount of research examining how the theory of planned behavior impacts individual behavior, there is a lack of research comparing environmental awareness, perceptions, and perceived ease or difficulty of behaviors in influencing occupant behavior in different building cases. Beyond occupant behavior, several studies have compared LEED vs non-LEED certified buildings in analyzing energy consumption (Menassa, Mangasarian et al. 2011, Azar and Menassa 2014) and energy simulations (Azar and Menassa 2012). The few occupant behavior LEED vs non-LEED certified building comparative studies have mostly focused on Indoor Environmental Quality (IEQ) and perceived productivity and satisfaction (Abbaszadeh et al. 2006, Altomonte and Schiavon 2013) chiefly in residential buildings (Attari et al. 2010). One recent study explored a virtual environment, in which a simulated scenario was used to examine the effect of LEED branding on pro-environmental behavior (Khashe et al. 2015). This study found that the LEED branding group chose natural light and recycling more than control group, suggesting that increasing environmental knowledge might increase pro-environmental awareness. Nevertheless, whether and how actual occupants in a real-world building exhibit pro-environmental behaviors in

different building cases is lacking in the literature. To fill this gap in knowledge, **the objective of this study was to understand the relationship between building cases (i.e., LEED vs. non-LEED, green featured vs. not green featured buildings) and occupants' proclivity towards pro-environmental behavior, as well as to ascertain if building cases influence psychological strategies that impact an individual to exhibit pro-environmental behavior.**

To address the objective, it was necessary to define the building cases for this study based on different attributes. For this study, the three building cases were defined as:

- *Traditional Building:* Building that does not have any third-party rating system certification or very few attributes that enhances the building's environmental friendliness by saving energy, reducing waste of environmental resources, and/or enhances the quality of life of occupants.
- *Green Features Building:* Building that has attributes that enhances a buildings' environmental responsibility by saving energy, reducing waste of environmental resources, and/or enhances the quality of life of occupants. Even though the building has environmentally responsible attributes, the building is not certified by a third-party rating system.
- *LEED Certified Building:* A building that used LEED as a third-party rating system metric to achieve sustainability goals. Sustainability choices are chosen based on cases and specific credits within LEED and must achieve a certification status of either certified, silver, gold, or platinum.

There were two main research questions which relate to the objective and building case definitions which are:

1. Do environmental awareness, perceptions, and perceived ease or difficulty of pro-environmental behavior influence the frequency of occupants exhibiting pro-environmental behavior across different building cases?

2.What is the effect of green features and LEED certification on occupant environmental awareness, perceptions, perceived ease or difficulty of behaviors, and, more generally, on pro-environmental behavior?

The research questions assess whether the physical environment influences environmental awareness, perceptions, perceived ease or difficulty of behaviors, and pro-environmental behavior across the three different building cases.

3. Methodology

3.1 Hypothesis Development

To begin to answer the research questions, four hypotheses were formulated relating to the factors of environmental awareness, perceptions and perceived ease or difficulty of behaviors. Hypothesis 1 addresses the overall research question of how the ensuing hypotheses (H2 – H4) affect pro-environmental behavior.

H1: Positive environmental awareness, perceptions, and perceived ease or difficulty of behaviors will influence the frequency of occupants exhibiting pro-environmental behavior

Hypothesis 2 addresses the concept that occupants in the LEED certified building case should have a higher perceived behavioral control than occupants in the green featured building case and the traditional building case. With the pro-environmental design of LEED buildings, one would expect implementing pro-environmental behavior to be perceived as easier in the LEED building case than in the green featured or the traditional building case.

H2: Occupants in the LEED certified building will perceive implementing pro-environmental behavior as easier than occupants in the green featured building and the traditional building

Hypothesis 3 addresses the expectation that the occupants in the LEED certified building case should have a greater awareness of pro-environmental behavior than in the green featured and traditional building case, since there is more branding involved in green certification (Khashe et al. 2015).

H3: Occupants in the LEED certified building will have a greater environmental awareness than occupants in the green featured building and the traditional building

Because individual opinion ranges from person to person, Hypothesis 4 supposes that perceptions range from building to building (Owens and Driffill 2008).

H4: There will be no significant difference between occupant's environmental perceptions across all building cases

3.2. ICTAS (Institute of Critical Technology and Applied Science) Facilities

To test these hypotheses, three ICTAS buildings on Virginia Tech's campus were identified as test cases for data collection. These three buildings were ICTAS A: Corporate Research Center (CRC), ICTAS I: Kelly Hall, and ICTAS II. All three buildings have a mix of occupants, including; students, faculty, and facility and administrative staff, as well as a mix of laboratories, office spaces, and conference rooms. In total, there are 883 people that work in these three ICTAS facilities: ICTAS A (CRC) has 304 occupants, ICTAS I (Kelly Hall) has 495 occupants, and ICTAS II has 263 occupants. This sums to a number greater than 883 as 179 people have access to more than one building. In regards to how occupants are assigned to each facility, occupants cannot self-assign themselves to a specific ICTAS facility. Space is assigned based on research, specifically the level of research each faculty member generates as well as the grouping of similar researchers to facilitate collaborations. More detail about each of the ICTAS facilities is provided

in Appendix B: Section 1 and 2 including what types of occupants answered the survey, what types of distinct spaces are in the ICTAS facilities, and the overall energy consumption of the ICTAS facilities.

To classify each ICTAS facility into cases (traditional, green features, and LEED), green attributes were identified and compared across all three building types. After further evaluation, ICTAS CRC was identified as fitting in the traditional building case by having no LEED certification and very few attributes enhancing the building's environmental responsibility. ICTAS I was identified in the green features building case by having many more green features than ICTAS CRC, but still not having LEED certification. ICTAS II was identified as being in the LEED certified case because the building has green features and LEED Gold certification. A summary of the building categorization is provided below in Table 1. More detail about the classification and categorization of the ICTAS facilities is provided in Appendix B: Section 4 and 5.

Table 1: ICTAS Facility Building Categorization

	LEED Rating	Green Features	Case
ICTAS CRC	Not Certified	Very Few (2 of 11)	Traditional Building
ICTAS I	Not Certified	Many (6 of 11)	Green Features Building
ICTAS II	LEED Gold Certified	Most (10 of 11)	LEED Certified Building

3.3. ICTAS Building Energy Survey

A survey was used to gather responses from occupants in the ICTAS facilities. The survey was based, in part, on the survey employed in the article *Public Perceptions of Energy Consumption and Savings* (Attari et al. 2010). In addition, the survey was split into seven sections to evaluate the four hypotheses. Table 2 summarizes the different survey sections, which hypothesis was being

addressed, and the information being gathered by that question. More detail about how the ICTAS Building Energy Survey differs from the survey developed in Attari et al. (2010) can be seen in Appendix C.

Table 2: Summary of ICTAS Building Energy Survey Sections

Section	Section Name	Hypothesis Addressed	Information being Gathered
1	Demographics	All	What types of occupants are in the ICTAS facilities
2	Baseline Environmental Awareness	1 and 3	Overall environmental awareness of occupants
3	Perceptions of Environment	1 and 4	Climate change perceptions and environmental perceptions about buildings
4	Ease or Difficulty of Pro-Environmental Behavior	1 and 2	How occupants perceive implementing pro-environmental behavior as easy or difficult
5	Pro-Environmental Behaviors	1	Frequency the occupants exhibit pro-environmental behavior and reasons why occupants do not exhibit pro-environmental behavior
6	Motivation	None	Incentives that motivate occupants to exhibit more pro-environmental behavior
7	Conclusion	All	Free response section about overall energy conservation within ICTAS facilities

The survey was tested on a similar population as the ICTAS facility to make sure the questions of the survey were clear and to make sure respondents were answering the questions with congruence. In addition, the survey was reviewed by two high-level facility managers of ICTAS to make sure the questions accurately characterized the pro-environmental behaviors that can be exhibited in the ICTAS facilities and that the questions made sense for the context of the occupants and buildings. When the survey was completed, congruence was checked again between the types of occupants that answered the survey and their responses to check for response biases.

The online survey questionnaire was distributed by email, via the facility manager to the occupants of the three buildings to assess their environmental awareness, perceptions, perceived ease or difficulty of pro-environmental behaviors, and frequency of pro-environmental behavior of occupants. Out of 883 potential survey responses, 106 data responses were collected. From the 106 data responses, a total of 74 were completely filled out surveys that were used for the data analysis. When the survey achieved less than a 10% response rate, appropriate follow up measures were taken including 2 follow up emails to ICTAS occupants as a reminder to take the survey, notes to do the survey in the ICTAS facility newsletter, and leaving the survey open for a longer period time to allow for more responses.

3.3. Data Analysis

Pro-environmental behaviors for the study were selected based on interactions with ICTAS facility management, as previously noted. These behaviors were chosen because they could potentially lower the energy consumption of the ICTAS facilities and they could be done in all three ICTAS facilities. These pro-environmental behaviors were:

1. Turning off overhead lights
2. Closing fume hoods in the lab
3. Turning off computers in my workspace
4. Turning off desk lamps
5. Turning off lab equipment that does not need to be on
6. Unplugging electronics out of electrical sockets
7. Recycling

Once the pro-environmental behaviors were chosen, an evaluation was completed on whether the process of implementing the seven pro-environmental behaviors was the same in all three buildings. This was evaluated by using the free response question on the survey to see the occupant's perspective on which pro-environmental behaviors were harder to implement based on ICTAS facility. After further evaluation, there were two behaviors (turning off overhead lights and

recycling) where the process of doing these two behaviors was substantially different across the three buildings. This is described in more detail in Appendix B: Section 3. As a result, these two behaviors were treated as uncontrolled variables in the study. To control for this, those variables were removed and a total of five pro-environmental behaviors were used for analysis.

For coding the responses, each participant received a score base on a summation of points in relation to the following sections: general environmental awareness, perceptions, ease and difficulty of behaviors, and pro-environmental behavior**.** Scores were calculated based on general correctness and positive behavior. For general environmental awareness, possible responses were most, second most, third most, and least. Answering the question in the correct order resulted in a higher score for two questions. For perceptions, a Likert scale was used and positive pro-environmental perceptions of the environment were used to determine a score. For the nine questions, a higher score was achieved when the answer chosen was "agree". For ease or difficulty of pro-environmental behavior, a Likert scale was used and "easy" was considered positive for the seven behaviors. A higher score was achieved if "easy" was chosen. For pro-environmental behavior, if the participant did the behavior 4 out of 5 days a week, the score would be considered positive for the same 7 behaviors and resulted in a higher score.

Once the responses were coded, two tests were completed to test the hypotheses of the study. The first test was a one-way ANOVA test to understand how environmental awareness, perceptions and perceived ease or difficulty of pro-environmental behaviors influenced frequency of exhibiting pro-environmental behavior in each building case. To address hypothesis 1, a one-way ANOVA test was chosen since the data consisted of continuous response variables with categorical predictor variables. The second test was a two-tailed t-test to compare the means of environmental awareness (H3), perceptions (H4) and perceived ease or difficulty of behaviors (H2) and how these factors

varied between the different building cases. Pro-environmental behavior was also tested to see how occupant behavior changed based on building case.

Because the research involves human subjects and behavior, significant values were designated by a p-value of 0.05 and marginally significant by a p-value of 0.10.

4. Results

For Hypothesis 1, ease or difficulty of pro-environmental behaviors and environmental awareness was significant and marginally significant in the LEED certified and green featured building case. There was no significant finding for the traditional building case in ease or difficulty of pro-environmental behavior, environmental awareness, or perceptions. The significant p-values for the ANOVA test are provided in Table 3.

Table 3: P-Values for Hypothesis 1 from One-Way ANOVA Test

Hypothesis 1	**Ease or Difficult of Behaviors**	**Environmental Awareness**	**Perceptions**
Traditional Building Case	0.8743	0.4706	0.8949
Green Features Building Case	0.0001586***	0.01613**	0.9587
LEED Building Case	0.05264*	0.02981**	0.2464

***p<0.001, **p<0.05, *p<0.10

For the T-test in addressing Hypothesis 1, pro-environmental behavior was distinct and marginally significant comparing the green featured building case with the traditional building case and significant when comparing the LEED certified building with the traditional building. In Hypothesis 2, ease or difficulty of behaviors was statistically distinct in both the green featured and the LEED certified building in comparison to the traditional building. For Hypothesis 3, there

was no significant change in the values for environmental awareness across all building cases. For Hypothesis 4, the LEED certified building compared to the traditional building was marginally distinct with a significant value of 0.0815. A summary of the significant values of the two-tailed T-tests is provided in Table 4.

Table 4: Two-Tailed T-test of Hypothesis 1,2,3, and 4

	P-Value			
	Hypothesis 1: Pro-Environmental Behavior	**Hypothesis 2: Ease or Difficulty of Behaviors**	**Hypothesis 3: Environmental Awareness**	**Hypothesis 4: Perceptions**
Comparing Green Features with Control	0.0741*	0.0066**	0.9448	0.3091
Comparing LEED Gold with Control	0.0049**	0.0141**	0.5325	0.0815*
Comparing LEED Gold with Green Features	0.1428	0.9392	0.5263	0.3309

***p<0.001, **p<0.05, *p<0.10

5. Discussion

The main goal of this study was to explore the effects of different building cases on pro-environmental behavior related to the factors environmental awareness, perceptions, and perceived ease or difficulty of adopting pro-environmental behavior. Researchers Lopes et al. (2012) found that the adoption of pro-environmental behavior requires more than just positive environmental awareness and perceptions of the environment. Based on the results for Hypothesis 1, ease or difficulty of behaviors and environmental awareness were significant factors in influencing pro-environmental behavior in the LEED and green featured building. This contributes a new perspective, similar to the idea of Lopes et al. (2012), that occupants may need an environment

where behaviors are perceived to be easier to complete coupled with an environmental awareness of how their actions affect their surroundings to exhibit pro-environmental behavior.

Researchers Khase et al. (2015) found that in their virtual environment, occupants in the LEED branding group exhibit more pro-environmental behavior, which in their study was recycling and natural light, than occupants in the control (not LEED branded) group. The results in this study suggest that pro-environmental behavior does differ based on building case. The factor of pro-environmental behavior is significant based in the LEED certified and green featured building compared to the traditional building. This result contributes a new perspective, similarly found in Khase et al. (2015), that occupants in the LEED certified and green featured building exhibit more pro-environmental behavior than occupants in the traditional building. The results of this study build upon the results by Khase et al. (2015), by studying the effects of LEED and green features on occupants doing pro-environmental behavior in real buildings as opposed to a hypothetical virtual building case.

The results would suggest that being in a LEED certified building appears to influence occupants to exhibit pro-environmental behavior. Also, there is evidence to suggest that being in a green featured building appears to also influence occupants to exhibit pro-environmental behavior as well. When comparing the green featured and LEED certified building, findings were statistically indistinct. Even with the green featured building only having 6 of the 11 green features (while the LEED certified building had 10 of the 11 features), the LEED certified building case and the green featured building case were statistically indistinct as seen in Table 4. This finding strengthens the reliability of the results by obtaining statistically significant values from a building with just 6 out of the 11 green features.

Researchers Abrahamse and Steg (2008) found that perceived behavioral control most strongly related to pro-environmental behavior. In response to Hypothesis 2, occupants in the LEED certified and green featured building perceived pro-environmental behavior as easier than occupants in the traditional building. This finding contributes a new idea to the literature suggesting that how occupants perceive behavior as easy or difficult can change based on building case. In this study, those cases were occupants in a LEED building and a green featured building.

Steg (2008) found that even though many gains have been made to educate occupants about the environment, given the complexity of commercial buildings, confusion is still likely. A similar finding was found in response to Hypothesis 3 when there was not any significant change between the mean distributions of environmental awareness between the three buildings. Since the ICTAS buildings are multi-use buildings which include laboratories and offices spaces, there are complex systems that may not be present in a typical office building. As a result, occupants may have an incorrect view of what actually uses the most energy (Steg 2008). This finding contributes to the idea posed by Steg (2008) where environmental awareness is still a complex theme that needs further research.

Researchers Owens and Driffil (2008) found that given the complexity of individual opinion, it is reasonable to expect that perceptions would also be different. In response to Hypothesis 4, occupants in the LEED certified building have more positive environmental perceptions than occupants in the green featured and traditional building. The results suggest a new idea that builds

upon Owens and Driffil (2008) and Khase et al. (2015) that the LEED branding that exists in ICTAS II may influence occupants to have more positive perceptions of the environment.

6. Limitations and Future Research

In regards to possible alternative explanations for the results, ICTAS I has more office and open space in comparison to the other ICTAS facilities. Since ICTAS I, in the green featured building case, has more office and open space, it could be easier to exhibit pro-environmental behavior in the green featured building case of ICTAS I than in ICTAS CRC, the traditional building case, which has more labs. More buildings within each building case of traditional, green featured, and LEED certified would have controlled for this and strengthened the results, which can be addressed in future research. In addition, a building that used LEED as a design guide, but did not apply for certification, would have been a good case to study in comparison to the LEED certified building case had it existed. Future researchers working in this area may wish to include such a building in their study design.

In addition, when evaluating the results for other alternatives for the study outcomes, it was noted that ICTAS I has the whole half of the third floor dedicated to office spaces of facility management personnel of ICTAS facilities. Leaders of ICTAS facility management have offices in one or more buildings of ICTAS, but all major staff of ICTAS facilities have their base office in ICTAS I. This location setup of facility management is different than any other setup of management in the other ICTAS facilities. In addition, the facility manager of the ICTAS facilities was the individual who sent out the survey by email to ICTAS occupants. This visible presence of management in ICTAS I could have influenced the respondents of the survey who work in ICTAS I to answer in ways that are more pro-environmentally responsible than without their presence. However, ICTAS staff did

not respond in large numbers to the ICTAS Building Energy survey, so the effect of ICTAS facility management on survey respondents of ICTAS I would have been small.

For future work, there is room to study how motivation plays a role in occupants exhibiting pro-environmental behavior. In addition, this study aimed to explore the psychological strategies that affect occupant behavior including environmental awareness, perceptions, and perceived ease or difficulty of adopting pro-environmental behavior. More research is necessary to explore how structural strategies affect occupant behavior. Green features and third party certification could be considered a structural strategy since the building shapes and constrains people's choices to adopt pro-environmental behavior. The specific physical constraints of being in different building cases can be explored to see if the context of being in a LEED building impacts an occupant's behavior.

7. Conclusion and Implications

Building occupants have substantial influence in reducing the energy consumption of buildings. For green buildings to reduce energy consumption, it is crucial that occupants are adopting and exhibiting pro-environmental behavior. In conclusion, this study explored the effects of different building cases—traditional, green featured, and LEED certified—on pro-environmental behavior. In addition, the study also explored how the factors of environmental awareness, perceptions, and perceived ease or difficulty of behaviors were effected based on building case.

The results suggest that being in a LEED certified building influences occupants to exhibit pro-environmental behavior. Also, being in a building with green features also influences occupants to exhibit pro-environmental behavior. There are many reasons that owners and designers would want to choose LEED as a green rating system, but these results are valuable for those owners that want to encourage occupants within their building to exhibit pro-environmental behavior.

ENGINEERING SIGNIFICANCE

It is important that individuals adopt pro-environmental behaviors to achieve long-term sustainability goals. The study prepared for this thesis has helped understand the importance of occupant behavior and its association to different building cases. This study also explored the effects of different building cases—traditional, green featured, and LEED certified—on pro-environmental behavior. The results suggest that being in a LEED certified building appears to influence occupants to exhibit pro-environmental behavior. Also, being in a building that has green features also appears to influence occupants to exhibit pro-environmental behavior. When comparing the green featured and LEED certified building, findings were statistically indistinct. These results are valuable for those owners that want to encourage occupants within their building to exhibit pro-environmental behavior.

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APPENDIX A- ICTAS Building Energy Survey

ICTAS Building Energy Survey

Informed Consent Form: ICTAS Building Energy Survey

Introduction
This study attempts to collect information about building energy performance with ICTAS facilities.

Procedures

The questionnaire will take approximately 20 minutes to complete. Questions are designed to understand your perspective on energy related issues within the ICTAS facility in which you most frequently work. This questionnaire will be conducted with an online Qualtrics-created survey.

Risks/Discomforts
Risks are minimal for involvement in this study.

Benefits There are no direct benefits for participants. However, it is hoped that through your participation, researchers will learn more about energy performance in buildings. The results of this study may be published.

Confidentiality
All data obtained from participants will be kept confidential. All questionnaires will be concealed, and no one other than the primary investigator and research assistant listed below will have access to them. The data collected will be stored in the HIPPA-compliant, Qualtrics-secure database until it has been deleted by the primary investigator.

Compensation
There is no direct compensation for participating in this study.

Participation

Participation in this research study is completely voluntary. You have the right to withdraw at any time. If you desire to withdraw, please close your internet browser.

Questions about the Research

If you have questions regarding this study, you may contact (John Taylor, Principal Investigator) at jet@vt.edu, or (Adrienne Hill, Research Assistant) at (804) 301-5525, amz326@vt.edu.

Questions about your Rights as Research Participants

If you have questions you do not feel comfortable asking the researcher, you may contact (John Taylor), jet@vt.edu. You can also contact the director of Virginia Tech's Institutional Review Board, David Moore (540) 2314991; moored@vt.edu

Q2 I have read and understood the above consent form and desire of my own free will to participate in this study.

- ❍ Yes
- ❍ No

If No Is Selected, Then Skip To End of Survey

Q3 What is your current age?

- ❍ Less than 18
- ❍ 19 to 24
- ❍ 25 to 34
- ❍ 35 to 44
- ❍ 45 to 54
- ❍ 55 to 64
- ❍ 65 or over

If Less than 18 Is Selected, Then Skip To End of Survey. If 65 or over Is Selected, Then Skip To End of Survey

Q4 In which facility do you MOSTLY work?

- ❍ ICTAS @CRC
- ❍ ICTAS I: Kelly Hall
- ❍ ICTAS II

Answer If In which facility do you MOSTLY work in? ICTAS II Is Selected

Q5 Have you been on the ICTAS II Building Tour?

- ❍ Yes
- ❍ No
- ❍ I do not know

Q6 How many hours per week do you work in the above selected facility? (In hours)

Q7 How long have you worked in this facility (In years)?

Q8 On which floor do you work?

- ❍ First Floor
- ❍ Second Floor
- ❍ Third Floor ❍ Fourth Floor

Q9 Have you worked in other facilities on campus within the last 5 years?

❍ Yes

❍ No

Answer If Have you worked in other facilities on campus within the last 5 years Yes Is Selected

Q10 If yes, please list the other facilities where you have worked.

Q11 In your opinion, which of the following modes of transportation uses the most energy per mile to transport one ton of goods? Please drag the mode that uses the most energy, second most, the third most, and the least energy to the appropriate box.

	Most energy	Second Most Energy	Third Most Energy	Least Energy
Ship	❍	❍	❍	❍
Train	❍	❍	❍	❍
Airplane	❍	❍	❍	❍
Truck	❍	❍	❍	❍

Q12 In your opinion, which of the following processes uses the most energy, second most, third most, and the least energy? Please drag the process to the appropriate box.

	Most Energy	Second Most Energy	Third Most Energy	Least Energy
Making a can out of aluminum that has never been used before	❍	❍	❍	❍
Making a can out of recycled aluminum	❍	❍	❍	❍
Making a glass bottle out of glass that has never been used before	❍	❍	❍	❍
Making a glass bottle out of recycled glass	❍	❍	❍	❍

Q13 Please drag the activity that CONSERVES the most energy, the second most energy, the third most energy, and the one that conserves the least energy to the appropriate box.

	Conserves Most Energy	Conserves Second Most Energy	Conserves Third Most Energy	Conserves Least Energy
Turning off lights after leaving a space	❍	❍	❍	❍
Closing fume hoods	❍	❍	❍	❍
Turning off computers	❍	❍	❍	❍
Unplugging electronics from outlets	❍	❍	❍	❍

Q14 Please check the response that most accurately reflects how you feel about each statement. Please indicate whether each item is true or false in the ICTAS facility you most frequently work.

	True	False	I Do Not Know	Not Applicable
The ICTAS building I work in most frequently is LEED Certified	❍	❍	❍	❍
There is adequate light in my building	❍	❍	❍	❍
There are opportunities to recycle in my building	❍	❍	❍	❍
There are occupancy sensors where I work	❍	❍	❍	❍
I can control how much light comes into my workspace	❍	❍	❍	❍
I use the bicycle racks provided by my building	❍	❍	❍	❍

The temperature is comfortable in my building	❍	❍	❍	❍

Q15 Please indicate how strongly you agree or disagree with each of the following statements.

	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree
Humans need to change their lifestyles to address global warming and climate change	❍	❍	❍	❍	❍
Humans are responsible for global warming and climate change	❍	❍	❍	❍	❍
I believe my actions contribute to global warming and climate change	❍	❍	❍	❍	❍
I believe that I need to change my lifestyle to address global warming and climate change	❍	❍	❍	❍	❍
I believe that my behavior has an effect on how much energy a building consumes	❍	❍	❍	❍	❍

I think it is possible to consume more energy in a LEED building than in a building that is not LEED certified	❍	❍	❍	❍	❍
I do not think it is okay to consume more energy in a LEED building than in a building that is not LEED Certified	❍	❍	❍	❍	❍
There are actions that I could take to reduce energy consumption in my building	❍	❍	❍	❍	❍
I am comfortable in the building in which I work most frequently	❍	❍	❍	❍	❍

Q16 Reflect on how easy or difficult the following activities are within your workspace in the ICTAS facility you most frequently work in.

	Easy	Somewhat Easy	Neither Easy nor Difficult	Somewhat Difficult	Difficult	Not Applicable
Turning off overhead lights in my workspace	❍	❍	❍	❍	❍	❍
Closing fume hoods in my lab	❍	❍	❍	❍	❍	❍
Turning off computers in my workspace	❍	❍	❍	❍	❍	❍

Turning off desk lamps in my workspace	❍	❍	❍	❍	❍	❍
Turning off lab equipment that does not need to be turned on	❍	❍	❍	❍	❍	❍
Unplugging electronics out of the electrical socket	❍	❍	❍	❍	❍	❍
Recycling	❍	❍	❍	❍	❍	❍

Q17 In the ICTAS facility you most frequently work in, if you complete the following activities 4 out of 5 days of the week, select the response "I already do it". If you complete the activity 3 out of 5 days of the week or fewer, select one of the reasons why.

	I Already Do It (4 out of 5 days a week)	I Cannot Do it Because of Research Restrictions	Too Busy	I Forget	I Do Not Care	Not My Responsibility	Too Difficult	Other	Not Applicable
Turning off overhead lights in my workspace	❍	❍	❍	❍	❍	❍	❍	❍	❍
Closing fume hoods in my lab	❍	❍	❍	❍	❍	❍	❍	❍	❍
Turning off computers in my workspace	❍	❍	❍	❍	❍	❍	❍	❍	❍
Turning off desk lamps in my workspace	❍	❍	❍	❍	❍	❍	❍	❍	❍

Turning off lab equipment that does not need to be on	❍	❍	❍	❍	❍	❍	❍	❍	❍
Unplugging electronics out of the electrical socket	❍	❍	❍	❍	❍	❍	❍	❍	❍
Recycling	❍	❍	❍	❍	❍	❍	❍	❍	❍

Q18 If you selected "other" for any behavior, please explain.

Q19 I would be more willing to do the previous actions if...

	Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Disagree
Someone paid me	❍	❍	❍	❍	❍
I knew I was helping the environment	❍	❍	❍	❍	❍
All my peers did those behaviors	❍	❍	❍	❍	❍
It was a competition with my peers	❍	❍	❍	❍	❍
Someone reminded me	❍	❍	❍	❍	❍
I was given recognition for my efforts	❍	❍	❍	❍	❍
I had more information about which behaviors saved the most energy	❍	❍	❍	❍	❍

Q20 Do you have any additional thoughts about energy use or energy conservation you would like to share?

Q21 Do you have any additional thoughts about how occupants can help conserve energy or create a more sustainable future in the ICTAS facility you most frequently work that you would like to share?

Q22 What is your gender identity?

Q23 What is your job function?

- ❍ Full-time faculty
- ❍ Part-time faculty
- ❍ Full-time staff
- ❍ Part-time staff
- ❍ Student
- ❍ Volunteer
- ❍ Other

Answer If What is your job function? Other Is Selected

Q24 If you selected "other", please describe your job function.

Q25 What is the highest level of education that you have completed?

- ❍ Some schooling, no diploma
- ❍ High School Diploma/GED
- ❍ Technical School
- ❍ Some College
- ❍ College Graduate
- ❍ Some Graduate School
- ❍ Graduate Degree

Q26 What is your political inclination?

- ❍ Very Liberal
- ❍ Liberal
- ❍ Slightly Liberal

- ❍ Moderate
- ❍ Slightly Conservative
- ❍ Conservative
- ❍ Very Conservative ❍ Prefer not to answer

Q27 Do you require any special accommodations (as it relates to facilities) to complete your assigned tasks?

- ❍ Yes
- ❍ No

Answer If Do you require any special accommodations (as it relates to facilities) to complete your assigned... Yes, Is Selected

Q28 If yes, please describe.

APPENDIX B-Building Details

The purpose of this appendix is to provide detail about the three ICTAS facilities in which the surveyed occupants worked. Appendix B is split up into the following sections:

Section 1: General Building Information of Each ICTAS Facility Section 2: Breakdown of Building Occupants and Spaces

This section will go into detail about the different types of individuals in each building as well as the types of spaces that are in each building.

Section 3: Difficulty of Pro-Environmental Behavior in relation to Each ICTAS Facility

This section will go into detail about how each of the pro-environmental behaviors discussed in the ICTAS Building Energy Survey relates to each ICTAS building. How each behavior is implemented in each building will be assessed based on the comments provided by respondents of the survey.

Section 4: Building Attributes

This section will go into detail about the different building attributes that exist in each of the three ICTAS facilities. The focus is on attributes that are present in one ICTAS facility, but not others.

Section 5: Building Categorization

This section will go into the process of categorizing each ICTAS facility into the three building cases discussed in the thesis: Traditional, Green Features, and LEED.

Section 1: General Building Information

ICTAS CRC

ICTAS CRC: Corporate Research Center, is a two-story building with 32,000 sq. ft. and 304 occupants. The building hosts several research areas including nano CT, X-ray imaging, bioAFM, nanobiomaterials, sensors and structural health monitoring, SuperDARN radar development. These areas are very sensitive to vibrations due to the amount of highly sensitive microscopes that are on the first floor. The building does not have BSL2 (Biological Safety Level 2) labs, which are high energy use labs due to the ventilation required to isolate different biological contaminants. The labs are composed of:

1st Floor

- Bio AFM (Roman) – Lab 1019
- Nanophotonics (Xu) – Lab 1020

- Nanoscale Characterization and Fabrication Laboratory, NCFL (Reynolds/Hunter) – First Floor Labs 1004 – 1016 (12 labs)

2nd Floor

- Disaster Risk Management (Martin) – Lab 2003
- EXTREME Lab (Case/Lattimer) – Lab 2007 and Lab 2008
- Sensors and Structural Health Monitoring (Kapania) – Lab 2004
- Turbo and Propulsion Lab (O'Brien) – Lab 2002

ICTAS I

ICTAS I: Kelly Hall, is a four-story building with 99,411 sq. ft. and 495 occupants. The building has several research areas including delivery of nanomedicine, tissue engineering, cognitive radio, environmental nanoscience and technology, sustainable energy, biobased materials, and advanced multifunctional materials. This building is also home to the School of Biomedical Engineering and Sciences (SBES). The building also has 3-4 BSL2 (Biological Safety Level 2) labs.

1st Floor

- Bio-Engineered Devices, Systems Biology of Engineered Tissues, and Bio-Imaging (Davalos/Rajagopalan/Cao) - Lab 130
- Center for Injury Bio-mechanics (Duma/Hardy/Gabler) - Lab 120
- Cognitive Radio Control Group (Reed) - Lab 123
- Targeted Delivery of Nanomedicine (Sriranganathan/Riffle) - Lab 140'

2nd Floor

- Bio-Based Materials (Roman/Whittington) - Lab 220
- Targeted Delivery of Nanomedicine Group (Edgar) - Lab 240
- VT Center for Sustainable Nanotechnology (VTSuN) (Hochella) - Lab 230

3rd floor

- Biomedical Optical Devices (C. Rylander) - Lab 330A
- Cell and Tissue Engineering (Davalos/Rajagopalan/Verbridge) - Lab 330
- Nanotherapeutics (N. Rylander/Lee/Goldstein) - Lab 340
- School of Biomedical Engineering and Mechanics

4th floor

- Advanced Multi-functional Materials (Joseph/Campbell/Mahajan/Priya/Nain) - Lab 430
- Center for Injury Biomechanics (Duma/Hardy/Gabler) - Lab 440 □ Sustainable Energy (Ellis, Dillard, Moore, Case) - Lab 420

ICTAS II

ICTAS II is a three-story building with 42,190 sq. ft. with 263 people. The building is certified as LEED Gold and is Virginia Tech's first LEED Gold certified building. Through LEED certification, the building achieved an energy cost savings of 23.8% and energy use savings 15.4% over the baseline building model. This was accomplished through a water-cooled chiller, central steam supply, variable frequency fan drives, high performance window glass, and efficient exterior lighting.

The building houses several research areas including applied environmental biochemistry, fluvial processes, a global laboratory for bioinspired science and technology, nanobiology, nonlinear imaging and spectroscopy, organic nanostructures, pathogen ecology, pipeline corrosion, sustainable water, and a humanoid hospital. The building hosts 1 BSL2 (Biological Safety Level 2) lab.

1st Floor

- Ecohydraulics and Pipeline Microbial Ecology (Edwards) – Labs 165, 187
- Nanostructures and Nanosensors (Robinson, Heflin) – Labs 151, 155, 157, 163, 175

2nd Floor

- ICTAS Humanoid Hospital, IcHHo (Priya) – Lab 265
- Nano-Biology Materials (Long) – Labs 275, 285

3rd floor

- Applied Environmental Biochemistry Laboratory (Edwards/Pruden-Bagchi) – Lab 375
- Global Laboratory on Bio-inspired Engineering Science, GLOBES (Muëller/Socha)– Lab 355
- Pathogen Ecology Laboratory (Pruden-Bagchi) – Lab 385
- Sustainable Water (Edwards) – Lab 365
- Sustainable Water Infrastructure Management (Sinha) – Lab 351

Section 2: Breakdown of Building Spaces

Table 5 was created to provide more detail on the demographics of the occupants who responded to the ICTAS Building Energy Survey, segregated by ICTAS facility.

Table 5: Demographics of ICTAS Building Energy Survey

	Student	Part-time Faculty	Faculty	Staff	Did not Answer	Total
ICTAS CRC	3	0	12	4	2	21
ICTAS I	13	1	17	5	4	40
ICTAS II	14	0	3	2	2	21

Table 6 was created to provide more detail of the types of building spaces that exist in each ICTAS facility. The numbers are estimates based on visual inspection and website provided lab details. In comparing the building spaces, there are more office and open spaces in ICTAS I than in the other two ICTAS facilities.

Table 6: Break-down of Building Spaces in ICTAS Facility (# of Distinct Spaces)

	Labs	Conference Rooms	Open Space/Break Rooms	Offices	Cubicle Farms	Seminar Rooms
ICTAS CRC	19	6	3	16	2	1
ICTAS I	13	8	14	42	1	1
ICTAS II	15	3	4	16	3	0

Table 7 compares the energy consumption of the ICTAS facilities. There was no data collected for ICTAS CRC, but ICTAS I and ICTAS II details are provided. ICTAS I consumes less energy by kwh.sq. ft and kwh/person than ICTAS II. This could be because, as seen in Table 6, there are more office and open spaces in ICTAS I and more labs in ICTAS II.

Table 7: Energy Consumption of ICTAS Facilities

Building	Average kwh (monthly)	kwh/sq. ft.	kwh/person
ICTAS I	212440	2.13	429
ICTAS II	133680	3.17	508

In comparison to the ICTAS facilities, the average monthly kwh/sq. ft. is 1.09 for the buildings on Virginia Tech's campus. However, the average is a mix of academic buildings, dormitories, and dining halls. The monthly energy report from Virginia Tech's Office of Sustainability was used to calculate this value.

Section 3: Pro-Environmental Behavior in relation to ICTAS Facilities

It was necessary to evaluate whether the process of doing the seven pro-environmental behaviors was the same in all three buildings. After detailed evaluation and on-site inspection, there were two behaviors (turning off overhead lights and recycling) where the process of doing these two behaviors was different for all three buildings. As a result, those uncontrolled variables were removed from the analysis. The evaluation is provided in the following sections.

Behavior 1: Turning off overhead lights in my workspace

In ICTAS CRC and ICTAS I, not doing the behavior of turning off overhead lights is due to others working around them in the same workspace. In ICTAS II, the main reason for not turning off the

overhead lights is because the lights are controlled by occupancy sensors. Based on the comments, occupants in ICTAS II have very little control over the overhead lights in their spaces. This lack of control makes the process of turning off overhead lights harder in ICTAS II to implement than in ICTAS I and ICTAS CRC. Specific comments from occupants in each ICTAS facility illustrating this difference are provided below:

ICTAS CRC

- "I work in the main office and am not the last one out"

ICTAS I

- "Most of the labs have lights on in the hallway of Kelly Hall even in the wee hours of the nights."
- "The overhead lights in my workspace are the overhead lights for other people, sometimes there are still people here when I leave for the day."
- "I would keep overhead lights off and just use a desk lights and natural light, but other coworkers are not in favor of this practice"
- "Also, most people seem to leave lights off but other lights in the building aren't like that."

ICTAS II

- "We have outdoor lights on the back of the building that remain on all the time.
- "Do not turn off overhead lights because I need them to work."
- "Some lights are always on and we can't do anything about it. Some lights on "occupancy" sensors turn off while I'm in my office and I have to wave my hand to get them to come on."
- "The overhead lights in my workspace have a sensor associated with them so I do not turn them off when I leave."
- "Occupancy sensors are good idea but in an office setting workspace they are SO ANNOYING TO HAVE TO KEEP MOVING EVERY 5 MINUTEs."

Behavior 2: Closing fume hoods in my lab

Based on the facility walk-through and talking with the facility manager, there seems to be no difference in the process of closing fume hoods in all the ICTAS facilities

Behavior 3: Turning off computers in my workspace

In all three buildings, almost no one turns off their computers for the following reasons:

- IT recommends computers stay on for updates
- Rebooting computer after being shut down takes too long
- Individuals work remotely or need to do lab activities that require the computer to stay on

As a result, the barriers of turning off computers are the same in all three ICTAS facilities. Specific comments based on each ICTAS facility are provided below:

ICTAS CRC

- "Time to reboot computers and re-open applications/documents is the primary reason I do not turn off/unplug my compute. That would cost me >10 min a day in productivity."
- "My computer can take almost 5 minutes to boot up from an off state, so I usually leave it in sleep mode."
- "Leave computer on b/c work from home and sign in to work computer."

ICTAS I

- "Computers must remain connected to the VT system for upgrading purposes."
- "I usually only turn off the computer over the weekend. Sometimes because I'm running code overnight, but usually I think that sleep mode is adequate when leaving during the week."
- "Takes too long to reboot in the morning."
- "For computer I turn it off on the weekends or if I take my laptop with me but that's the only time… it takes too long to reboot during the week if I turned it off every day.
- "I cannot unplug my computer-it must be on in order to receive updates."

ICTAS II

- "I am used to put the laptop in sleeping mode."
- "I leave my computer on so that I can connect remotely."
- "Instructed to leave them on in the sleep mode, not to turn them off at night and weekends."
- "I have been told by IT we should not turn off computers, they do updates after hours plus when I turn off my computer I have a hard time rebooting."

Behavior 4: Turning off desk lamps in my workspace

In regards to implementing the pro-environmental behavior of turning off desk lamps in an individual's workspace, the reasons for doing or not doing the behavior are similar across the ICTAS buildings. Comments on ICTAS I and CRC indicate it is relatively easy to turn them on or off. Implementing the behavior depends on whether the space is shared or on misunderstanding of what is required of occupants. However, the reasons do not make the behavior easier or harder to implement in each building. Below are comments supporting this:

ICTAS CRC

- "The lights in my workspace have to stay on because it is a shared space and the main office for our center. Lights out looks unwelcoming and like no one is there"

ICTAS I

- "Switching off lab lights in not required"
- "I turn off my lights off during the day on sunny days because there is enough natural lights that comes in"

Behavior 5: Turning off lab equipment that does not need to be on

In each ICTAS facility, there are individuals who need to keep lab equipment on for lab purposes. For some, turning off lab equipment would influence the calibration of machines or experiments. Specific comments focusing on this pro-environmental behavior is provided below:

ICTAS I

- "I turn off equipment that is not in use"
- "especially on the third floor, we work with living things and processes that are affected in various way (aka turning on and off the lights may cause an adverse reaction and if ICTAS starts turning lights off at 5pm automatically that would be a problem."

ICTAS II

• "Some lab equipment has to be left on or plugged to work properly, or it would take so long to boot it up it's too inefficient from a time standpoint to want to do it"

Behavior 6: Unplugging electronics out of electrical sockets

Barriers to implementing the pro-environmental behavior of unplugging electronics out of electrical sockets seem to be common across all the ICTAS facilities. This sentiment is voiced in the comments below:

ICTAS CRC

- "Additionally, electrical outlets are not easily accessible (behind the desk on floor). Therefore, it is difficult to plug/unplug devices."
- "If the electrical outlets were more conveniently placed instead of behind things and lower on the wall it might be feasible to unplug them."

ICTAS I

- "I did not think I had to unplug all my electronics, I use a surge protector so that protects my electronics."

- “It never occurred to me to unplug the docking station when I’m not in the office.”
- “Some little things like dust vacuums are left plugged in (but it’s those bulky plugs that heat up even when not in use).”
- “I unplug certain smaller things that can be unplugged, but most larger things cannot.”

Behavior 7: Recycling

The options to recycle vary among ICTAS facilities. Because the process of how occupants recycle varies among the three ICTAS facilities, this pro-environmental behavior was not factored into the analysis. How recycling stations vary among ICTAS facilities is discussed in occupant survey responses below:

ICTAS CRC:

ICTAS CRC recycling is as pictured below. It is comprised of a trash can with a green top for bottles and different bins for different types of paper. Also, there were comments by occupants of ICTAS CRC to have more recycling bins around the building.

Figure 1: Recycling Station in ICTAS CRC

ICTAS I:

The recycling station for ICTAS I is similar to ICTAS CRC except the recycling bins have a blue top instead of green. In addition, the bins for different types of paper are similar to the bins used in ICTAS CRC. Some comments from occupants in ICTAS I on recycling are provided below:

- “I save my recycling, but it is inconvenient to go into the breakroom to properly dispose of them. It would be more convenient is recycling containers were near each trash can.”
- “For recycling, I do try to recycle as much as I can, but I wouldn’t say its 4 out of 5 days.”

- "Having the housekeepers collect the recycling again would make people more willing to do it. Most people do not want to make the trip to the first floor just to empty their recycle bins all the time."
- "It would be easier to recycle if we had a recycle bin in our office."

Figure 2: Different Recycling Stations in ICTAS I

ICTAS II

ICTAS II has the most organized recycling system with the office spaces wooden bins indicating which recycling goes where. ICTAS II is the only facility that has recycling bins organized in this fashion. Therefore, this pro-environmental behavior process was deemed too distinct for inclusion in the analysis.

Figure 3: Typical Recycling Station in ICTAS II

Section 4: Building Attributes

This section goes into detail about the different attributes present in each ICTAS facility that are present in one facility, but not in others.

ICTAS CRC:

Compared to the other ICTAS facilities, by visual inspection, ICTAS CRC has less windows and accessibility to natural light than the other two facilities. This is because of the nature of the labs in ICTAS CRC. Most of the labs on the first floor of ICTAS CRC are laser/X-ray research or having to deal with large microscopes. Any outside light would greatly affect the research in these labs. However, light does come in on the stairwell, to try and heat the stairwell in the winter.

The second floor of ICTAS CRC and mostly office spaces. As a result, there are more windows in these offices. However, based on respondent comments in the survey, the light coming into ICTAS CRC creates office spaces that become too warm, so the blinds are used to block the natural sunlight This behavior was also visually seen during multiple visits to the ICTAS CRC facility, where the majority of potential light coming from the windows was blocked by blinds either to prevent glare or to block heat coming into the space.

(a) (b)

Figure 4(a and b): Hallway of ICTAS CRC

ICTAS I

ICTAS I, compared to the other 2 ICTAS facilities, has more dedicated open space. Open space is defined in Appendix D. These open spaces are different than just breakrooms and conference rooms. These spaces seem to take potentially unutilized spaces and make them useful for building occupants.

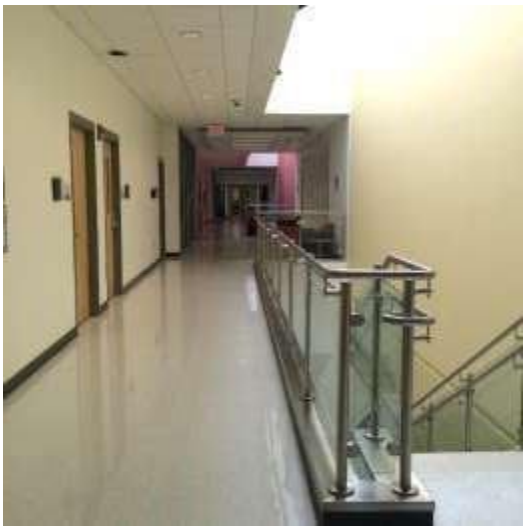
(c): Whiteboard and Chair next to Elevator on all floors of ICTAS I

(a): First Floor Lobby of ICTAS I

(b): Whiteboard and Chair on Multiple Floors of ICTAS I

Figure 5(a,b,c) : Variety of Open Spaces within ICTAS I In addition, the feature that exists in ICTAS I that is not present in the other ICTAS facilities is the use of skylights to bring in more natural lights into the building.

(a): Skylight in ICTAS I



(b): Effect of Skylight on Lower Level Hallways of ICTAS I

Figure 6: Skylight bringing in Natural Daylight in ICTAS I

ICTAS II:

The key attribute of ICTAS II that is different than the rest of the ICTAS facilities is the LEED Gold certification. Other green and sustainable features of the ICTAS II building include:

- Exterior shading from window overhangs and vertical fins.
- Green cleaning/housekeeping program.
- Open exterior space (29,040 sf) over twice the building footprint (13,980 sf).
- Use of low-emitting materials for adhesives and sealants, paints and coatings, carpet, composite woods and agrifiber products.
- Interior lighting (occupancy sensors) and comfort (CO2 monitors) controls.
- Alternative transportation including public access to bus routes, bicycle storage, and a change room.
- Storm water design including bioretention for quantity and quality control and porous pavers.
- Water efficient landscaping including native plants and no irrigation.
- Enhanced commissioning during startup and refrigerant management.
- Construction waste management with over 80% diverted to recycling/reuse.
- Materials recycled content over 10%, regional materials over 10%, and use of certified wood

Evidence of the steps taken for LEED certification is provided at various locations throughout the building. As an individual walks in the building, there is LEED branding in the form of a LEED plaque, a display board listing the cases of LEED used in certification, and callout boxes listing specific cases of LEED completed for certification.

(a): Display Board of LEED Gold Certification

(b): LEED Gold Plaque

(c): TV with Information about LEED

(d): Typical Callout Boxes with LEED Cases
Specific to ICTAS II

Figure 7 (a,b,c,d): LEED Information present in ICTAS II

Section 5: Building Categorization

To evaluate the ICTAS facilities as potential sites for my research design, the next step was to identify and compare what green features each ICTAS facility had. Features were identified through facility walk-throughs and website information.

Table 8: ICTAS Facility Green Features

Features	ICTAS CRC	ICTAS I	ICTAS II
Daylighting		✓	
Water Conserving Toilets		✓	✓
Open Space		✓	✓
Occupancy Sensors		✓	✓
Recycling Stations	✓	✓	✓
Porous Pavers in Storm Water Design			✓
Water efficient Landscaping			✓

Enhanced Commissioning			✓
Alternative Transportation	✓	✓	✓
Recycled Materials Used in Construction			✓
Third Party Certification			✓

Based on the information presented in Table 8, ICTAS I has many of the same green features as ICTAS II (which is LEED Gold certified), but without any third-party certification. In addition, ICTAS CRC has many fewer green features than ICTAS II and ICTAS CRC. As a result, the ICTAS facilities were categorized for the purposes of my research into the following cases.

Table 9: ICTAS Facility Building Categorization

	LEED Rating	Green Features	Case
ICTAS CRC	Not Certified	Very Few (2 of 11)	Traditional Building
ICTAS I	Not Certified	Many (6 of 11)	Green Features Building
ICTAS II	LEED Gold Certified	Most (10 of 11)	LEED Certified Building

APPENDIX C-Survey Comparison

Attari et al. 2010 investigated public perceptions of energy use and potential energy savings associated with a variety of activities, devices, and technologies. In it, a survey was developed to examine these perceptions. In this study, participants with higher numerical scores and stronger pro-environmental attitudes had more accurate perceptions of which behaviors saved the most energy.

In my ICTAS Building Energy study, I utilized this validated survey with some adaptations and extensions. My survey builds upon Attari et al. 2010's survey by linking positive pro-environmental attitude to occupants' exhibiting pro-environmental behavior.

Attari based her quantification of pro-environmental attitude on 3 sections: Environmental Awareness, Attitudes, and Ease or Difficulty of behaviors. I adopted this format as well with some extensions described below.

The Attari et al. 2010 Survey was longer than mine, and was estimated to take more time to complete. I was concerned that the overall length of the Attari et al. 2010 survey would discourage respondents to not complete the survey. As a result, efforts were made to make the ICTAS Building Energy Survey of appropriate length so that respondents would answer all questions on the survey. The target time for the ICTAS Building Energy Survey was 15 minutes.

In the following sections, I describe specifically how my survey either replicates the Attari et al. 2010 survey or adapts/extends the Attari et al. 2010 survey, with justifications for each.

<u>Section 1: Demographics</u>

In both surveys, demographics were split into two sections: one at the beginning of the survey, one at the end. This was done so that pertinent demographics questions were at the beginning, just in case respondents did not complete the whole survey.

Attari et al. 2010 Survey	ICTAS Building Energy Survey	Justification
Do you consume more or less energy than the average individual in the United States?	Not Included	Question not Included to reduce survey length. Additionally since I am studying workplace energy use, most people are not directly aware of their kwh workplace energy consumption.
About how much was the last monthly electric bill for your household? Please provide a	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.

dollar amount (rounded to the nearest dollar) with no other text. Your best estimate is fine.		
About how much did your household pay for gas (for transportation) last month? Please provide a dollar amount (rounded to the nearest dollar) with no other text. Your best estimate is fine.	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.
How many people are there in your household?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.
For the vehicle you use most, approximately what is the vehicle's gas mileage? (Assume your normal mix of city and highway driving.)	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.
Do you have any compact fluorescent light bulbs or fluorescent linear bulbs (tube lights) installed in your home?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.
When buying large household appliances (like refrigerators, dishwashers, etc.), do you consider their energy efficiency in your purchasing decisions?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.
When buying small household appliances (like coffee makers, blenders, etc.), do you consider their energy efficiency in your purchasing decisions?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.

Have you ever had an energy audit of your home? (A home energy audit is done to	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.

evaluate measures you can take to make your home more energy efficient.)		
This past year, was anything done to weatherize your home? (Examples include caulking and weather stripping to seal air leaks around windows and doors, etc.)	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.
Does your home have any double-paned windows (two glass panels set in a frame, separated by a small space) or storm windows (installed on the interior or exterior of the primary window)?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.
Have you ever bought renewable energy from your electricity provider?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.
This past year, did you send a letter to any political official about environmental or energy issues?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context.
Do you consider yourself an environmentalist?	Not Included	This question did not fit within the research questions of the project.
Do you rent or own the place where you live?	Not Included	This question did not fit within the research questions of the project.
In the last election, for whom did you vote?	Not Included	This question was not relevant to the research questions of the study.

During 2008, what was your yearly household income before tax? Your best estimate is fine.	Not Included	This question was not relevant to the research questions of the study.
What is your sex?	What is your gender identity?	The more current approach to asking this question is to use the term "gender identity" instead of "sex".
Modified	What is your job function?	Because each of the ICTAS facility buildings have different types of occupant

		roles within each building (faculty, students, staff, etc.) the question aims to gain more understanding of how job function relates to the overall research question.
What is the highest level of education that you have completed?	Included	The question stayed the same for the survey. The level of education of respondents could influence how respondents answer survey questions.
How would you describe your political beliefs?	What is your political inclination?	For future research, it would be interesting to see if political inclination has an effect on environmental awareness, perceptions, perceived ease or difficulty of behaviors, and pro-environmental behaviors.
What is your age?	What is your current age?	This question was asked to make sure no respondents under the age of 18 were taking the survey. In addition, for future research, it would be interesting to explore if age relates to positive pro-environmental behavior.

Modified	In which facility do you MOSTLY work?	The focus of the project was to compare environmental awareness, perceptions, and perceived ease or difficulty of behaviors, and pro-environmental behavior between each building. As a result, respondents had to be placed within one of the three buildings. Because some respondents have offices in more than one ICTAS facility, respondents were asked to pick the facility they mostly work in.
Modified	Have you been on the ICTAS II Building Tour?	ICTAS II has a tour that anyone can go in to see how the designers of ICTAS II
		achieved LEED Gold certification. Being on the tour might have influenced occupants to have more positive environmental awareness and perceptions.
Modified	How many hours per week do you work in the above selected facility? (In hours)	In future research, this question would be related to see how the time occupants spend in a building may affect their pro-environmental behavior.
Modified	How long have you worked in this facility (In years)?	This question was Included because in order to answer questions about doing pro-environmental, they would have needed to be in their building for an extended period of time.
Modified	On which floor do you work?	In future research, this question would examine how floor residence affects pro-environmental behavior.

Modified	Have you worked in other facilities on campus within the last 5 years	This question was asked to see if respondents worked in other ICTAS facilities on campus. The question was worded this way as to not influence the respondents to think about another ICTAS facility that was different than the one they most frequently work in.

Section 2: Baseline Environmental Awareness

This is the first part of the pro-environmental attitude developed in the Attari et al. 2010 survey. Two questions were taken from the Attari et al. 2010 Survey. Most of the baseline general environmental awareness questions addressed in the Attari et al. 2010 survey pertained to the residential sector, which did not fit with the commercial attributes of the ICTAS facilities. As a result, questions of this nature were not included to the ICTAS Building Energy Survey. The scale used to rank the general environmental awareness questions (Most, second most, third most, least) were the same in both surveys.

Attari et al. 2010 Survey	ICTAS Building Energy Survey	Justification
Please enter whole numbers with no other text (not decimals, ranges, or percent signs).	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.
What percentage of the total energy consumed per year by an average household in the United States is attributed to energy used by household operations?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.

A 100-Watt incandescent light bulb uses 100 units of energy in one hour. How many units of energy do you think each of the following devices typically uses in one hour? Enter a number less than 100 if you think the device uses less energy than a 100-Watt bulb. Enter a number greater than 100 if you think the device uses more energy than a 100-Watt bulb. Your best estimates are fine. Please enter whole numbers with no other text (not decimals, ranges, or percent signs).	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.
Replacing one 100-watt incandescent bulb with equally bright compact fluorescent bulb that is used for one hour would reduce energy use by how many units?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.
Replacing one 100-watt kitchen bulb with a 75-watt bulb that is used for one hour would reduce energy use by how many units?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.

Drying clothes on a clothes line (not using the dryer) for one load of laundry would reduce energy use by how many units?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.

In the summer: turning up the thermostat on your air conditioner (making your home warmer) by 5° F would reduce energy use by how many units?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.
In the winter: turning down the thermostat on your heater (making your home cooler) by 5° F would reduce energy use by how many units?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.
Changing washer temperature settings from "hot wash, warm rinse" to "warm wash, cold rinse" for one load of laundry would reduce energy use by how many units?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.
Driving a more fuel efficient car (30 miles per gallon instead of 20 miles per gallon) at 60 miles per hour for one hour would reduce energy use by how many units?__	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.
Tuning up the car twice a year (including air filter changes) would reduce energy use by how many units for the whole year?	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In addition, adding this question would have made the survey too long.
Assume that you are driving a 20-miles-per-gallon car for 60 miles. Reducing your	Not Included	This question more pertains to the residential sector, which did not fit in with the ICTAS facilities context. In

highway speed from 70 miles per hour to 60 miles per hour would reduce energy use by how many units for the trip?		addition, adding this question would have made the survey too long.
In your opinion, which of the following modes of transportation uses the most energy per mile to transport one ton of goods? Please check the mode that uses the most energy, the second most, the third most, and the least energy.	In your opinion, which of the following modes of transportation uses the most energy per mile to transport one ton of goods? Please drag the mode that uses the most energy, second most, the third most, and the least energy to the appropriate box.	This question is exactly the same. The question better fit with the research question.
In your opinion, which of the following uses the most energy? Please check the activity that uses the most energy, the second most, the third most, and the least energy.	In your opinion, which of the following processes uses the most energy, second most, third most, and the least energy? Please drag the process to the appropriate box.	This question is exactly the same. This question better fit with the research question.
Modified	Please drag the activity that CONSERVES the most energy, the second most energy, the third most energy, and the one that conserves the least energy to the appropriate box.	The question was meant to compare occupants environmental awaresness of which behaviors conserve the most energy vs. ICTAS facility management's view on which behaviors conserve the most energy.
Modified	The ICTAS building I work in most frequently is LEED Certified	This question was meant to understand if occupants know they are in a LEED building or not.
Modified	There is adequate light in my building	This question was meant to understand if occupants believe there is enough light coming into their building

Modified	There are opportunities to recycle in my building	This question ties into understanding people's perceived behavior control in opportunities to recycle. People should recycle more if occupants feel that there is an easy avenue for them to accomplish this task.
Modified	There are occupancy sensors where I work	The point of the question was to understand if occupants were aware of their surroundings of their building when it comes to energy saving measures.
Modified	I can control how much light comes into my workspace	While a previous question asks whether there is enough light, this question addresses occupants control over that light.
Modified	I use the bicycle racks provided by my building	In the LEED manual, companies can get extra points for putting bike racks. This question was meant to understand how many people actually use the bike racks.
Modified	The temperature is comfortable in my building	The point of the question was to understand what do occupants think of the temperature in their building.

Section 3: Perceptions

This second part of the pro-environmental discussed in the Attari et al. 2010 survey were attitudes. For the sake of length, not all of the questions used in the Attari et al. 2010 Survey were used in the ICTAS Building Energy Survey. Questions in the Attari et al. 2010 survey associated more with climate change perceptions were used as opposed to general perceptions about the earth and environment.

Attari et al. 2010 Survey	ICTAS Building Energy Survey	Justification
We are approaching the limit of the number of people the earth can support. (Attitudes)	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.

Humans have the right to modify the natural environment to suit their needs.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
When humans interfere with nature it often produces disastrous consequences.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
Human ingenuity will insure that we do NOT make the earth unlivable.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
Humans are severely abusing the environment.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.

The earth has plenty of natural resources if we can just learn how to develop them.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
Plants and animals have as much right as humans to exist.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
The balance of nature is strong enough to cope with the impacts of modern industrial nations. (Attitude2)	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
Despite our special abilities, humans are still subject to the laws of nature.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
The so-called "ecological crisis" facing humankind has been greatly exaggerated.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.

The earth is like a spaceship with very limited room and resources.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
Humans were meant to rule over the rest of nature.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
The balance of nature is very delicate and easily upset.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
Humans will eventually learn enough about how nature works to be able to control it.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.

If things continue on their present course, we will soon experience a major ecological catastrophe.	Not Included	This question was not Included due to making sure the length of the survey wasn't too long overall and wanting to ask perception questions pertaining to climate change.
Humans do not need to change their lifestyles to address global warming and climate change.	Humans need to change their lifestyles to address global warming and climate change.	These questions were kept the same because perception questions related to climate change. All maximum values to be positive were changed to be positive.

Humans are responsible for global warming and climate change.	Included	These questions were kept the same because perception questions related to climate change
I believe that my actions contribute to global warming and climate change.	Included	These questions were kept the same because perception questions related to climate change
I believe that I need to change my lifestyle to address global warming and climate change.	Included	These questions were kept the same because perception questions related to climate change
Modified	I believe that my behavior has an effect on how much energy a building consumes.	This question was Included to see how perceptions changed when the focus was shifted from perceptions due to climate change to buildings
Modified	I think it is possible to consume more energy in a LEED building than in a building that is not LEED certified.	This question was Included to understand the perception of respondents as it relates to LEED buildings
Modified	I do not think it is okay to consume more energy in a LEED building than in a building that is not LEED certified.	This question was Included to understand the perception of respondents as it relates to LEED buildings
Modified	There are actions that I could take to reduce energy consumption in my building.	This question was Included to see how perceptions changed when the focus was shifted from perceptions due to climate change to buildings
Modified	I am comfortable in the building in which I work most frequently.	This question was Included for to understand if perceptions of comfort changed across the different ICTAS facilities

Section 4: Ease or Difficulty of Energy Saving Behaviors

This is the third part of the pro-environmental attitude discussed in the Attari et al. 2010 survey. The purpose of the section was to investigate how respondents perceived certain pro-environmental

behavior as easy or difficult. The scale (easy-difficult) was kept the same. The behaviors used in the Attari et al. 2010 survey were behaviors more geared toward the residential sector. Therefore, possible pro-environmental behaviors were changed to fit the context of the ICTAS facilities. Behaviors were chosen by first contacting ICTAS facility management and the Office of Sustainability to learn what behaviors they have identified to be important to reduce energy consumption in ICTAS facilities. Then, behaviors were checked to make sure the pro-environmental behaviors chosen could be implemented in all three ICTAS buildings.

Attari et al. 2010	ICTAS Building Energy Survey	Justification
Tuning up the car twice a year (including air filter changes)	Not Included	Behavior is geared toward the residential sector and does not fit within the context of the ICTAS facilities.
Replacing 85% of all incandescent bulbs with equally bright compact fluorescent bulbs	Not Included	Behavior is geared toward the residential sector and does not fit within the context of the ICTAS facilities.
Turning up the refrigerator thermostat from 33° F to 38° F and the freezer thermostat from –5° F to 0° F	Not Included	Behavior is geared toward the residential sector and does not fit within the context of the ICTAS facilities.
Drying clothes on a clothes line (not using the dryer) for 5 months of the year	Not Included	Behavior is geared toward the residential sector and does not fit within the context of the ICTAS facilities.
Watching 25% fewer hours of TV each day	Not Included	Behavior is geared toward the residential sector and does not fit within the context of the ICTAS facilities.

Installing a more efficient washer (replace a 2001 or older non–Energy Star washer with a new Energy Star unit	Not Included	Behavior is geared toward the residential sector and does not fit within the context of the ICTAS facilities.
Changing washer temperature settings from "hot wash, warm rinse" to "warm wash, cold rinse"	Not Included	Behavior is geared toward the residential sector and does not fit within the context of the ICTAS facilities.
Replacing two 100-watt kitchen bulbs with 75-watt bulbs	Not Included	Behavior is geared toward the residential sector and does not fit within the context of the ICTAS facilities.
Modified	Turning off overhead lights in my workspace	Behavior fits more toward the context of the ICTAS facility and also behavior the facility management identified to be important to reducing energy consumption within ICTAS facilities.
Modified	Closing fume hoods in my lab	Behavior fits more toward the context of the ICTAS facility and also behavior the facility management identified to be important to reducing energy consumption within ICTAS facilities.
Modified	Turning off computers in my workspace	Behavior fits more toward the context of the ICTAS facility and also behavior the facility management identified to be important to reducing energy consumption within ICTAS facilities.

Modified	Turning off desk lamps in my workspace	Behavior fits more toward the context of the ICTAS facility and also behavior the facility management identified to be important to reducing energy consumption within ICTAS facilities.
Modified	Turning off lab equipment that does not need to be turned on	Behavior fits more toward the context of the ICTAS facility and also behavior the facility management identified to be important to reducing energy consumption within ICTAS facilities.
Modified	Unplugging electronics out of the electrical socket	Behavior fits more toward the context of the ICTAS facility and also behavior the facility management identified to be important to reducing energy consumption within ICTAS facilities.
Modified	Recycling	Behavior fits more toward the context of the ICTAS facility and also behavior the facility management identified to be important to reducing energy consumption within ICTAS facilities.

Section 5: Pro- Environmental Behaviors

This section is completely new from the Attari et al. 2010 survey to the ICTAS Building Energy Survey. The Attari et al. 2010 survey's research question did not address whether respondents with positive environmental attitudes correspond to respondent's doing more pro-environmental behavior. This question aims to take one more step towards answering that question.

Using the same pro-environmental behaviors used in section 4, this question identifies how often do respondents do these pro-environmental behaviors. If the respondents did the pro-environmental behaviors 4 out of 5 days of the work week, it was considered that the respondents "already do it". The phrase, "already do it" was used in section 4 of the Attari et al. 2010 survey and used in this part of the ICTAS Building Energy survey. If respondents did not already do the pro-environmental behavior, there were multiple options as to why the respondents could have

chosen including I can't do it for lab purposes, too difficult, I do not care, etc. A full list of possible responses for this section is provided in Appendix A.

Section 6: Motivation

This section was not included in the Attari et al. 2010 survey. There are numerous studies that seek to understand the best way to motivate occupants within buildings to implement pro-environmental behavior. This section of the survey serves as input for future research in comparing literature studies of how occupants are best motivated to do pro-environmental behavior vs. what occupant's themselves believe is the best way to motivate themselves to do pro-environmental behavior.

Section 7: Conclusion

The conclusion in both the Attari et al. 2010 Survey and the ICTAS Building Energy Survey served as a way for respondents to give their personal thoughts on energy conservation. Questions were included to best fit the context of the ICTAS facilities.

Attari et al. 2010 Survey	ICTAS Building Energy Survey	Justification
Do you have any additional thoughts about energy use or energy conservation, or any comments about the survey that you would like to share with us?	Do you have any additional thoughts about energy use or energy conservation you would like to share?	The part about comments relating to the survey was taken out by recommendation of committee members
In your opinion, what is the most effective thing that you could do to conserve energy in your life?	Do you have any additional thoughts about how occupants can help conserve energy or create a more sustainable future in the ICTAS facility you most frequently work that you would like to share?	The question was Included to shift the focus of personal energy conservation to thoughts about energy conservation within the ICTAS facility they mostly work in. Answers to this question were insightful in understanding each respondent's perspective of how energy conservation was perceived within their specific building.

Other Sections in Attari et al. 2010 Survey that were not included to the ICTAS Building Energy Survey:

This was one section of the Attari et al. 2010 survey that was not included because the section did not fit into the context of the ICTAS facilities or the research question of the study.

Math Questions:

Math questions in the Attari et al. 2010 paper had no relevance to the questions being asked in the ICTAS Building Energy Survey. In addition, the addition of these questions would have extended the length of the survey, something that I was trying to avoid.

- Imagine that we flip a fair coin 1,000 times. What is your best guess about how many times the coin would come up heads in 1,000 flips?

- In the BIG BUCKS LOTTERY, the chance of winning a $10 prize is 1%. What is your best guess about how many people would win a $10 prize if 1000 people each buy a single ticket to BIG BUCKS?

- In ACME PUBLISHING SWEEPSAKES, the chance of winning a car is 1 in 1,000. What percent of tickets to ACME PUBLISHING SWEEPSAKES win a car?

APPENDIX D: Definitions

Different Building Cases Discussed in Thesis:

Traditional Building: Building that does not have any third-party rating system certification or very few attributes that enhances the building's environmental friendliness by saving energy, reducing waste of environmental resources, and/or enhances the quality of life of occupants.

Green Features Building: Building that has attributes that enhances a buildings' environmental responsibility by saving energy, reducing waste of environmental resources, and/or enhances the quality of life of occupants. Even though the building has environmentally responsible attributes, the building is not certified by a third-party rating system.

LEED Certified Building: A building that used LEED as a third-party rating system metric to achieve sustainability goals. Sustainability choices are chosen based on cases and specific credits within LEED and must achieve a certification status of either certified, silver, gold, or platinum.

Other Useful Definitions:

Psychological Strategies: Strategies to change an individual's behavior that is psychological in nature. Strategies would include changing an individual's environmental awareness, perceptions, motivations, and norms related to energy use and conservation (Steg 2008). Based on the theory of planned behavior.

Building Characteristics: Characteristics defined within the study as a traditional building, green features building, or a LEED certified building.

Open Space: A space that encourages interaction with the environment, social interaction, passive recreation, and/or physical activities.

Daylighting: the illumination of buildings by natural light through properly designed windows and/or skylights

Environmental Awareness: An individual being conscious of the fragility and our role in the environment

Pro-Environmental Behavior: Activities that promote sustainable actions while at the same time eliminating negative ones (Kollmuss and Agyeman 2002)

APPENDIX E-Student's Contribution

** This appendix is required by the Civil and Environmental Engineering Department

Adrienne Hill collected data from occupants from ICTAS facilities. The idea for the research and data analysis came from Adrienne. All sections were written by Adrienne, while being supervised by Dr. Taylor with additional mentorship from Yilong Han. Comments from Adrienne's academic advisor and committee members were incorporated into the paper as she saw fit.