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Examination of LEED Certified Building's Electricity Usage

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EXAMINATION OF LEED CERTIFIED BUILDING'S ELECTRICITY USAGE

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The number of buildings seeking LEED certification has been growing steadily over the past few years. In this study, three academic buildings which were designed and built to LEED certification standards were targeted in Bowling Green, Kentucky. Their electricity consumption and cost effectiveness were examined and compared with pre-designed LEED efficiency models of those three buildings. This research directly examined cost effectiveness of LEED buildings in terms of electricity usage. Three case studies were completed to find the initial and on-going electricity costs of LEED buildings and to verify the LEED standard results. LEED aspects of these buildings were discussed with contractors, architects, project managers, and building maintenance personnel who participated in LEED projects and non-LEED sustainable projects.

Introduction

There are new standards and certification programs available in the market which define, guide, demonstrate, and document the sustainability of high performance buildings. By 2013, there were approximately 600 green buildings across the globe. More than a hundred of those buildings were in the United States of America. The number continues to increase dramatically. U.S. Green Building Council (USGBC) was a contributing partner of the Dodge Data & Analytics World Green Building Trends Report which was conducted in nearly 70 countries in 2016. According to the results of this study global green building doubles every three years. There are different rating systems around the world. It is not an easy task to determine which standards and rating systems are more credible and beneficial in a project (U.S. Green Building Council **[**USGBC], 2014) (USGBC, 2016). There are three types of standards: ISO defined green products, Green product certifications, and green building certifications.

The literature review will offer a brief comparison of the three different green rating systems. Leadership in Energy & Environmental Design (LEED) is the predominant green building rating system in United States of America, Canada, and 30 other countries. “LEED standards have been applied to approximately 83,452 registered and certified LEED projects worldwide” (USGBC, 2015). The U.S. Green Building Council's (USGBC) standards in energy and environmental design were established in 1993. The USGBC’s main objective were to promote sustainability in construction. After the establishment of USGBC by Rick Fedrizzi, David Gottfried, and Mike Italiano in 1993, representatives from 60 firms and non-profit organizations met and developed the idea of a green building rating system. After the year 2000, many buildings started to achieve LEED certification in America and many other countries. LEED certification has grown considerably since its first handbook was published. The target of the movement were the established economic benefits of building "green". According to Greene (2008), large and small businesses, educational and medical care, institutions, government facilities at all levels, and home builders/owners are all profiting from resource efficiencies, improved comfort, and productivity. LEED includes approximately 100 credit points which can be earned in seven different areas: site selection, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, regional priority, and innovation in design. A building has to attain a certain number of credit points, in order to achieve LEED certification. This thesis studies energy and atmosphere (EA), to determine if LEED certified buildings are electricity efficient.

Greene (2008) argued the common belief, building green adds to initial costs, has been proven wrong and architects have found ways to keep costs low and save money on expenses. Later editions of LEED have focused on cost problems related to building green. New sections have been added to green building principles which relate to cost and energy saving strategies in LEED. However, lately there have been articles published which argue LEED certified buildings are less energy efficient than uncertified buildings. Benchmarking energy and electricity efficiency is one significant way to promote efficiency in buildings. (Chung, Hui &Lam, 2006). Some buildings are more energy intensive than others; for instance, public buildings have higher EUI (Energy Unit Intensity) due to more hours of usage and a greater number of occupants. According to Baylon & Storm (2008), LEED certified buildings have improved energy efficiency compared to buildings which are not LEED certified. However, according to a recent article published in Forbes (2014), LEED certification does not necessarily reduce a building's EUI. Swearingen (2014) takes it further by explaining how LEED certification has been done as an online process and this certification does not require building owners to follow any computer models. They can simply win points in areas like site selection, energy efficiency, solar panels, comfort, and productivity. According to Swearingen (2014), building owners can add LEED points to their buildings by the addition of bike racks or the removal of a few parking spots. These are the easiest paths for achieving LEED points. According to Watson (2015), many of these easy points do very little to improve energy and electricity efficiency while contributing to higher LEED certification costs (LEED exposed, n.d.).

When it comes to efficiency in buildings, it is a professional's job to quantify and analyze the impact LEED has on different energy saving strategies regarding electricity and energy use including lighting and HVAC. Electricity and energy efficiency can be achieved by energy and atmosphere credit (EA) under the optimize energy performance credit. There are different ways to achieve LEED points under EA (Trane, 2008). LEED has devoted seventeen credit points to energy and atmosphere efficiency. However, the following three prerequisites must be met: Prerequisite 1. Fundamental Commissioning of the Building Energy Systems R, Prerequisite 2. Minimum Energy Performance, and Prerequisite 3. Fundamental Refrigerant Management. The seventeen credits points are: Credit 1. Optimize Energy Performance (1–10 points), Credit 2. On-Site Renewable Energy (1–3 points), Credit 3. Enhanced Commissioning (1 point), Credit 4. Enhanced Refrigerant Management (1 point), Credit 5. Measurement & Verification (1 point), and Credit 6. Green Power (1 point) (USGBC, 2005).

Problem Statement

LEED certification adds value to buildings and brings reputation to public buildings, such as, those on university campuses. According to Swearingen (2014), there is nothing wrong with building green or having LEED certified properties if they improve energy savings and reduce costs. According to Zheng (2013), LEED models can be precise and functional if the post occupancy assumptions made for buildings are correct. Zheng (2013) argued LEED does not guarantee energy savings and determining their post occupancy performance can prove to be a very difficult job. In a study conducted by Energy Trust of Oregon (2014), a correlation was found between LEED optimized energy performance points and energy savings. In most LEED certified buildings, a considerable amount of source energy and electricity was saved (Cropp, Lee, & Castor, 2014). Considering LEED certification has gained popularity and similar to a mandate employed in the construction industry, buildings should be able to reduce energy usage and increase payback in a specific period of time. It would be a serious problem if LEED certification could not guarantee energy savings and increased paybacks considering the high administration and application costs associated with LEED certification.

Significance of the Research

Buildings in the United States consume more than 70% of electricity. There were approximately 15 million new projects constructed by the end of 2015. The economy is projected to grow; therefore, the need for new buildings will increase. CO_2 emissions will eventually increase and accelerate climate change. Sustainability movements are a good way to reduce the effects of construction-related climate change. Average green buildings are meant to reduce electricity use and save huge amounts of CO_2 emissions per year (USGBC, n.d.)

There were a total of 32 LEED certified buildings in Kentucky in 2014: Two were platinum, fifteen were gold, eleven were silver, and four were certified. Three of the buildings in Western Kentucky University's campus were the target of this study to collect detailed data about electricity efficiency and its cost analysis. This study was an attempt to provide facts about electricity efficiency of LEED certified buildings. This study attempted to translate data in the form of transparent and clear information to answer the question "Is LEED certification the solution for reducing electricity costs?". In addition, the study provided information for individuals to look for efficient and globally recognized ways to increase the energy efficiency and long-term paybacks.

Purpose of the Research

The purpose of the present study was to highlight how building designed and built to LEED standards affects levels of electricity usage in buildings. The results of this study can have innovative impacts on the community by approving or disapproving energy saving aspects of LEED. Depending on the results of this study, it may encourage the employment and improvement of LEED certification. If not, it may lead to considering an alternative green building rating system.

Research Questions

This study examined the electricity consumption of three buildings designed and built to LEED standards. The study was carried out on Downing Student Union, Augenstein Alumni Center, and Gary A. Ransdell Hall to answer the following questions.

1. Are buildings designed to LEED standards efficient in terms of electricity

consumption?

2. Are buildings designed to LEED standards cost effective in terms of electricity?

3. Do buildings designed to LEED standards add excessive electricity cost to the building cost?

Assumptions

The present study assumed building owners and authorities would provide easy access to all utility and electricity data throughout the study. The present study assumed the buildings studied would not be renovated nor demolished throughout the study. The present study assumed people who participated in the discussions would not be biased in answering the questions and would maintain honesty throughout the discussion.

Limitations

This research study took place in Kentucky and targeted three buildings on Western Kentucky University's campus in Bowling Green built to LEED standards.

Delimitations

The sample selection was limited to three buildings in Bowling Green, Kentucky. It was decided to narrow the study to only consider electricity usage. Studying energy usage would be challenging and very time consuming; there are electricity meters available in each building but only one central plant for heating and cooling of all buildings. Different sources, such as, steam and gas support HVAC at Western Kentucky University.

Definition of Terms

AIA: American Institute of Architects

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers Handbook

BOD: Basis of Design

BOMA: Building Owners and Managers Association

Certified: Earning 40-49 points.

CxA: Commissioning Authority

CEUS: California Commercial End Use Survey

DOE: Department of Energy

EA: Energy and Atmosphere

EIA: U.S. Energy Information Administration

EUI: Energy Use Intensity

EPA: Environmental Protection Agency

FSC: Forrest Stewardship Council

Gold Certification: Earning 60-79 points.

Green Product Certifications:

a. Energy Star

b. Water Sense

c. Forrest Stewardship Council

d. SCS Global Services

e. Green Seal

f. Cradle-to-Cradle

g. Green Guard

Green Building Certifications

a. Leadership in Energy and Environmental Design (LEED)

b. Green Globes

c. Living Building Challenge

d. Beam

e. Building Research Establishment Environmental Assessment Methodology (BREEAM)

f. Comprehensive Assessment System for Built Environment Efficiency (CASBEE)

g. Green Star SA (South Africa)

h. Pearl Rating System for Estidama

GSA : U.S. Public Building Services

HVAC and R: Heating, Ventilation, Air Conditioning and Refrigeration

IPMVP: International Performance Measurement and Verification Protocol

ISO defined green products:

a. ISO 14024

b. ISO 14021

c. ISO > 14025

LEED: Leadership in Energy & Environmental Design

Moore's Law: The observation, over the history of computing hardware, the number of transistors in a dense integrated circuit has doubled approximately every two years.

M&V : Measurements and Verifications

NAHB : National Association of Home Builders

NEM: Net Metering or Net Energy Metering allows consumers who generate some or all of their own electricity to use that electricity anytime, instead of when it is generated.

OPR : Owner's Project Requirements

Platinum Certification: Earning 80+ points.

RECS: Residential Energy Consumption Survey

Silver Certification: Earning 50-59 points.

SQ FTI: Sustainable Forestry Initiative

USGBC: U.S. Green Building Council

Review of Literature

The concept of globalization is an ongoing process which started in the 14th century when mercantilism started to grow. It has transq ftormed the planet and changed the environment. Globalization is currently in a contemporary stage with new aspects such as IT development, Moore's Law I, connecting the world via internet, e-commerce, modern transportation infrastructure,and more investments in growing industries (Musoro, 2001).

Globalization has been viewed by economists as a sheer virtue of the era which is infinite and can solve the world's economic crisis. However, one might forget that resources available on earth are limited and humans do not have an unlimited capability to handle pollution caused by globalization. Globalization creates a currency "race to the bottom". Due to globalization, taxes are moved from corporation and industries and are forced on to individuals. Job opportunities transq fterred from developed to less developed countries. Oil prices increased and conflicts grew in regions with major fossil fuels. Consumption of finite fossil resources increased rapidly. Carbon dioxide emissions have increased drastically (Tverberg, 2013).

Sustainability Movement

Carbon foot print continues to increase and it accelerates global warming. People are becoming more conscious of their environment. The concept of sustainability was created to keep the social and environmental systems in balance in a way people would benefit from it. According to Daly (1990), environmental sustainability includes a few varying viewpoints. While consuming finite resources, it is necessary to seek alternative infinite energy sources, too. Harvest rate should be consistent with regeneration rate of resources. Recently, renewable sources of energy have been developed, such as, solar panels. Another way to empower the sustainability movement is by blocking regulations which allow major oil and gas pipeline systems, such as, keystone. These companies are a threat to the envinroment since they increase the green house gases and lead to global warming. Restoration of farmer markets and local food is one more way to help with the sustainability movement. Banning plastic materials, improving public transportation, banning genetically modified products, promoting sustainability in construction, and phasing out non-renewable resources are other ways to help with sustainability (Caradonna, 2015).

Housing , Sustainability, and Necessity of Building Green

According to USGBC (2015), the construction industry is a major pollutant of the environment with 39% of the annual CO_2 emissions. The construction sector creates greenhouse gases more than any other sector. Most of these CO_2 emissions are the result of consuming nonrenewable resources to produce HVAC and generate electricity. In the United States of America, residential, and commercial buildings use up to 70% of electricity generated and add 40% of greenhouse gases to the atmosphere (U.S.EIA,2012). It becomes imperative to reduce greenhouse gases and to create energy efficient and eco-friendly buildings. Building green contributes to the reduction of CO_2 emissions reduction. It also incorporates sustainable HVAC (heating, ventilating, and air conditioning) systems. Building green creates efficient operations and maintainence of existing buildings. It optimizes the lighting system by maximizing the daylight use in buildings and efficient use of artificial lighting. In addition, it uses recycled materials. Building green ,also, reduces the use of portable water and replaces it with efficient sources. Waste and recycling management are applied in green buildings. It incorporates green energies, such as, solar panels. The incorporation of local materials, local resources, and local work force reduces transportation costs. Green buildings focus on proper site selection close to public transportation in order to reduce transportation costs.

A green building project proposes operations which have a healthy approach towards the environment, land use, water resources, and costs. “Thinking green” should start at early stages of construction in order to increase the potential and financial payback of the project. It is critical to start “building green” early since these solutions are less available and more expensive to incorporate in projects and design processes. “Building green” processes start from the site selection stage and continue throughout the project (United States Environmental Protection Agancy [EPA] , n.d).

Green Organizations

During, the beginning of the green movement, a number of organizations started to create green building rating systems and implement them in construction projects. The Forest Stewardship Council (FSC) and the Sustainable Forestry Initiative (SQ FTI) were established in 1993 and 1994 respectively, by environmental activists and other companies due to the concern of forest destruction with the goal of sustainable forest management and promoting industrial forests. The US Green Building Council (USGBC) founded in 1993 implemented their first green rating system LEED in 2000. LEED started certifying buildings by giving them points in regards to site selection, water and energy efficiency, material use, and indoor pollution. Green Globes, National Association of Home Builders (NAHB) , BREEAM, Estidama, Greenstar, Living Building Challenge, CASBEE, and BEAM are a few other green building rating organizations known globally (Greenwash, 2014).

LEED

The Leadership in Energy and Environmental Design (LEED™) is a green building rating system representing USGBC. It provides guidelines to improve the well-being of residents of buildings, increase efficiency, and increase paybacks. LEED certification grew from being a building standard to being a standard design system for existing buildings and new projects. These standards have been implemented in more than 83,000 projects worldwide, especially, in the United States and Canada.

LEED Credit Categories

LEED grades buildings based on different credit categories, such as, selecting sustainable sites and land use, water harvesting and efficiency, energy efficiency and atmosphere, sustainable materials and renewable resource, indoor environmental quality, indoor pollution, innovation in projects, and regional priority. Lately, LEED has been trying to be conscious about costs and paybacks.

LEED certification attempts to improve buildings in various ways by focusing on materials which affect human health and the environment. It is based on performance regarding the indoor quality of the building to create comfort for residents. It is moving towards a demand-based system by taking advantage of smart grid thinking to reward the credit points. Evaluating total water use allows LEED to have a clear picture of water sustainability in the building (USGBC, 2005).

LEED Certification for different projects include: (a) Design and construction phase including new projects, medical buildings, core and shell projects, and academic institutions, (b) Interior design and decoration including commercial buildings and retail interiors, (c) Building operation and maintenance including new projects and maintaining existing projects; (d)Town planning and neighborhood designs, and (e) Home designs which are slightly different in reward categories.

Credit Points of LEED Certification and Certification Process

There are four types of LEED certified buildings: (1) Certified: includes 40-49 credit points, (2) Silver: includes 50-59 credit points, (3) Gold: includes 60-79 credit points, and (4) Platinum: includes 80 and above credit points.

Before receiving certification, buildings must earn all the required points. After achieving the appropriate number of points, the project can start the certification process (USGBC, 2005) (VIRACON, 2013). After applying for LEED certification, a preliminary review of design will occur prior to achieving LEED certification. An application may have some or all the design point requirements for LEED certification. Later, an optional design review can occur. A board of reviewers evaluate the first stage review. After the design review phase, the construction review phase starts. The application must meet some or all the construction points. It can have added design points at this stage which were not available during the previous stage. Lastly, the optional final construction review happens and the application can be completed by paying the fees and filling online forms (USGBC, 2015).

This thesis studied the electricity efficiency aspect of LEED buildings at Western Kentucky University; therefore, there was a need to comprehend the different electricity efficiency aspects of LEED and its credits. Electricity efficiency can be achieved by energy and atmosphere credit (EA) under the optimize energy performance credit in

LEED. There are different ways to achieve LEED points under EA (Trane, 2008).

LEED has devoted seventeen credit points to energy and atmosphere efficiency. According to LEED, these points include: Prerequisite 1. Fundamental Commissioning of the Building Energy Systems R, Prerequisite 2. Minimum Energy Performance, and Prerequisite 3. Fundamental Refrigerant Management. The seventeen credits points are: Credit 1. Optimize Energy Performance (1–10 points), Credit 2. On-Site Renewable Energy (1–3 points), Credit 3. Enhanced Commissioning (1 point), Credit 4. Enhanced Refrigerant Management (1 point), Credit 5. Measurement & Verification (1 point), and Credit 6. Green Power (1 point) (USGBC, 2005).

The main intent of Prerequisite 1, Fundamental Commissioning of the Building Energy Systems, is to verify that installation of all the energy and electricity systems are adjusted based on the main requirements of the project, design basics, and construction documents and codes. Prerequisite 2, Minimum Energy Performance, requires the building to be designed in such a way it increases the energy performance in different areas, such as, HVAC, and lighting, etc**.** The main purpose of Prerequisite 3, Fundamental Refrigerant Management, is to reduce the amount of ozone gas exhaustion. Prerequisite 3 requires the use of systems which have no CFC base refrigerants in their HVAC and R systems **(**USGBC, 2005).

Credit 1: Optimize Energy Performance (1–10 points)

The intent of this Optimize Energy Performance is to increase the performance levels above prerequisite standards; thus, decreasing the environmental and economical effects related to extreme energy use. The process energy cost is 25% of the total energy cost for the baseline project. When the energy cost is less than 25% of the total energy cost, the LEED professional must submit documents which validate the energy inputs are appropriate. The least energy cost savings percentage for each point threshold is as per LEED is shown in Table 1.

Table 1.

Least Energy Cost Savings Percentage for Each Point Threshold

New buildings	Renovations	Credit points
10.50%	3.50%	1
14%	7%	2
17.50%	10.50%	3
21%	14%	4
24.50%	17.50%	5
28%	21%	6
31.50%	24.50%	7
35%	28%	8
38.50%	31.50%	9
42%	42%	10

Note. Adapted from "Energy Saving Strategies for LEED Energy and Atmosphere Credit 1", by TRANE, 2008, Engineers Newsletter (Vol 37-2). Retrieved from http://www.trane.com

The followings are the main four ways to increase the energy performance level: 1. Energy simulation (1-10 points) includes an improvement percentage demonstrated to be compared to the baseline per ASHRAE/IESNA standard by a whole building project simulation using the performance rating method. 2. Using ASHRAE advanced energy design guide for office buildings can increase the energy performance level by four points. 3. Two to three points are available for schools, educational buildings and offices, public assemblies, and retail projects which comply with section one of the core performance guide and are under 100,000 square feet. 4. Using Advanced Buildings

Benchmark™ Basic Criteria and Prescriptive Measures increases the energy performance level by one point. However, the project must comply with the criteria established in

According to LEED, the building design and concept should maximize the energy performance. Computer models can be employed to simulate the performance and find cost effective energy efficient measures. Quantifying energy performance and comparing it to a baseline building is helpful **(**USGBC, 2005).

Credit 2: On-Site Renewable Energy (1–3 points)

The On-Site Renewable Energy credit intends to increase the levels of green energy to reduce the environmental impacts and increase cost efficiency related to fossil energy use. It requires the use of green energy (renewable energy) to balance the energy cost. Table 2 can be used to calculate the points achieved in a green building which uses renewable energy.

A project can be evaluated for solar system, wind system, geothermal, low impact hydro, biogas, and biomass strategies which are non-polluting and renewable energies. When these strategies are applied, net metering can be used with the local utility **(**USGBC, 2005).

Table 2.

Points Achieved in Green Buildings by Using Renewable Energy

%Renewable energy	Points
2.50%	1
7.50%	2
12.50%	3

Note. Adapted from “Energy Saving Strategies for LEED Energy and Atmosphere Credit 1”, by TRANE, 2008, Engineers Newsletter (Vol 37-2). Retrieved from http://www.trane.com

Credit 3: Enhanced Commissioning (1 point)

The Enhanced Commissioning credit intends to start the commissioning process early in the project. This requires the designation of a commissioning authority (CxA) prior to the construction of the building. The CxA shall conduct at least one commissioning design review of the owner's project requirements (OPR), basics of design (BOD), and design documents. It shall review the submitted documents to ensure they match the OPR and BOD. A manual must be designed for future staff. Necessary trainings for personnel and occupants must take place. It must be assured the CxA will be involved in performance verification within the next ten months **(**USGBC, 2005).

Credit 4 Enhanced Refrigerant Management (1 point)

Enhanced Refrigerant Management intends to reduce ozone exhaustion and minimize any direct impacts on global warming. Facilities with mechanical cooling and refrigeration equipment require constant maintenance of equipment to prevent the leaking of a refrigerant into the atmosphere **(**USGBC, 2005).

Credit 5: Measurement & Verification (1 point)

Measurement & Verification intends to create a plan which is accountable for building energy consumption over a long period of time. Developing a Measurement & Verification plan helps to assess the energy performance of the building. Installing essential equipment helps with measuring the energy use. Therefore, real performance can be compared to predicted performance. Energy efficiency can be assessed and evaluated by comparing the actual performance to the baseline building performance. International Performance Measurement and Verification Protocol (IPMVP) guides toward specific actions which leads to energy efficiency related to energy conservation. This LEED credit expands those objectives (USGBC, 2005).

Credit 6: Green Power (1 point)

The Green Power credit intends to encourage the use of green energies which are based on zero pollution. The Green Power credit has a requirement to generate a minimum of 35% of the electricity of the building from renewable energies. Baseline electricity use can be determined by using the annual electricity consumption or by using the Department of Energy's (DOE) energy consumption survey database. The power does not need to be green energy certified. Saving strategies of LEED help to increase the levels of energy performance above the prerequisite standards. Green Power reduces the environmental and economic impacts of excessive energy use (USGBC, 2005).

LEED adds credibility to the construction and places emphasize on the environmental benefits. LEED is considered a way to help the green movement grow. LEED is one of the reasons the "green building" concept was enforced in North America. LEED can also be viewed as a business investment (Kim, 2012). LEED's disadvantages include a long payback time period and ignoring context and performance at times while earning LEED points. It is also feared the more LEED is mandated, the less thoughtfully it will be followed. The LEED certification process adds to building costs; therefore, one would hope it does pay back (Quirk, 2012). It becomes a difficult task to go beyond the constraints and categories created by LEED. There is little room for innovation. Due to its bureaucratic framework, this system will always be linked to the past and be very slow to update (Quirk, 2012). According to Swearingen, (2014), LEED is wasteful when it comes to creating value for the customers. She argues rewarding buildings with certifications does not make rating organizations credible sources. For instance, LEED as a private, non-profit organization is remitted by the government of the United States. The United States government does not focus on demonstrating facts regarding LEED is ahead of the energy curve. LEED modeling can be completed long before building occupation. Some points are easier and more economical to achieve than others. For instance, creating an efficient HVAC system requires more effort than adding bike racks to a parking lot. Taxpayers are the ones who endure these costs. According to the General Services Administration (2014), registration fees and consulting fees add approximately $150,000 to the expenses of a building excluding construction costs. Swearingen (2014) argues in an article published by Forbes, LEED buildings are less sustainable regarding energy, performance, and cost saving than uncertified buildings. Even in the green building council of Washington, DC, buildings were less sustainable and “green”. Other green building rating systems, such as, Energy Star and Energy Protection Agency’s (EPA) function differently. Building owners are obligated to submit their utility bills to those rating systems to achieve the green certification and seal. Comparisons have demonstrated no relation between LEED functionality and Energy Star. Swearingen (2014) mentioned LEED certified buildings are costly to construct and to occupy. It will be a challenge for business owners and individuals to find affordable spaces to work and live. Green movements started with the objective of improving life experiences and improving efficiency. However, they have become expensive and complicated. Corporations trick people’s sympathy with the infinite urge to improve life. No doubt LEED certification adds value to buildings. However, it has strayed from its mission and adds excessive costs to the construction process compared to the sustainable buildings which are not LEED certified. Many of the critics agree that LEED certification does not guarantee energy and electricity efficiency and performance. The U.S. Green Building Council (USGBC) has been conducting different studies to counter those claims. Out of 450 LEED projects, approximately 31% had EUI less than the national median for EUI. Earlier versions of LEED did not necessarily guarantee efficiency and performance as per Energy Star standards. LEED Vol. 3 mainly focuses on efficiency, performance, and carbon depletion. In 2013, USGBC published LEED Vol. 4 which assigns 20% of all LEED points to energy performance and atmosphere based on the American Society of Heating, Refrigerating, and Air-Conditioning Engineers Handbook (ASHRAE) 90.1-2010 standard. This might be the biggest shift to limit carbon depletion in the history of LEED (USBGC, 2014).

LEED received another boost in 2013 when president Obama passed a bill lifting limitations in using the funding by US Department of Defense (DOD) to get LEED certification for Gold and Platinum buildings. The DOD has more LEED certified buildings more than any other organization in the United States. The DOD manages more than 2.3 billion square feet of LEED certified buildings. However, DOD decided to grant permission to its facilities to replace certification process with Green Globes Certification Program as an alternative (Wilner, 2014).

LEED plays an important role in gaining attention for sustainability. However, there has been little academic research on savings and performance of LEED certified buildings with regards to energy, electricity, and performance of LEED. A few case studies were reviewed. These six case studies analyzed the saving aspects of LEED certified buildings regarding energy and electricity. In the following case-studies, the word energy refers to electricity and HVAC, simultaneously.

Case Study 1: Evaluating Results for LEED Buildings in an Efficiency Program

In this study, post occupancy energy use of three LEED certified buildings on University of California, Berkeley campus were compared to energy use in conventional buildings. LEED energy and performance models and pre-LEED certification building energy were used. The University of California, Berkeley (UC Berkeley or Cal) has six LEED certified buildings ranging from certified to gold. All the new buildings on campus are designed and constructed following LEED standards (UC Berkeley, 2011). LEED is supposed to reduce energy and electricity usage and increase performance. To investigate energy savings of LEED, post occupancy EUI per square feet and per capita from three buildings on campus were compared to conventional buildings of the same nature and age. Total average of EUI per month and monthly EUI were calculated by using monthly utility bills to find out the energy consumption in each building. Later, LEED data gathered from the study was compared with regional averages of energy consumption which were available at California Commercial End Use Survey (CEUS). LEED data was compared using the residential energy consumption survey (RECS) at the US Energy Information Administration (EIA). Additionally, the post occupancy energy use of the buildings was compared with pre-construction models for estimated energy use which is in accordance with ASHRAE standards. For better understanding of efficiency and performance, facility managers were interviewed about daily and seasonal operation schedules, lighting schedules, thermal comfort, and other forms of energy consumption. The results of this case study suggested the buildings varied in efficiency levels and performance period. The entire university village uses more energy than the average state household, but depletes the same amount of greenhouse gases as the average household. In this study, building B (Blum Hall) used about half as much energy as an average office building. However, building D (Durant Hall) used more than average. Building D used more energy per square foot after renovation and achieving LEED. Building D was serving as the LEED energy model. Building B used less energy than the model previously suggested. However, building D used more electricity, but it was performing better than the baseline. Building D' energy use varied by season. Building D used more energy in the winter and less energy in the summer which was due to the building design. The bottom line was that LEED was inconsistent in producing predictable results. It can be concluded that the LEED energy model can be accurate if the assumptions for post occupancy model are true. This study supported LEED certified buildings save energy and improve performance. However, LEED does not consider the post occupancy energy use for certification. Post occupancy energy use and performance should be monitored to figure out if LEED really helps to reduce energy use and electricity costs and then decide whether it should become a mandate to pursue or not (Zheng, 2013).

Case Study 2: Do LEED-Certified Buildings Save Energy?

In another study conducted in 2009, 100 LEED certified buildings, including commercial and residential buildings, were analyzed. Data was collected and compared to the energy use of general US commercial building stock. Energy use by LEED certification and by energy related credit points achieved during certification were compared. The data indicated that LEED certified buildings used 18-39% less energy per floor area than the traditional buildings. Additionally, 28-35% of the LEED buildings consumed more energy than their conventional matches. The study found the certification level had little to do with energy performance and efficiency level. This study suggested that LEED certified buildings increased energy savings. However, further research must be conducted to ensure success for individual building level. This study suggested the study should be repeated when a larger sample is available (Newsham et al, 2009).

Case Study 3: Energy Performance of LEED for Newly Constructed Buildings

According to Turner & Frankel (2008), LEED certified buildings add to energy savings. LEED building energy use is 25-30% less than the national average which is similar to what was estimated by LEED modeling. Energy savings increased as performance goals increased with the higher certification types. Gold and Platinum LEED certified buildings have an average of 45% better EUI than non-certified buildings.

In this case-study, the LEED buildings were different in performance. A handful of the buildings had serious energy consumption problems, whereas, some of the LEED buildings really helped reduce the energy use. Some buildings use more energy than expected, such as, lab buildings. Neither the LEED nor the modeling programs clearly presented this fact. It is assumed the LEED certified buildings' energy saving is higher than the national baseline. However, Turner & Frankel, (2008), suggested the average performance of the buildings was almost the same as the average national baseline. However, the LEED program needs improvements to be applied in quality control and follow up. Some of the LEED credit points, such as, commissioning, measurement, and verifications should be revised and more relevant credits related to energy savings should be implemented (Turner & Frankel, 2008).

Case Study 4: UNC Building Performance: Analysis of Energy Efficiency and Occupant Comfort in UNC Campus Building

Nine academic/administrative, residential, and laboratory LEED buildings were selected across the University of North Carolina (UNC) campus buildings. They were analyzed with regards to energy consumption, performance, and comfort. Various qualities, such as, the age of the buildings, renovations, HVAC system, building type, and high-performance standards impacted overall energy efficiency. Energy data of these buildings was collected through utility bills and EUI were collected. Overall, the UNC buildings, had high levels of performance when compared to the national median. This study suggested LEED buildings used the same amount or even less energy than proposed baseline (Gates et el, 2014).

Case Study 5: Energy Efficiency & Financial Performance

According to a study conducted by Better Buildings (2015), a nationwide study of 1,199 buildings' utility and energy expenses, energy consumption was reduced 12.9% per sq ft for Energy Star certified buildings. Energy Star seems to be a better option for building certification according to this study. According to this report, an average reduction of 13.1% in electricity bills in both LEED and Energy Star buildings. A 2012 study of 494 buildings owned by PNC bank found that LEED certified properties save $675.29 per employee in utility expenses compared to the non-LEED buildings. Based on this report, LEED buildings showed reduced utility expenses ($1.76) than the average listed on building owners and managers association records (BOMA) ($2.09). According to the U.S. Department of Energy (2009), twenty-three additional case studies supported utility expense reduction. However, they warned the results of these studies may have been affected by tenant occupancy schedules (Better Buildings, 2015).

Case Study 6: Green Building Performance: A Post Occupancy Evaluation of 22 GSA (General Services Administration) Buildings

The General Services Administration (GSA) studied 22 green buildings from its nationwide projects. Sixteen buildings were LEED certified and the rest of the buildings had been constructed by implementing sustainability strategies to reduce energy use and increase building performance. In this study, building factors, such as, EUI, energy cost, CO2 emotions, maintenance costs, electricity use, water use, and occupant satisfaction were measured and analyzed. Based on the results of this study, green building practices, including LEED certification, pays off. Key findings of this study suggested LEED certified building use 25% less energy when compared to conventional buildings (66 kBtu/sq ft/yr vs. 88 kBtu/sq ft/yr). Their aggregate operational costs were 19% lower than their conventional matches ($1.60/sq ft vs. $1.98/sq ft) and they reduced CO2 emissions by 36%. The results indicated the selected sample for this study outperformed commercial buildings. The study suggested the GOLD LEED-certified buildings are on top of the list when it comes to performance and energy savings (Fowler, Rauch, Henderson& Kora, 2011).

Methodology

The present study was conducted to determine if LEED standards affect levels of electricity usage in buildings. Do buildings which are built to LEED standards reduce or add excessive costs to the electricity costs of a building? Are buildings designed to LEED standards efficient in terms of electricity consumption?

To answer these questions, data was collected through three case studies of buildings on the Western Kentucky University campus which were designed and built according to LEED standards. Two of the buildings, Gary A. Ransdell Hall and Augenstein Alumni Center, are LEED certified; whereas, Downing Student Union was pending certification. This study used the Berkley study on LEED certified buildings as the model. In the Berkley Campus case-study, three buildings were studied to find out if LEED certified buildings save energy. Due to the small sample size, no statistical tests were conducted (Zheng, 2013).

To find out the difference between the energy uses of the LEED certified buildings and conventional buildings, this study used one year of data for each LEED certified building in order to analyze and compare the average energy consumption. Monthly billing data of LEED certified buildings were compared to their conventional matches. To determine how LEED affects energy consumption, seven years of data prior to renovation and LEED certification was collected for D buildings being studied. Post-occupancy consumption data was compared to pre-construction LEED models to investigate if they perform as estimated. Pre-construction models depend on several variables, such as, climate, daily schedules, materials, and plug loads. Most of these factors may remain constant; however, plug loads change due to changes made in further stages of design or financial changes.

In the present study, data was collected by examining post occupancy documents, meter readings, utility bills, plug loads, and pre-construction LEED models of Western Kentucky University campus buildings. Pre-construction LEED electricity consumption models, including baseline design and proposed design were collected. Post-occupancy electricity consumption data of the buildings in use were collected and compared to the pre-construction models. Baseline design is a computer-generated presentation of a hypothetical design which was based on the proposed building project. Baseline design was the basis for calculating the baseline building performance. Baseline design is used for assessment of design standards. The proposed design was a computer-generated presentation of the actual proposed building design which was used as the basis for calculating energy consumption and cost. Post-occupancy data was collected to evaluate how well the building was operating to improve its performance (Rosenberg, 2007).

A target energy performance calculator located on the Energy Star website was used to calculate and estimate the pre-construction LEED model. Improvements were documented in the building performance when compared to the baseline building performance rating per ASHRAE/IESNA standard 90.1-2007 or California Title 2-2005. The simulation program used was the HAP and the energy code used was ASHRAE 90.1.2007 (Appendix G. ASHRAE 90.1). Appendix G was used for code compliance and it served as a baseline for energy efficient programs, such as, LEED. A revised ASHRAE 90.1 (Appendix G) was published in 2016. It is a manual of performance rating methods (ASHRAE, 2016).

The data was supplemented through discussions with individuals associated with the building design, construction, and operations. After data were collected and analyzed, the results were presented in tables and illustrative patterns, such as, charts and graphs. A computer data analysis program (Microsoft Excel) was used to analyze the data collected from the three buildings on Western Kentucky University's campus and face to face discussions.

Data Collection

To understand if LEED buildings were electricity efficient, the electricity consumption of the three buildings designed to LEED standards were analyzed. To study electricity use of LEED buildings, total building electricity use data were collected from physical campus-plant, PDC (planning, design and construction), and facilities management at Western Kentucky University. In the six online case studies mentioned in the literature review section, energy was studied as a combination of electricity use and HVAC. However, on Western Kentucky University's campus HVAC is supported by different sources during different seasons, such as, gas and steam boilers. Therefore, it was a challenge to study both electricity and HVAC. This study only collected and analyzed electricity data. Monthly electricity use was calculated from monthly utility bills and electricity consumption data. Electricity consumption of each building was analyzed for a year. Monthly use and cost were illustrated in graphs for better understanding of annual and seasonal energy use fluctuations. The collected data was compared to pre-construction LEED computer simulated models. These pre-construction models incorporated variables, such as, interior and exterior lighting, space heating and cooling, interior fans, service water heating, etc.

Sample Selection

There were more than 32 LEED certified buildings in Kentucky in 2014. This study narrowed down the research from this wide field of buildings to three Western Kentucky University campus buildings. Downing Student Union (DSU), Western Kentucky University's main student center on campus, underwent a $49 million renovation project in 2014. DSU was renovated to be LEED certified with sustainable materials, energy and electricity efficient systems, and was pending certification. DSU's four levels included offices, meeting rooms, stores, a food court, an auditorium, and study areas. Augenstein Alumni Center's three stories included ball rooms, a museum, an atrium, a library, an auditorium, a call center, and a conference room. Its LEED certification was awarded in 2015 after receiving 41 points out of 110 possible points; 7 points out of a possible 35 points in energy and atmosphere category. The Gary A. Ransdell Hall was constructed in 2009. It was the first LEED certified building on the Western Kentucky University campus earning a Gold LEED certification in 2011. The three-story building included offices, classrooms, auditoriums, and a clinic. Optimized energy performance, water efficiency, and improved air quality were a few of the credits for which it earned LEED certification (WKU, 2017).

The main reason for limiting the sample size was easy access to the buildings and ease of data collection. This study narrowed the field of study from energy (electricity and HVAC) to electricity only since WKU had various complicated sources to support its HVAC system which made analysis of individual buildings very complicated if not impossible. Post-occupancy electricity usage was compared with pre-construction models for electricity at DSU, Augenstein Alumni Center, and Gary A. Ransdell Hall. The pre-construction models were calculated in accordance with ASHRAE 90.1-2007. The data gathered was supplemented with discussions with relevant personnel.

Participants

The participants for the discussions included contractors, plant managers, sustainability coordinators, project managers, and architects who have participated in multiple LEED projects and NON-LEED projects, and who were able to rate differences regarding electricity costs and energy savings.

Variables

LEED certification was the main independent variable in this study. Dependent variables were the responses caused or influenced by the independent variable (Creswell, 2014). In Alumni Center, Gary A. Ransdell Hall, and Downing Student Union, electricity efficiency and actual performance (dependent variables) varied based on their unique designs, construction methods, building operation hours, and maintenance (independent variables).

Instrumentation and Materials

Data was provided by the personnel of Planning, Design, and Construction (PDC) and the plant management at Western Kentucky University including LEED documents based on ASHRAE and electrical bills. Data was analyzed using excel software. The breakdown of the data per building was completed through excel software.

Threats to Validity

Inaccurate data could have been collected while analyzing the data, calculating areas, and reading meters.

Findings

The post-occupancy electricity consumption and cost data of Downing Student Union, Augenstein Alumni Center, and Gary A. Ransdell Hall were collected and compared with pre-construction electricity data calculated in accordance with LEED standards. This information can be found in Table 3 through Table 11. A written summary of the data is included below.

Downing Student Union

Downing Student Union was constructed in 1970. It is the primary dining location on the campus of Western Kentucky University and it serves as a meeting and dining facility. Downing Student Union consist of three floors. The WKU store, printing center, postal service, and ATMs are located on the ground floor. Food courts, an auditorium, offices, recreation area, night classes, and study lounges are located on the first floor. The second floor consist of offices, a gallery, chambers, and meeting rooms. Only meeting rooms are located on the third floor. Total gross square footage of this building was 250,250 sq ft; 41,002 sq ft for new construction gross square footage, 186,406 sq ft for existing, renovated gross square footage, 21,346 sq ft for existing non-renovated gross square footage, and 234,706 sq ft for gross square footage used in the energy model. There are visitor and paid parking provided for Downing Student Union across the street. Downing Student Union underwent a two year, $49 million renovation project based on LEED standards. Renovation was finished in the fall of 2014. The Downing Student Union was pending LEED certification at the time of this study. Much of the building was closed in phases for two years and student activities were relocated to other buildings. Most of the dining facilities were relocated to Topper Cafe near the Preston Center (WKU, 2017).

The following tables included pre-construction energy models including proposed and baseline electricity consumption and cost based on ASHRAE/IESNA standard 90.1-2007, as well as, post-construction electricity consumption and cost.

Table 3

Electricity Consumption Summary for DSU in KWh

Total Baseline Electricity Consumption	3,442,500.00
Proposed Electricity Consumption	2,407,845.00
Post-occupancy Electricity Consumption	3,376,996.00

Table 4

Electricity Cost Summary for DSU in USD

Total Baseline Electricity Cost	231,680,25.00
Proposed Electricity Cost	162,047,97.00
Post-occupancy Electricity Cost	290,421,66.00

Table 5.

Monthly Post-Construction Electricity Consumption and Cost Summary for DSU

Months	Consumption (KWh)	Cost (USD)
2017-Jan	218,008.00	18,966.70
2017-Feb	262,940.00	22,875.78
2017-Mar	278,454.00	24,225.50
2016-Apr	309,618.00	26,936.77
2016-May	266,968.00	23,226.22
2016-Jun	277,700.00	24,159.90
2016-Jul	308,074.00	26,802.44
2016-Aug	306,624.00	26,676.29
2016-Sep	371,592.00	32,328.50
2016-Oct	325,658.00	28,332.25
2016-Nov	270,454.00	23,529.50
2016-Dec	180,906.00	15,738.82
Total	3,376,996.00	290,421.66

Augenstein Alumni Center

This building serves as a home for Western Kentucky University alumni and it was designed to be consistent with the rest of the buildings on Western Kentucky University campus. Augenstein Alumni Center was funded through alumni donations. The first floor consists of an atrium, a museum and ballrooms. The second floor consists of a living room, an auditorium, a library, a call center. and several rooms. Conference rooms are located on the third floor. Total gross square footage of the building is 30,421 sq ft and total project cost was $6,800,000. It was LEED certified in 2015. It received 7 points out of 35 possible points for energy and atmosphere.

Table 6.

Electricity Consumption Summary for Augenstein Alumni Center in KWh

Total Baseline Electricity Consumption	383,667.00
Proposed Electricity Consumption	334,674.00
Post-occupancy Electricity Consumption	476,600.00

Table 7.

Electricity cost Summary for Augenstein Alumni Center in USD

Total Baseline Electricity Cost	40,551.00
Proposed Electricity Cost	35,574.00
Post-occupancy Electricity Cost	47,756.00

Table 8.

Monthly Post-Construction Electricity Consumption and Cost Summary for Augenstein Alumni Center

Months	Consumption (KWh)	Cost (USD)
2016-Jan	19,200.00	2,283.00
2016-Feb	32,000.00	2,998.00
2016-Mar	35,200.00	4,117.00
2016-Apr	39,600.00	3,509.00
2016-May	42,400.00	4,260.00
2016-Jun	53,200.00	5,340.00
2016-Jul	51,800.00	5,243.00
2016-Aug	50,400.00	5,127.00
2016-Sep	40,600.00	4,026.00
2016-Oct	38,800.00	3,818.00
2016-Nov	32,000.00	3,298.00
2016-Dec	41,400.00	3,738.00
Total	476,600.00	47,756.00

Gary A. Ransdell Hall

Ground was broken in 2008 and construction was completed in 2010 on the Gary A. Ransdell Hall. There are classrooms, a clinic, an auditorium, an educational resource center, and support spaces on the first floor. There are offices, an auditorium, and classrooms on the second floor. The third floor consists of classrooms and offices. Total gross square footage is 116,591 sq ft. It was the first building on campus to be built with LEED certification in mind. In 2011, it achieved LEED gold certification. It received 11 out of 17 points for energy and atmosphere.

Some of the specific features included its easy access to public transportation, reflective coating on the roof to reduce heat island effect, sustainable landscaping, low flow plumbing fixtures, optimized energy performance, use of recycled materials, and low emitting materials for improved air quality (WKU, 2017) (KYUSGBC, 2014).

Table 9.

Electricity Consumption Summary for Gary A. Ransdell Hall in KWh

Total Baseline Electricity Consumption	3,442,500.00
Proposed Electricity Consumption	2,333,146.00
Post-occupancy Electricity Consumption	730,793.00

Table 10.

Electricity cost Summary for Gary A. Ransdell Hall USD

Total Baseline Electricity Cost	231,680.25
Proposed Electricity Cost	162,047.97
Post-occupancy Electricity Cost	63,578.99

Table 11.
Monthly Post-Construction Electricity Consumption and Cost Summary for Gary A. Ransdell Hall

Months	Consumption (KWh)	Cost (USD)
2016-Jan	60,449.00	5,198.61.00
2016-Feb	62,400.00	5,366,40.00
2016-Mar	63,311.00	5,444,75.00
2016-Apr	60,784.00	5,227,42.00
2016-May	58,412.00	5,023,43.00
2016-Jun	59,367.00	5,105,56.00
2016-Jul	58,167.00	5,002,36.00
2016-Aug	62,035.00	5,335,01.00
2016-Sep	64,928.00	5,583,81.00
2016-Oct	65,373.00	5,622,08.00
2016-Nov	63,089.00	5,425,65.00
2016-Dec	52,478.00	4,513,11.00
Total	730,793.00	63,57,99.00

Analyzing the Findings

The findings included baseline design data, proposed design data, and post-occupancy data for the three buildings studied on Western Kentucky University's campus. They highlight the differences between pre-construction consumption data and post-occupancy consumption data. Findings are illustrated in Figures 1 through Figure 6.

Downing Student Union

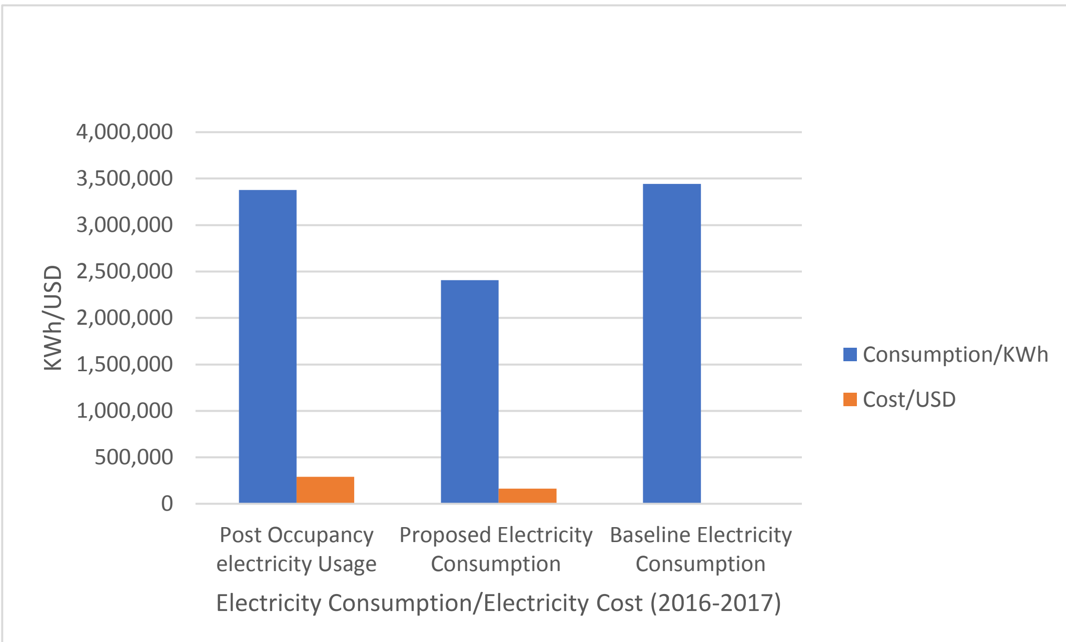

Figure 1. Comparison Between Post-Occupancy Electricity Usage and Pre-Construction LEED Model at DSU (April 2016 -April 2017)

There was no savings indicated in the post-occupancy data. However, the post-occupancy data took demand charges into account. Most of the time electricity use is metered and the costumer is charged in two ways: 1. Based on the actual total consumption in a month with a fixed unit cost (0.087) and 2. By the demand which is based on the peak capacity of required electricity during the given billing period. Some buildings use large amounts of electricity occasionally. Electricity cannot be stored;

therefore, meeting costumers' needs requires keeping expensive electrical equipment. Customers who create this exceptionally high demand are charged more. There was a difference between the post-occupancy cost and the proposed LEED model cost at Downing Student Union. LEED reports do not consider demand charges and days, such as, Christmas or summer days. LEED's pre-construction Model was calculated only based on actual consumption cost considering the unit cost at 0.087. Unit cost is a measure to create one unit of electricity (Woodcock, 2013).

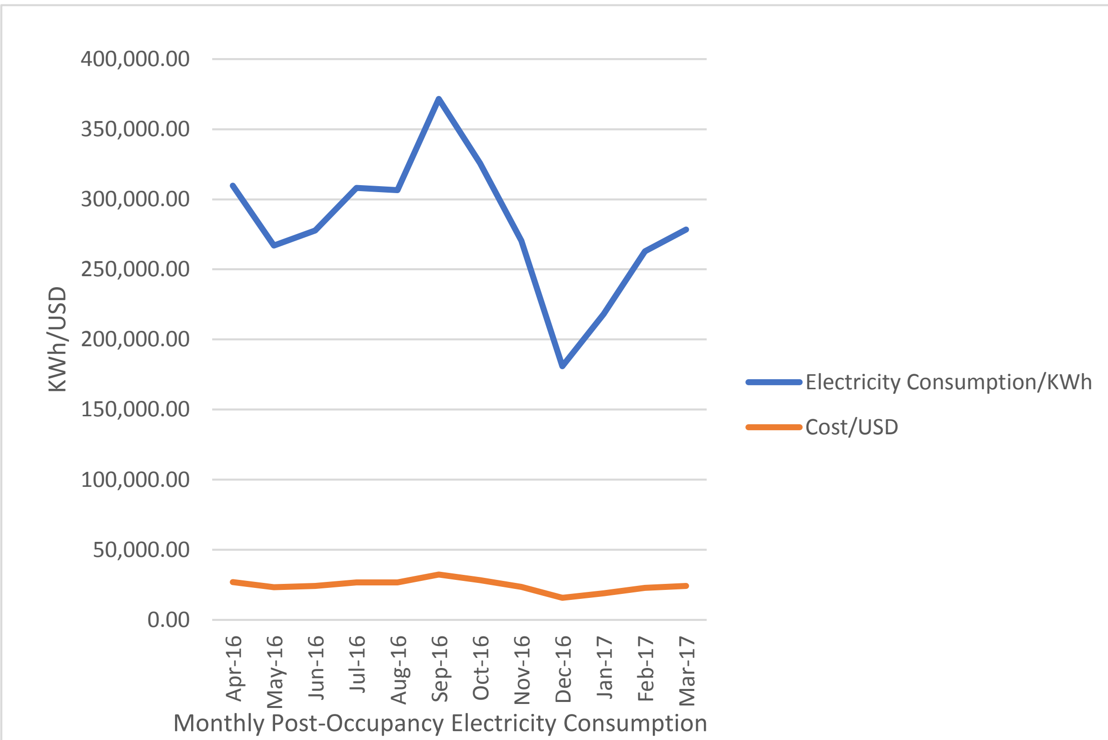

Figure 2. Post-Occupancy Electricity Consumption and Cost for Downing Student Union

Comparing post-occupancy electricity consumption and cost of Downing Student Union's proposed LEED Model, it was found that Downing Student Union used more electricity than the proposed LEED Model; thus, it costs more per year. However, its consumption and cost were closer to the baseline design. The actual total gross square footage was 250,250 sq ft Whereas, the total gross square footage used in LEED energy model was 234,706 sq ft This 15,544 sq ft difference contributed to high numbers being reported for post-occupancy data. This building was renovated to be more sustainable. Based on the findings of a study conducted at the Berkley campus, renovated buildings used more electricity per square feet after achieving LEED certification. Before renovation, during the peak periods, less electricity was used when compared to electricity use after renovation (Zheng, 2013). Based on Figure 2, Downing Student Union consumed more electricity in September and April. The lowest energy consumption occurred during December. The closure of Western Kentucky University campus for fifteen days during December may be attributed to the low electricity consumption during December.

Augenstein Alumni Center

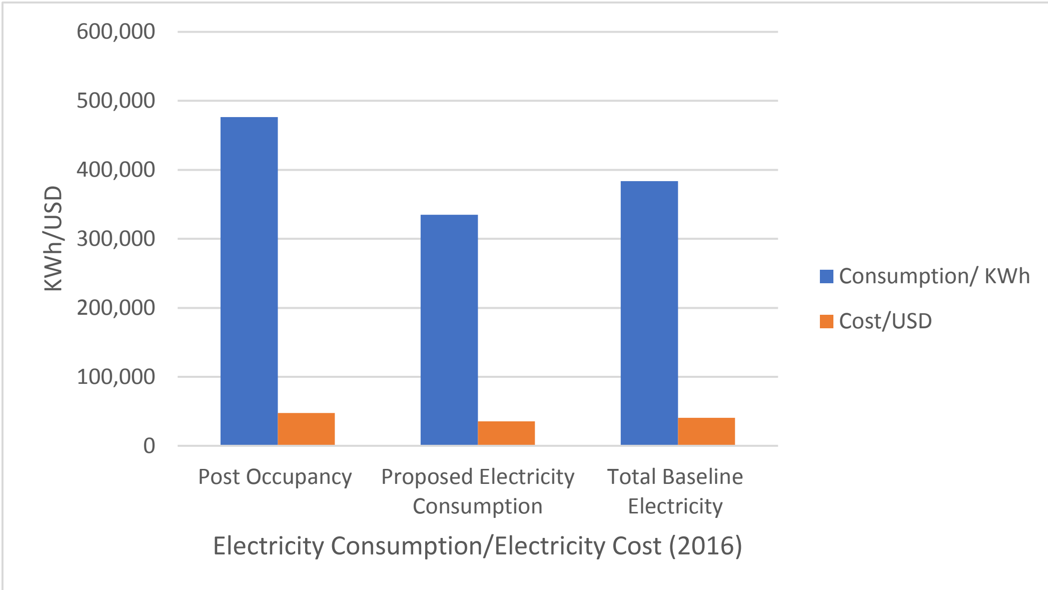

Figure 3. Comparison Between Post Occupancy and Pre-construction LEED Model at Augenstein Alumni Center

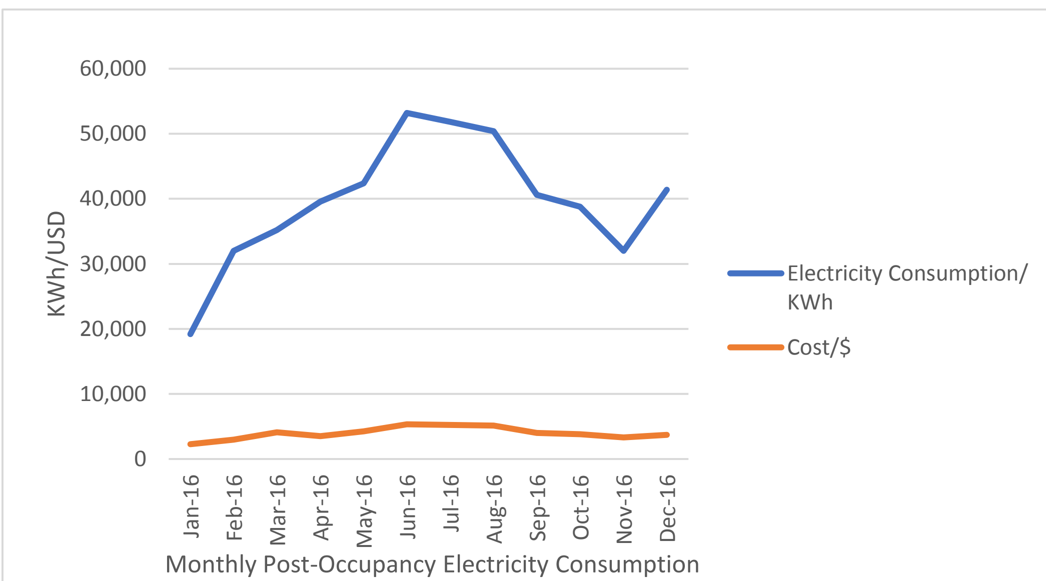

Figure 4. Post Occupancy Monthly Electricity Consumption and Cost for Augenstein Alumni Center

Comparing post-occupancy electricity consumption and cost of the Augenstein Alumni Center with the pre-construction baseline design and proposed design LEED model, it was found the Augenstein Alumni Center used more with regards to electricity than the baseline and proposed LEED model and it cost more per year. Electrical consumption cost peaked during the summer in the Augenstein Alumni Center.

According to Figure 4, this building used more electricity during June and August. A request made by a donor to install a water fountain was fulfilled during this time which increased electricity consumption. Also, during this time, orientations and graduation ceremonies were held in the Augenstein Alumni center and they caused high electricity consumption and cost.

Gary A. Ransdell Hall

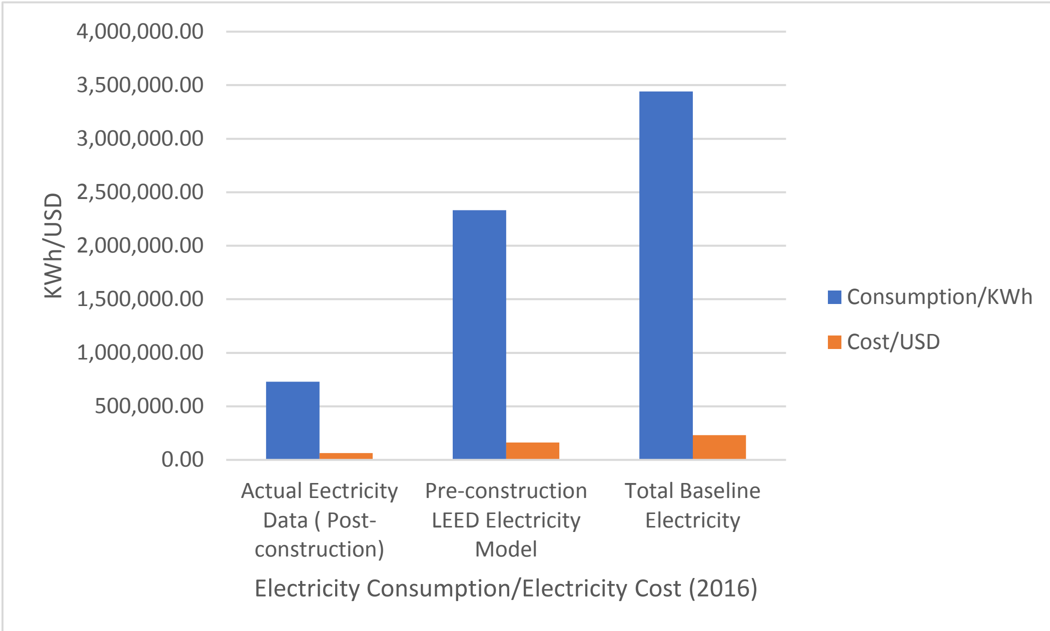

Figure 5. Comparison Between Post-Occupancy Data and Pre-Construction LEED Model at Gary A. Ransdell Hall

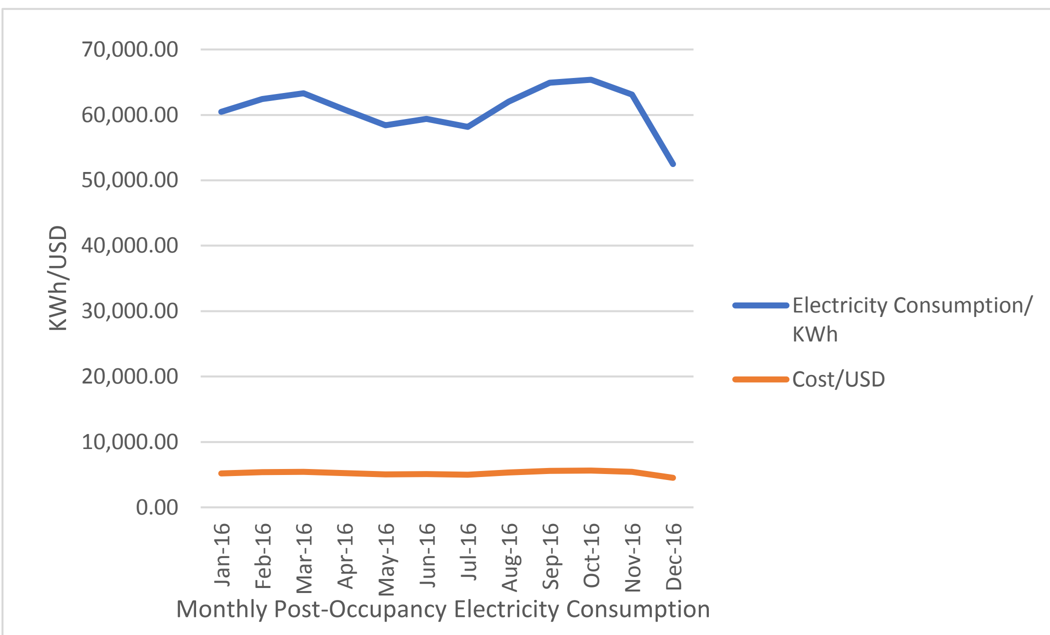

Figure 6. Post occupancy monthly electricity consumption and cost for Gary A. Ransdell

Comparing electricity post-occupancy consumption and cost of Gary A. Ransdell Hall with the baseline design and proposed design pre-construction LEED model, it was found that Gary A. Ransdell Hall used less electricity than the LEED Model and its electricity cost were lower, too. This building consumed less electricity than both the baseline design and the proposed design. Post-occupancy electricity costs were less than the pre-LEED construction costs. This building was one of the few buildings on Western Kentucky University campus that was occupied most of the summer.

Figure 6. suggested consistency with regards to electricity consumption throughout the year. Highest consumption was during October and September. Lowest consumption was during December due to a decrease in activities on Western Kentucky University's campus.

Conclusions and Recommendations

The aim of this thesis was to highlight how buildings designed and built to LEED standards affect levels of electricity usage in buildings. The electricity consumption of three LEED buildings was analyzed. To study electricity use of LEED buildings, total building electricity use data was collected from physical campus-plant, and facilities management at Western Kentucky University. This study only collected and analyzed electricity data. Electricity consumption and cost of each building was calculated for a year. The collected data was compared to pre-construction LEED baseline design and proposed design computer simulated models to answer the following research questions:

1. Are buildings designed to LEED standards efficient in terms of electricity consumption?

2. Are buildings designed to LEED standards cost effective in terms of electricity?

3. Do buildings designed to LEED standards add excessive electricity cost to the building cost?

Upon completion of this study, it was determined Downing Student Union was not efficient in terms of electricity consumption. Downing Student Union is not cost effective in terms of electricity and excessive electricity cost were added to the building cost at Downing Student Union. Additionally, Augenstein Alumni Center was not efficient in terms of electricity consumption. Augenstein Alumni Center was not cost effective in terms of electricity and LEED certification added excessive electricity cost to the building cost. Gary A. Ransdell Hall was efficient in terms of electricity. Gary A. Ransdell Hall was cost effective in terms of electricity and it did not add excessive electricity cost to the building costs.

For the Downing Student Union, the actual total gross square footage was 250,250 sq ft, whereas, the total gross square footage used in the LEED energy model was 234,706 sq ft. This 15,544 sq ft difference contributed to high numbers for post-occupancy data. Based on Figure 2. electricity consumption reached its peak by early September due to population fluctuation rates caused by orientations, job fairs, research conferences, performances, and events in the Downing Student Union. The Downing Student Union was used extensively on weekends which possibly added to the increased consumption. In the spring semester, during finals, students got together to study, rooms were occupied more, and electricity consumption increased in the building. Fluctuation in the number of occupants occurred in this building which makes it difficult for pre-construction models to follow a fixed schedule. Lowest energy consumption happened in mid-December after the final examinations when the food courts were closed. LEED certification may contribute to sustainability and efficiency for some buildings, but it clearly does not promise consumption and cost will meet the proposed pre-construction data.

At Augenstein Alumni Center, electricity consumption increased during June and August. The addition of a water fountain contributed to the increased consumption during those months. According to the plant management at Western Kentucky University, the water fountain and large TV screens were added to the Alumni Center later at the request of a donor. The water fountain used a large capacity water pump which increased energy cost. The water fountain used a lot of water and consumed a lot of electricity. The plug loads, number of lights used, and the electricity used by the water fountain were relatively high. The Augenstein Alumni Center was entirely built through alumni donations. Donor requested features, such as, the water fountain and large TV screens increased electricity consumption. To offset electricity consumption in the Augenstein Alumni Center, LEED was not the answer and it is time to aspire for other building standards. The Augenstein Alumni Center was not a great LEED example. The building met LEED requirements; however, electricity consumption and cost negated it. The Augenstein Alumni Center was not cost effective in terms of electricity and excessive electricity cost were added to the building cost of the Augenstein Alumni Center.

At the Gary A. Ransdell Hall, less electricity was used per year when compared to the pre-construction baseline design and proposed design LEED computer simulated models. Consistency in electricity consumption throughout the year was observed for this building, with highest consumption during October and September and lowest usage during December. Gary A. Ransdell Hall had maximum occupancy during the summer. There were activities continuously scheduled in this building throughout the year. Based on a report published by the Department of Energy (2009), the results of studies might be affected by different types of tenant occupancy schedules. Gary A. Ransdell Hall was the only building which saved a considerable amount of electricity during this study. This study supported LEED certified buildings save energy and improve performance. Gary A. Ransdell Hall was efficient in terms of electricity consumption and it was cost effective in terms of electricity. Gary A. Ransdell Hall does not add excessive electricity cost to the building cost. This case study supports "A post occupancy evaluation of 22 GSA buildings" study, suggesting that GOLD LEED-certified buildings are on top of the list when it comes to performance and energy savings (Fowler, Rauch, Henderson &

Kora, 2011).

According to the study conducted by Turner & Frankel, (2008), LEED buildings are different in performance. Many of the LEED buildings have serious energy consumption problems, whereas, some of them reduce electricity consumption and cost. Some buildings use more electricity than expected such as Downing Student Union which has a food court and auditoriums. According to USGBC, LEED certified buildings' energy savings is higher than the national baseline (USGBC, 2005). However, Turner & Frankel, (2008), suggested the average performance of the buildings was almost the same as the average national baseline. The LEED program should be open to improvements. LEED certification does not guarantee electricity efficiency. Additionally, it is not an easy task to determine whether LEED certified buildings will follow pre-construction LEED models. The data and the conclusions from Downing Student Union, Augenstein Alumni Center, and Gary A. Ransdell Hall are inconsistent when stating conclusions regarding the effects of LEED certification on electricity consumption in general.

Recommendations

Downing Student Union has a high occupancy rate during the beginning and at the end of semesters. It is the major dining center on campus which causes a high process load on this building. Lab buildings and food courts use more electricity than average office buildings. There should be considerations regarding baseline and proposed LEED models address it. Future studies could be conducted to compare electricity usage by the type of activities which occur in the buildings.

Students and occupants should be educated on green buildings, LEED standards, and their purposes to increase an appreciation for LEED. The building itself can be an educational tool: a tile, a sign on a bathroom door, or a brick in the wall. Lack of education on the LEED project is a huge downfall. Future studies can be conducted to find the relationship between electricity consumption and occupants knowledge of LEED.

Buildings on Western Kentucky University campus serve vastly different functions. Downing Student Union is the main dining and gathering center on campus. The Augenstein Alumni's primary purpose is to provide office space. Gary A. Ransdell Hall is an educational facility. Future studies can be conducted based on the type of buildings on one campus or different campuses which could help generate better comparisons.

Future studies could be conducted to find how the implementation of alternative energy sources can affect electrically intensive equipment. Solar panels, recirculating used water, and rain water harvesting are a few of the alternate ways to lower electricity consumption.

One reason the Gary A. Ransdell Hall is a good LEED example is due to its occupancy scheduling. Designing functional occupancy schedules will be a way to reduce electricity consumption and cost. Also, it can be recommended to design and build the building based on a fixed occupancy schedule depending on seasonal variables. Gary A.Ransdel Hall study and "post occupancy evaluation of 22 GSA buildings" study support Gold LEED-certified buildings are on the top of the list when it comes to performance and energy savings (Fowler, Rauch, Henderson& Kora, 2011).

Post-occupancy verification and measurement should be repeated. Peak months and days should be recognized and actions can be taken in order to reduce the electricity usage in those month. Additionally, there should be requirements to decide whether to pursue LEED certification or not.

Future studies can be conducted when bigger samples are available. Current study can be repeated with a larger sample to find if the electricity saving changes in the future.

Future studies could be conducted to compare the construction cost of LEED certified buildings versus conventional buildings. Future studies could evaluate LEED certification on both construction cost and electricity savings and compare the results with frequently used Green standards to understand if there is a better alternative than LEED. Green building standards, such as, living building challenge, Energy Star, and similar functional standards could be implemented in projects more often and could be considered as an alternative consistent with LEED.

Future studies could examine the possibility of making changes to LEED certification process requirements. Another area for study would involve finding methods to improve LEED certification. Instead of awarding LEED certification to buildings, conditional LEED certification could be given to buildings for a few years. After consistent verifications, authentications certification could be awarded. Placing more weightage on alternative green energy sources could be a major change in LEED certification procedure; therefore, buildings will be funded for green energy sources such as solar panels.

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