8-2015

The Adoption and Diffusion of LEED Certification in the Great Lakes Region: 2008-2015

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THE ADOPTION AND DIFFUSION OF LEED CERTIFICATION IN THE GREAT LAKES REGION: 2008-2015

by

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A thesis submitted to the Graduate College
In partial fulfillment of the requirements
for the Degree of Master of Science
Geography
Western Michigan University
August 2015

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Western Michigan University, 2015

This research examines multiple factors that were previously used to describe where LEED-certified homes locations from 2008 to 2015 in the Great Lakes states. This study includes an analysis of 1,040 buildings located in 144 cities across six Great Lakes states. Along with the data in the LEED homes dataset, LEED homes locations are compared using three climate factors: heating degree days, cooling degree days, and average annual temperature. Socio-environmental factors hypothesized to influence the location of LEED-verified buildings included the city population, the city's total area, water area, percent water area, land area, population density, and housing density. Two datasets incorporated these variables to study their influence on LEED home density in the Great Lakes region using univariate and multivariate statistical methods.

The climate factors in this study are not statistically significant variables, and will not describe the diffusion of LEED-certified homes. Socio-environmental factors had a slight but significant relationship to LEED home locations. The OLS multivariate regression model, using statistically significant variables, found that 13.4% of differences in LEED home density in 144 cities can be explained by the above variables. Multivariate regression residuals were mapped and show four significant clusters in the Great Lakes region, showing that there are additional factors that should be investigated to help describe LEED home diffusion.

ACKNOWLEDGMENTS

Another stage of learning completed and I am amazed at what has been accomplished. The entire Geography Department has been great advisors and friends throughout my two years at Western and I thank them for their support. I would specifically acknowledge Dr. Gregory Veeck as he took me under his wing in the spring semester of 2015, and helped me work through the many problems I had with my thesis so that I could finish before another school year started. He has done so much for me that I cannot thank him enough for his support and tolerance for me and my work. I will also thank Dr. Lisa DeChano-Cook, as she was a role model for me during my two years here, and not only helped me move forward in my thesis but also took time out of her day to ask me questions and learn more about me. Dr. DeChano-Cook also was my mentor during my graduate assistanceship and I learned a lot from her during my time at Western. I will thank Dr. Kathleen Baker as well. She also worked with me to finish my thesis, but also worked to learn more about the graduate students, which is something I appreciated. Finally I'd like to thank my family, friend, and especially my wife Jessalyn for praying and believing in me. I know I could never had made it through graduate school without their help and support.

Douglas Vander Hulst

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Leadership in Energy and Environmental Design (LEED) certification has become a well-known system for rating many different types of building projects throughout the United States. LEED certification is a rating system designed to identify buildings that have given extra concern for the environment and have taken measures to mitigate the negative effects the building will have on the surrounding environment. Through the certification process, buildings are assigned a ranking based on the number of points awarded for the measures taken towards a more sustainable building project.

There have been numerous research projects conducted assessing the efficiency of LEED buildings. Surprisingly, some research on LEED buildings finds a significant difference in energy savings between LEED and non-LEED buildings, while others do not. There have been other research projects that look at LEED building locations to determine if construction is related to spatially-variable factors such as demographics, institutional areas, and economics. Other LEED articles look at the effect of LEED buildings on climate change and how much these buildings help create a more sustainable environment. However there have been few articles that compare the location of LEED buildings and climate as a possible driver for the siting of

LEED buildings. This project focuses on LEED-certified homes, instead of office or industrial buildings, and the possible relationship that climate and other social and environmental factors may have with respect to LEED-certified home locations within the six Great Lake states of the midwestern United States. The Great Lakes states, at the time of data collection (March, 2015), have 1041 LEED-certified homes distributed in 144 different cities. This region was selected because the area contains a variety of climates, different sized cities, and a wide range of factors that might be used to explain the diffusion of LEED homes in the Midwest from the implementation of the Homes rating system (2008) until the present.

1.1 Purpose Statement

The purpose of this research project is to evaluate the relationship between LEED certified homes, climate, and other socio-environmental factors within urban areas of the Midwest, and to identify if climate and housing and population densities are significant predictors for the siting of LEED-certified homes. In looking to the future determining whether climate can be used as a means to determine LEED home locations, or if climate has no relationship will aid in further research of LEED-certified home locations in the Midwest. The main research question for this project is: Can the climate of a region be used to help determine locations of LEED certified homes? The secondary question explores whether or not the socio-environmental factors of the urban area in which these LEED homes are located, specifically the town or city, have a significant relationship to the diffusion of LEED-certified homes. This question can be determined, at least partially, by comparing population, population density, and housing density of the 144 cities incorporated into this study. The final question for this research project is to determine what other variables may be factors for determining LEED home locations, focusing on the effect policies may have on LEED locations, at both the city and state level.

1.2 Expected Results

Through this research, it is expected that some socio-environmental factors of the 144 urban areas in the six states will have a relationship for determining LEED home locations, and that climate will either have no relationship with LEED certified homes, or will have a minor relationship with the locations of LEED homes. Federal, state and local programs may also be important when determining LEED home locations. This research will use a variety on univariate and multivariate statistical tests, to be included later in the thesis, to determine these relationships.

CHAPTER 2

HISTORY AND BACKGROUND OF LEED IN THE US

Leadership in Energy and Environmental Design (LEED) was a new program started by the US Green Building Council (USGBC) in 2000. The USGBC a non-profit commerce organization, was founded in 1993 and was established to promote sustainable practices in the building and construction industries (USGBC 2015). The Council's goal, to promote sustainable practices, has become an important part of the growth of these industries in the United States, but the desire for more sustainable practices has come from the realizations that the world needs cleaner forms of energy. The US specifically has been looking for ways to develop more sustainable construction methods because of the desire to be less dependent on foreign oil, and also due to many technological advances in the US that have allowed progress towards that goal. Even though the US government has not specifically promoted sustainable living in the same way LEED does, sustainable building specifically, and LEED building standards are now an integral part of government "best practice" policies, setting an example for sustainable building practices. Over time the US government has come to be a huge advocate for LEED certified buildings and now requires all new government buildings to meet LEED-certified Gold requirements (GSA, 2015b).

The growth of LEED, and the drive to be LEED-certified, is evidenced by the dramatic growth of registered projects on USGBC's projects database. Table 2.1 shows the early growth of LEED from 2000 until August 2007. This growth of LEED certified buildings continues to increase throughout the United States and the Great Lakes States, the focus of this thesis (Figure 2.1). Figure 2.1 shows the growth of LEED-certified Buildings within the Great Lakes states from 2001, when the first LEED buildings were constructed in these states, until 2015. The Midwest saw significant increases in growth rates in 2007 and then another increase in 2010.

Table 2.1: Growth in registered and certified LEED projects

Year	Registered Projects	Certified Projects
2000	50	12
2001	262	17
2002	597	38
2003	1106	84
2004	1913	200
2005	3338	398
2006	5030	718
2007 (August)	8600	997

Source: CIdell, 2009

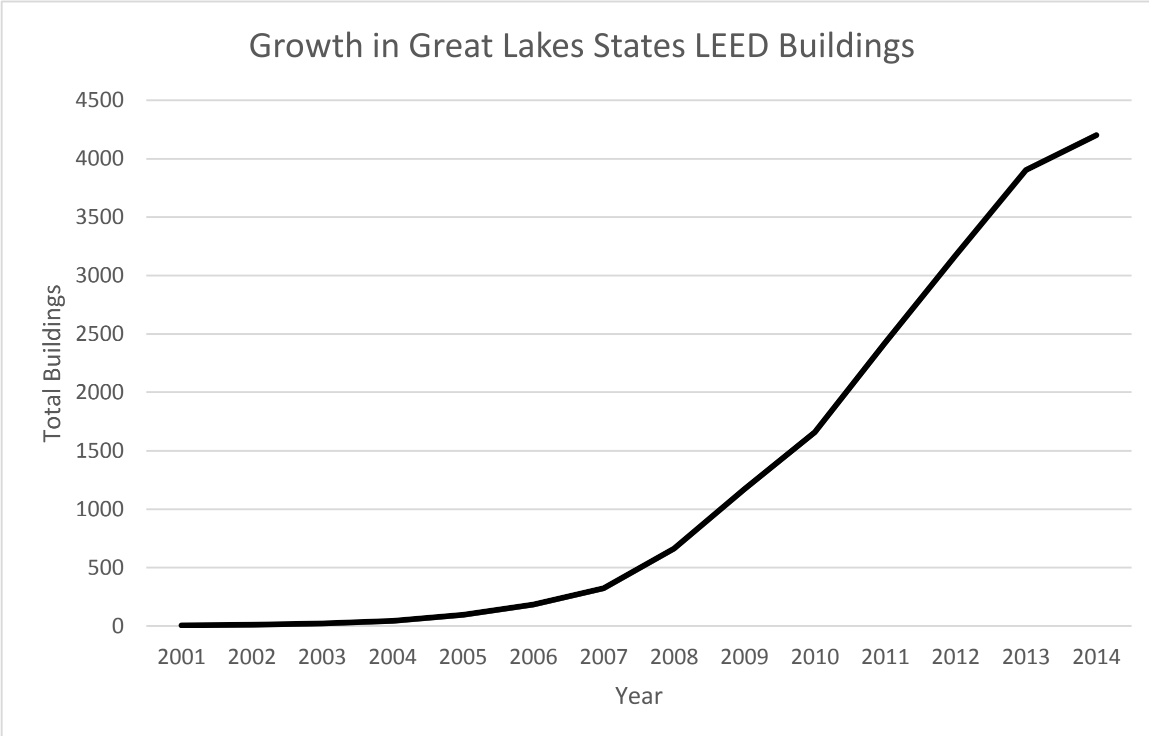

Figure 2.1: Total LEED Certified Buildings in the Midwest
Source: USGBC.org and Author calculations (accessed June 2015)

Obtaining LEED certification has become one of the most wide-spread sustainable building practices in the US, but it is not without its challenges and struggles, some of which have occurred in the past few years. In addition to the changing and diversification of LEED rating systems in order to help promote sustainability, the USGBC's LEED certification fast became only one of many possible green building programs to help promote sustainable building practices, adding confusion to the certification systems in the US. Some of the newer green buildings programs include the Green Globes program, the Living Buildings program, and Energy Star. Energy Star's program (www.energystar.gov) promotes sustainable products that can be used in buildings with a limited focus on the building construction which allows this program to help enable the growth of the building programs. The Living Buildings program (http://living-future.org/lbc) has a much different style towards sustainable buildings than LEED, but it is a growing program in some areas of the US. Green Globes sustainable building program (http://www.greenglobes.com) is quite similar to the LEED certification program. These similarities could cause LEED certification to become less dominate in the future. However, having multiple certification systems in effect can cause uncertainty among builders and consumers when determining which system to use. Government policies related to sustainable building practices have helped endorse and promote the LEED program, but government support has also caused some problems in the promotion of LEED certification policies.

In 2012, the National Defense Authorization Act prevented the use of funds to achieve gold or platinum LEED certification in section 2830 (Govtrack, 2011). The result of this prohibition on the use of public funds to achieve higher LEED certification than silver caused many people to wonder if the government was going to abandon the LEED program. An article written by Chris Cheatham, in March of 2012, focused on the US Army because of reports that the Army was creating an independent green building code. Cheatham argued that the Army was abandoning LEED possibly as a response to the Act preventing funds to go towards gold and platinum LEED certification, and questioned how long before the other federal agencies would abandon LEED certification as well (Cheatham, 2012a). About a week later Cheatham wrote another article recanting the information in the previous article. In the new article, and as an edit in the earlier article, he stated, "It is now clear to me that I misinterpreted the testimony of Dr. Dorothy Robyn, Deputy under Secretary of Defense. Instead, the Department of Defense is going to simultaneously require compliance with its green building code and with LEED certification" (Cheatham, 2012b). The 2013 National Defense Authorization Act section 2830 that prevented the use of funds to achieve gold and platinum LEED certification was sustained for the year of 2013, raising more questions about whether the government was going to abandon LEED certification. However, this time people were not questioning whether the government was going to abandon LEED certification altogether, but that they were going to stop only endorsing LEED certification to allow each federal agency to decide which sustainable building program to use. The government is currently reviewing a range of green building programs and through this process, may stop endorsing only LEED certification standards for building standards and may allow for other options as well (Melton, 2013). In the Energy Independence and Security Act, section 436 requires the government to review green building certification programs once every five years and decide which certification(s) is(are) the most environmentally safe and friendly. This decision determines which green building program(s) the government will endorse as strong sustainable program(s). The results of the review process were announced in October 2013. At that time, the government announced that there were two green building systems that best fit the desired standards: The Green Building Initiative's Green Globes and the USGBC's LEED certification. Henceforth, government agencies would be allowed to follow either of the two programs for their projects (GSA, 2015a).

LEED certification started out with a single rating system that was used for all buildings, but that quickly changed as it became evident that different types of buildings by use, and different types of development or redevelopment, needed different standards to achieve a more sustainable environment. LEED program developers soon realized this limitation and have since been updating the rating system as well as creating more rating systems for different project types. Since the LEED rating system began in 2000, the USGBC has divided the program into five main rating systems that focus on different aspects of the building process as well as different types of building projects. Of these five rating systems two focus on building construction, one on operations and maintenance, and the other two focus on homes and neighborhood development (USGBC, 2015).

The two construction-focused rating systems are Building Design and Construction (BD+C) and Interior Design and Construction (ID+C). The BD+C rating system focuses on new construction as well as buildings receiving major renovations. A few examples being “core and shell” renovations, schools, retail space, and warehouses. The ID+C rating system focuses on projects that have complete interior renovations or new interiors in newly constructed buildings (USGBC, 2015).

The next two rating systems focus on new construction at two different scales. The Building Operations and Maintenance (O+M) rating system concentrates on small scale improvements while the Neighborhood Development (ND) rating system is for large scale multi-building projects. The O+M rating system is for buildings having minor improvement renovations with limited, if any, additional construction. The ND rating system is for large scale new land development or redevelopment, and includes residential, nonresidential and mixed uses. ND projects can be adopted at any stage of the process, “from concept plans to construction” when brought into the LEED rating process (USGBC, 2015).

The final LEED rating system, and the rating system central to this thesis is the Homes Design and Construction (Homes) rating system. This rating system was established for single family and multifamily-homes. There are two different variations of this system, one is specifically for multifamily midrise buildings, up to eight stories. The other system is for homes and multifamily low-rise buildings, up to three stories (USGBC, 2014). USGBC’s website page related to their Homes rating system emphasizes the importance of having safe and clean homes for families. "LEED homes are built to be healthy, providing clean indoor air and incorporating safe building materials to ensure a comfortable home" (USGBC, 2014).

Again, the LEED Homes rating system was created to promote sustainable practices into the home buildings industry. Initially this system targeted the top 25% of new homes that had the best environmentally-friendly features and practices. USGBC worked with every facet of the home building industry to establish the regulations (USGBC, 2007). Starting out the rating system by targeting the top new homes allowed home builders to identify specific homes as the top sustainable homes in their markets. The rating system also allows for home buyers to distinguish between homes of higher quality and a standard home. This rating system is based on eight categories to measure the sustainability potential of homes.

The first category focuses on the Innovation and Design process (ID) for the house. This section is mainly for home design, construction methods, operations performance, and measures that are new or unique that increases the homes sustainability but are not addressed in the rating system (USGBC, 2007). This category promotes innovative designs and new construction methods in order to create a more sustainable final product, which helps builders and other contractors to look for different ways to build better homes with more sustainable practices. The rating system is designed to encourage builders and renovators to develop better ways to improve or maintain building efficiency.

The second and third categories focus on the actual lot where the home is being built or renovated as well as the area around it. The second category, Location and Linkages (LL), looks at how the home is placed in responsible ways, both socially and environmentally, within the community. Sustainable Sites (SS), the third category, reviews quality of the entire property and how the property is used to minimalize the home's impact on the environment (USGBC, 2007). Reviewing the site and situation of the project is an important concept in any new project, but is normally for economic purposes. The LEED program uses the site and situation concept to encourage a more focused look at the impacts in an environmental way as well as in terms of the "dollars and cents" of property development.

Categories four, five, and six focus on the efficiency of the building and are assessed in terms of water, energy, and materials. The Water Efficiency (WE) category analyzes the water conservation and usage methods inside as well as outside. The fifth category, Energy and Atmosphere (EA), focuses on the design of the house to encourage the most efficient energy use, including design of the heating and cooling systems for the house. The sixth category, Materials and Resources (MR), looks at the materials used in the building process, and how efficiently those materials are used on site to minimize waste. The USGBC provides a list of environmentally preferred products (EPPs) on their website and in their rating system guide (Table 2.2). Table 2.2 shows the types of materials that are preferred when building different aspects of the house. The assembly column is for very specific parts of the actual building process, with all the "other" cells being for extra possible components not required in the building process.

Table 2.2: Environmentally Preferred Materials

Assembly	Component	EPP specification (0.5 point per component)
Foundation	Aggregate	Recycles content of 25% post-consumer (no credit for post-industrail recycled content
Interior wall	Framing	Finger-joist studs
Interior wall and ceilings	Gypsum	Recycled content of 10% post-consumer or 95% post-industrial
Other	Cabinets	Bamboo w/ no added urea-formaldehyde resins
Other	Perimeter fencing (new)	Recycled content, reclaimed, or FSC-certified
Other	DHW supply piping (new)	Polypropylene or PEX
Other	Driveway (new)	Reclaimed, recycled, FSC-certified, or 30% flyash/slag

Author: USGBC
Source: http://www.usgbc.org/Docs/Archive/General/Docs3638.pdf

The seventh section of this system, Indoor Environmental Quality (IEQ), focus on the overall quality of the indoor environment, and the methods used to reduce air pollution in the interior environment (USGBC, 2007). Having a category that focuses on indoor air quality is beneficial to people of all ages since having an indoor environment with measures to reduce air pollutants inside the house will help maintain a cleaner and healthier environment for those who live there, and will encourage builders to contribute their expertise to this important problem.

The final category, Awareness and Education (AE), focuses on the homeowner, tenant, and/or building manager in apartment complexes. Assuring that these people know how to operate and maintain the home's green features is important for keeping these homes, or apartment(s), in good condition and working efficiently which justifies continued LEED certification. Even though the owners of the house, or apartment(s), may understand how to best maintain these green features, it does not mean that these people will follow the instruction regarding steps to maintain LEED certification. Requiring the builders to supply a manual of all LEED features and how to operate and maintain these buildings, as well as requiring a tour to show where each of these features are is important in educating the residents about LEED certification. In this way LEED certification efforts will increase the knowledge about sustainable building within the community.

2.1 History of LEED in the Great Lakes States

LEED certification in the Great Lakes states had a similar history as the rest of the United States. When LEED certification was launched in 2000, the numbers show builders and consumers in the Midwest did not jump onto the green building trend right away. It took a year or two to gain momentum, but after 2012 the growth rates of LEED-certified buildings in the Midwest are now similar to other part of the country. The first LEED certified projects in the Midwest are located in Illinois and Michigan. Illinois was the first of the Midwest states to have a certified LEED building with the certification of the Great Lakes Naval Training Center in August 2001 which is located north of Chicago, IL. In September 2001 the Steelcase Wood Furniture Manufacturing Plant in Caledonia, became the first Michigan LEED certified building (USGBC, 2015).

When the LEED certification system expanded into five distinct rating systems, including the homes rating system, the Midwest continued to see growth in LEED certification. Figure 2.2 shows the total number of LEED certified buildings, under the homes rating system, from its implementation in 2008 through early 2015. Although LEED certified houses have been increasing, it was not until 2012 that firms in the Midwest starting building more LEED certified houses. Table 2.3 shows the growth of LEED-certified homes per year throughout the Great Lakes States. In Table 2.3 years 2008-2009 were grouped together because these are the early years of LEED-certified housing in the Midwest, and these years had much lower certification rates. The 2014 and 2015 years have also been combined since it is still early in the 2015 year and many of the early projects certified in 2015 could have been finished in 2014, but failed to complete the certification process in 2014. Figure 2.3 shows the spatial variation of LEED-certified

Homes during the three major time periods where each dot represents one LEED home. The early period of LEED houses in the Midwest, 2008-2009, is the period right after the LEED Homes rating system was established, and very few builders and contractors attempted to follow this new system. The middle period of LEED homes, 2010-2013, is when most LEED homes were built and certified following the LEED Homes requirements. The most recent LEED-certified homes, 2014-2015, are the third period of time, showing where LEED-certified have been built in the past year. This figure shows LEED home growth and how LEED Home locations have varied over time.

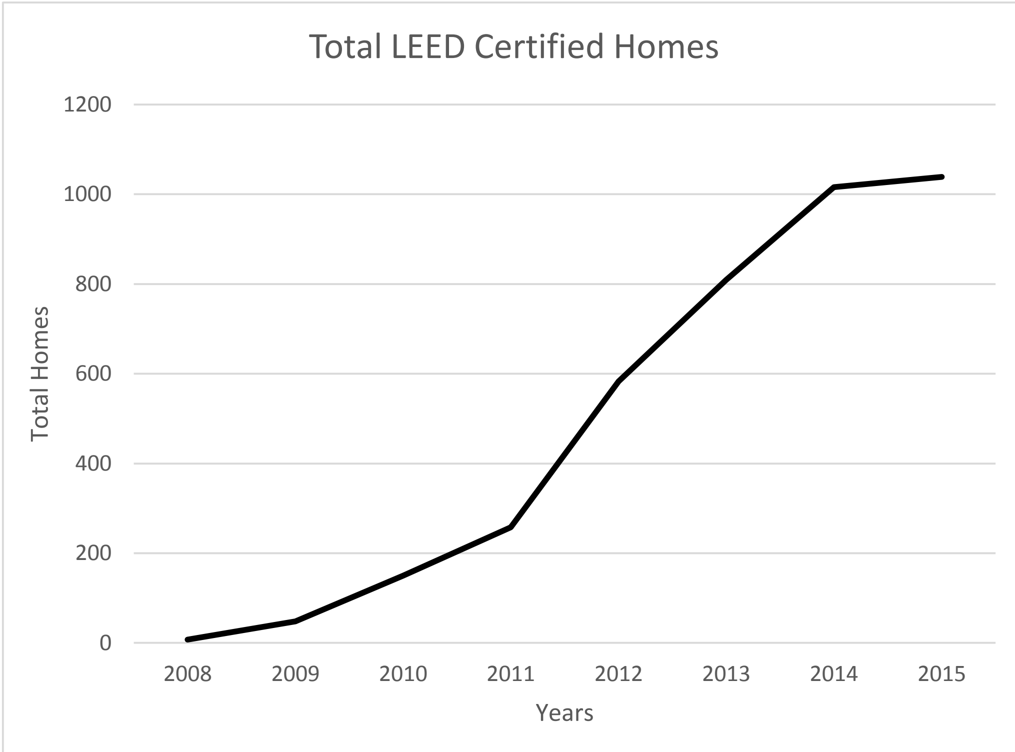

Figure 2.2: Total LEED Certified Houses in the Midwest

Table 2.3: Number and Average Rank of LEED certified Homes in the Midwest.
Rankings: 1:Certified, 2:Silver, 3:Gold, 4:Platinum

Year	Number of projects	Average Rank
2008-2009	48	2.27
2010	102	2.58
2011	108	2.63
2012	325	2.22
2013	226	2.30
2014-2015	230	2.34

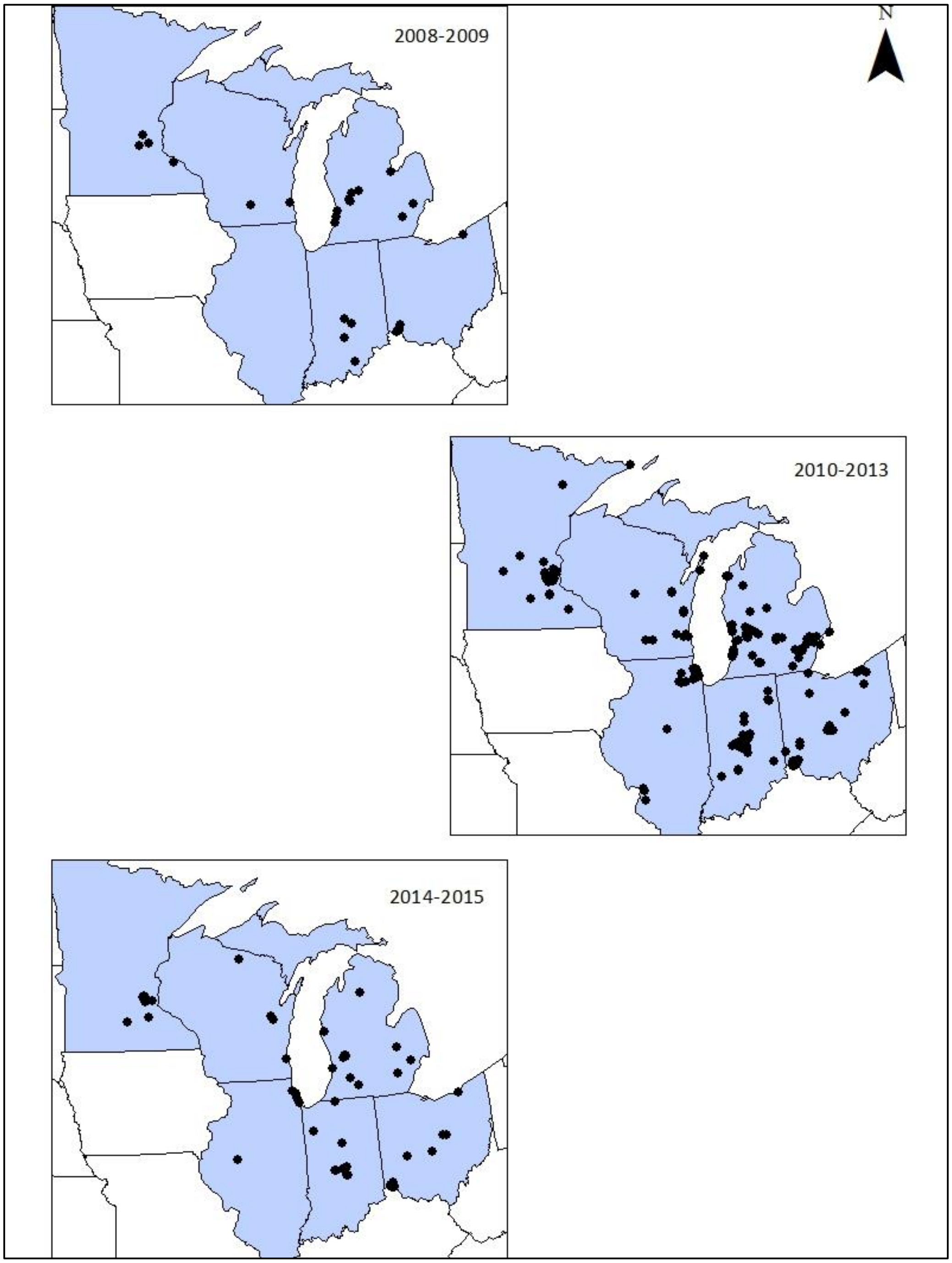

Figure 2.3: LEED Home Locations: 2008-2015

The growth of LEED homes through three periods of time

Projection: USA Contiguous Lambert Conformal Conic

This short history of the LEED certification program is important for understanding the LEED process for homes and how the program has grown substantially over the past 15 years. Like many programs, the LEED certification program started slowly as firms and consumers alike were uncertain of the regulations that needed to be fulfilled to achieve LEED certification. Through the 15 years that LEED has been available, it has seen years of extreme growth as well as years with minimal growth due to economic and political issues. LEED certification and related programs will continue to grow and adapt to new technologies, and be an important research topic for anyone interested in energy efficiency and environmentally friendly projects. The next chapter will review contemporary literature on the LEED program and similar programs from a variety of perspectives.

CHAPTER 3

LITERATURE REVIEW

3.1 Energy Efficiency of LEED

The main purpose of LEED certification is to promote sustainable building practices, and to develop a building identity that has less impact on the environment. Within the LEED rating system there is a section that focuses on energy efficiency, but these results are based on projected energy use and not the actual energy use of the building once the building is occupied (Newsham et al. 2009). Because of the inclusion of projected energy use in the LEED certification process, there have been many studies on the topic of energy efficiency of LEED buildings to determine the relative post-occupant energy efficiency of the buildings. An early study was performed at the Lawrence Berkeley National Laboratory, in 2006, to evaluate the performance of first generation LEED buildings. In this study researchers selected a sample of 21 LEED buildings and evaluated how the buildings were designed for energy efficiency. Using LEED guidelines, this study modeled results for energy savings, and the actual energy usage for the early years of operation (Diamond et al. 2006). Since the study only covered 21 buildings, the authors state that this study will likely be a starting point showing the general performance of LEED buildings, and is not a representative sample. Of the 21 buildings used in this study, 18 had actual billed performance for energy use and modeled energy usage (Diamond et al. 2006). For these 18 buildings, the actual energy performance was divided by the modeled performance of full energy usage to identify the percentage of predicted energy use that was actually used. Mean energy use was 99% indicating that for these 18 buildings, the modeled energy use is almost the same as the actual energy use of the building (Diamond et al. 2006). Even though this study must be taken at face value because of the small sample size, it can still be used as a study to show that LEED with post-LEED construction, predicted energy use is close to the actual energy usage. This study can also be used as a background for future studies that model predicted LEED performance and compare these estimates to the actual energy performance of LEED buildings.

A 2008 study by the New Building Institute evaluated a much larger sample of 552 LEED-NC buildings, using version 2.0 of the LEED rating system, for the period from 2000-2006. Of these 552 LEED-certified buildings only 121 buildings were actually used in the study because they were able to provide at least a year of measured energy usage while the building was occupied (Turner and Frankel, 2008). The study used three different methods for measuring energy consumption performance to determine whether the energy use of LEED buildings is better than the average energy use for commercial buildings. The first measure they used was energy use intensities (EUI). This method found that the average EUI for the 121 LEED buildings was 69 kBtu/sf, while the national average was 91 kBtu/sf. Looking at each type of certification, researchers found that the average for each individual level was below the average for all 121 LEED buildings (Turner and Frankel, 2008). The second measure of energy efficiency incorporated the Energy Star ratings. This program juxtaposes the energy use to a national average similar to the EUI method. However, the Energy Star method normalizes these numbers by key variables, including temperatures, home/work schedules and occupancy. The results for this method scored LEED buildings a rating of 68, meaning that the average LEED building is more energy efficient than 68% of non-LEED buildings with similar functions. The Energy Star rating system did have 1/4th of LEED buildings with a rating lower than 50. These buildings could be studied to identify shortcomings of LEED buildings and to find ways to increase overall performance (Turner and Frankel, 2008). The third measure Turner and Frankel used was a comparison of measured performance versus predicted performance. The average predicted savings for these buildings was 25%, and the measured average savings was 28%, which shows a close correspondence with the predicted measures. However, there were some major outliers for energy performance when LEED performance was evaluated using this method, as with the Energy Star rating.

Buildings that use more energy than the average building can be studied to identify why those buildings are using more energy than the national average and how this could be fixed (Turner and Frankel, 2008).

In 2009 two articles related to this research were published in the journal *Energy and Buildings*. The first article was published in the August issue of the journal and the other in December. These two articles showed different results in their research on LEED energy efficiency. The first article titled “Do LEED-certified buildings save energy? Yes, but…” was a study that used the Turner and Frankel methods as the foundation for the analysis. In this study, researchers focused on how each individual LEED building related to that of a single building on the commercial buildings energy consumption survey (CBECS) dataset that was closely related to the corresponding LEED building in terms of activity, size, age, and climate. After matching these buildings Newsham et al. (2009) performed t-tests to analyze the differences between the two sets of buildings. Before the researchers went to the individual level they organized the LEED buildings by activity, and then matched those activities to the closest related activities on the CBECS dataset, as the LEED activity list and the CBECS activities are not completely the same. From the results of these student’s t-tests, along with ANOVAs and regressions, the researchers found little statistical significance. The key findings of this research included an average energy savings of 18-39%

per floor area, which corresponds with the savings found by Turner and Frankel. These authors also found that 28-35% of LEED buildings use more energy than the matched building, which is 3-10% higher than what was found in the Turner and Frankel article, and that the certification level did not correlate with energy performance (Newsham et al. 2009).

Scofield (2009) used the same data as that used in the Newsham et al. (2009), but reached different results. He focused on the source energy for his analysis, which uses both on-site use and the transportation and generation of the energy, and found no significant result on average. The analysis did find that LEED buildings do use less site energy, on average, than non-LEED buildings with similar activities. Newsham et al. (2009) found 28-35% savings in site energy, but in Scofield's (2009) analysis he only found 10-17%. Scofield explains how using the analytical method found in Newsham Mancini and Birt's article is not an effective way to study LEED buildings, and explains that the overall average of LEED buildings is a better form of analyzing performance, even when there are only a few large buildings that use more energy (Scofield, 2009). Using the overall average does appear to be a good way to identify the overall efficiency of LEED, but looking at LEED buildings by comparing them to non-LEED buildings with similar characteristics is also a good way to identify certain aspects of energy efficiency. LEED buildings that are using more energy than non-LEED buildings with similar characteristics can be used to find more efficient methods to save energy in bigger buildings. The Energy Star analysis shows that 25% of LEED buildings have a lower performance than the national average all else held constant. The regression model included in Newsham et al. (2009) showed quite a few LEED buildings were outliers that brought the average savings down due to the increased amount of energy used in these buildings. In Scofield's (2009) analysis, he included the buildings that Newsham et al. (2009) considered outliers which would better explain the differences in their results for energy efficiencies.

Even though most studies focus on the actual energy performance of LEED buildings, there are other studies that look at both the predicted and actual energy performance of the building, following a Diamond et al. study from 2006. Stoppel and Leite (2013) compared predicted and actual energy performance and proposed a framework for evaluating the energy model through aggregated analysis. Through this framework these authors hoped to develop an aggregated analysis to identify potential error sources in the energy model. For this study, Stoppel and Leite looked at dormitory buildings because they wanted to focus on one building type and "to eventually compare multiple DoD LEED-Certified dormitories using the same method as the one presented in this paper" (Stoppel and Leite, 2013, pg 187). Dormitories were also selected as the building type because this building type had less variation in the size of each individual building. After finding buildings that met the criteria, the authors collected actual energy data and calculated the model's predictions. One important measure used for predicting energy usage includes variables related to meteorological conditions of the area. Most models of the type use typical meteorological year data, which is an average of the weather conditions in the area over a long period of time. This does not, obviously, account for weather extremes. These authors computed monthly heating degree days (HDD) and cooling degree days (CDD) from temperature readings and compared the calculations with the actual weather data sets acquired. Through the comparison Stoppel and Leite found the computed HDDs and CDDs to be fairly close to their actual weather data. These authors decided to use their computed HDDs and CDDs and not create another weather file for the actual data as the differences were not significant. Stoppel and Leite (2013) split the energy usage into multiple subgroups in order to better identify the actual energy use during heating and cooling seasons. To do this these authors obtained data from the public works department whose heating and cooling systems were implemented into the building to have the actual dates for the unit switching from heating to cooling and cooling to heating. The model underestimated the cooling season, therefore overestimating the heating season. This issue was one of the few model prediction errors that could easily be fixed by having more communication with the designers and builders during the planning phase. Another assumption made in the model was 100% occupancy, which is a good thing to have, but it certainly is possible to create a probability factor that would allow for a better representation of actual occupancy. Another problem was that the use of EUI did not allow the identification of areas in the model that might cancel each other out, creating more areas of possible change. Any model, no matter how well developed, will struggle with identifying what activities people will be performing throughout the day, and night, making it impossible for a perfect model for energy consumption because these variables simply do not systematically exist.

3.2 Occupancy Satisfaction and Health Benefits

There have been quite a few studies investigating occupant satisfaction using survey data from the Center for the Built Environment (CBE). A report presented at the Greenbuild Conference on occupancy satisfaction, held in November 2005 in Atlanta GA, looked at the satisfaction of those working in LEED buildings compared to those working in non-LEED buildings. Huizenga (2005) identified how LEED's Indoor Environmental Quality (IEQ) credits differ from those in the survey. LEED credits are assigned to thermal comfort, air quality, daylight and views, and controllability of systems. The satisfaction survey has eight categories, of these eight, four LEED categories cover only thermal comfort and air quality, and overlap with sections in the satisfaction survey database. Within this CBE survey database, there were 16 LEED buildings, and nine buildings are self-nominated green buildings. The median overall building satisfaction score is 1.11 on a scale of -3 to 3 where -3 means very dissatisfied and 3 means very satisfied. The median of non-green buildings is 1.08 while the green buildings median, including self-nominated buildings, is 1.39, showing that there is a difference in satisfaction, but the difference overall was not statistically significant. However, when looking at each section of the survey individually, LEED and self-nominated green building's higher scores were statistically significant for general building satisfaction, indoor air quality, and thermal comfort. The main conclusion is that LEED certification along cannot guarantee a better IEQ rating or a higher satisfaction rating than for non-green buildings (Huizenga et al. 2005).

Another report, by David Lehrer expands on the study by Huizenga et al. with results presented at the Greenbuild Conference in 2006. This study about green and LEED-certified building's occupant satisfaction is an ongoing study, now led by Stefano Schiavon and funded by the CBE Industry Consortium, in which researchers look into the effects of IEQ standards in LEED's credits and how these IEQ standards relate to the results of the CBE satisfaction survey (Schiavon, 2014-ongoing). The study compared occupant satisfaction of green and LEED buildings to that of other non-green buildings. A more recent study of LEED versus non-LEED buildings in occupant satisfaction found that LEED buildings indoor environmental quality is not significantly different from non-LEED buildings, even though previous studies found a significant relationship (Altomonte and Schiavon, 2013). Although many studies have focused on LEED versus non-LEED buildings, there have also been studies that compare the indoor environmental quality among LEED buildings. One of these studies focused on the IEQ differences of office types in US LEED buildings. For this study, these authors looked at five different office types from the view of employee satisfaction and job performance. The purpose of this study was to identify better office workspaces for each type of office in order to provide better workspaces for employees. LEED building data were collected from the CBE database from 2000 until March of 2007, the time of data acquisition. These authors analyzed data using descriptive statistics and ANOVA, finding that indoor air quality, thermal quality and lighting quality are key contributors to employee satisfaction and job performance (Lee and Guerin, 2010).

Along with studies about the indoor environmental quality of LEED buildings, there have been studies looking into health benefits of LEED buildings. There have been multiple studies on the effect of indoor environmental quality on the health of the employees. These studies range from looking at the effects of natural light on health and performance (Boyce et al. 2003; Heschong, 2003), to the general benefits of better indoor environments (Fisk, 2000; Singh et al. 2010). The idea of assuring better health from the creation of better indoor environments has been studied before LEED certification came out, and studies have found a significant relationship to indoor environmental quality and the health of the workers (Fisk and Rosenfeld 1997).

3.3 Spatio-temporal Analysis

Spatial, temporal and spatio-temporal analyses are important methods of analyzing and describe growth and data related to green buildings, and has been used in many other fields for many topics before the green building era. Spatio-temporal analysis is an important tool for many medical studies, including disease movement and rates as well as to better understand the body. One medical study, looking at male and female lung cancer risks through a spatio-temporal method, tried to combine issues and produce a joint analysis of male and female lung cancer risks (Richardson et al. 2006). Another study, looking at disease rates of lung cancer, used a modified spatio-temporal approach. Waller et al. (1997) used county data from 1968-1988 for Ohio, and expanded preexisting models to demonstrate this approach. Morkov chain Monte Carlo methods were used to implement the needed models as well as

Bayes methods to smooth out disease risk maps, and lessening variation in low-population areas. However, spatio-temporal analysis along with other spatial analytical methods have also become important methods for studying the green movement since the movement gained momentum in the 1990s.

As green buildings have grown in numbers and importance in the United States the study of green buildings became a topic of importance for the academic community. Understanding the growth of LEED-certified buildings, among other green building programs, became an important area of research in which spatial, temporal, and spatio-temporal methods are needed to understand the diffusion of these buildings over space and time. The study of green buildings through spatial analyses has arrived at some expected and some surprising results. Kaza et al. (2013) found that LEED buildings and Energy Star buildings both show clustered patterns, but these patterns are very different from one another. LEED buildings were usually located farther away from each other compared to Energy Star buildings. Much of this is due to the lower number of LEED buildings. However, even in census tract clusters of LEED buildings, Energy Star clusters were significantly larger, showing a more compact relationship among Energy Star buildings. These researchers also noticed that LEED and Energy Star buildings tend to be closer together. This interaction is evidence of a spillover effect in green building certification

(Kaza et al. 2013). This spillover effect was also questioned at the end of Kahn and Vaughn's (2009) article that focused on the clustering of hybrid vehicles and LEED registered buildings. This article is a two part study, one part focuses on hybrid vehicles, and the other on LEED buildings. Kahn and Vaughn (2009), too, realized that there seems to be a possible spillover effect with green buildings and hybrid vehicles, but were unable to test this effect at the time.

Many studies focus on spatial variation within LEED-homes and buildings, specifically the New Construction certification for LEED or LEED-NC. One such study found that builders and planners were using different sections of the LEED rating system more predominantly depending on the site and situation of the project. Although Pyke et al. (2012) did not have data to analyze the effect of regional circumstances on LEED building criteria, Pyke et al. (2012) hypothesized that multiple factors could play a role in spatial variations, including public policy, culture, and economics of the area. Cidel and Beata's (2009) study focuses on LEED-NC buildings and their spatial variation by certification category. Using a mix of spatial mapping, and statistical methods, the authors find that the six general categories showed little variation compared to 11 spatially oriented categories, which was expected. Analyzing the general categories in groups the authors noticed that Sustainable Sites (SS), Water Efficiency (WE), and Energy & Atmosphere (EA) showed clustering with each other while Materials and Resources (MR), Indoor Environmental Quality (IEQ), and Innovation & Design Process (ID) clustered together. This clustering shows a possible link between focusing on the spatial factors of the building process, using SS, WE, and EA categories, and focusing on building specific factors, using MR, IEQ and ID categories (Cidel and Beata, 2009).

CHAPTER 4

DATA AND METHODOLOGY

4.1 Data

The data obtained for this study is secondary archived data collected from multiple sources. All data is within the governmental bounds for the Great Lakes region as designated by the National Archives and the US General Services Administration, which includes Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. The LEED-certified buildings dataset was retrieved from the USGBC database that keeps track of buildings that applied for LEED certification, and are updated with certification level when the process is completed. At the time of data collection, there were 1040 LEED buildings that have received a rating of certified or higher within the study area. Demographic data at the city level was obtained from the US Census Bureau, and corresponded with each city in which there was at least one LEED-certified building within the city limits. Climate data used in this study was found on the National Center for Environmental Information (NCEI), formerly NCDC, a site powered by the National Oceanic and Atmospheric Administration (www.ncei.noaa.gov).

Before the analysis could start all data needed to be organized into datasets. These data were organized into two different datasets, one contained each individual LEED-certified building and the climate and demographic data was added to the corresponding city where the buildings was located. The second dataset focused on the city level, which requires consolidation of LEED-certified buildings by city, and then added demographic and climate data based on the corresponding city. In both datasets, there were gaps after the first stage of organization, as many smaller towns did not have their own weather station associated with NOAA, and some of the major cities had multiple weather stations within the city. In order to match the correct climate information with the nearest LEED building it was required that these data be added to ArcGIS 10.2. In order to create a layer for the LEED buildings the dataset was geocoded through ESRI's ArcGIS geocoder to give the building addresses geographic coordinates (ArcGIS 10.2, 2013). Once the LEED building data was geocoded and put into a unique layer, the weather station dataset was geocoded by the XY coordinates within he dataset to create the weather data layer. Once these layers were created, the spatial join tool (ArcGIS 10.2, 2013) was used to match climate data to the nearest LEED building, allowing data for each weather station to be added to multiple LEED building locations to ensure nearest distance, and better climate variable accuracy. Each LEED building was assigned the closest weather station. For the city dataset, the weather station matches were taken from the LEED building dataset. For cities containing multiple weather stations, data for the weather station that was closest to all the buildings on average was used. This could be determined by finding the distances from each building to each weather station and then averaging the total distance by the number of buildings in the city. Once built, these two datasets were transferred to SPSS for statistical analysis.

4.2 Methodology

To better visualize the data, tables and bar graphs were created in Excel showing changes in LEED home numbers through distinct time periods. From there data were transferred into SPSS where the rest of the analysis would take place. First descriptive statistics were computed for data at both the state and city level to identify the mean, maximum, minimum, and standard deviation of the two datasets. After the descriptives were derived, independent climate and socio-environmental variables were graphed to identify differences within the variables. One-way ANOVA and crosstabulation analysis was conducted to analyze the significance of specific variables. Correlations were also computed using the created datasets to identify any associations between LEED-certified homes and the climate and socio-environmental variables. This step was followed by multivariate regression analysis. Finally OLS multiple regression residuals were computed at the city level to identify if potential policies related to tax or building code policies would correlate with LEED home locations.

Chapter 5

RESULTS

Analysis of the LEED dataset revealed some interesting results reflecting reasons for the spatial distribution of LEED-certified housing. Tables 5.1 and 5.2 show the number of LEED-certified homes by state and city level respectively. These tables also show when LEED-certified homes were constructed over the three time periods discussed earlier in the thesis. The early period was designated as 2008-2009 because the Homes rating system of LEED certification started in 2008, and in 2009 people were still getting used to it. The middle period of 2010-2013 include the years with at least 100 new certified homes each year. The 2014-2015 period is the most recent with homes built in 2014 along with a few homes certified in 2015. Bar charts were also created to better visualize the data at both the state and city level. To differentiate the time periods black signifies the early years, blue the middle years, and purple represent the recent years (Figures 5.1 and 5.2). Table 5.1 shows Michigan and Ohio were the early adopters of LEED-certified homes in the Great Lakes States while consumers in the other states did not fully embrace LEED homes until the middle years of the LEED homes rating system. In Table 5.2 and figure 5.2 it is clearly visible that Cincinnati, OH, and Grand Rapids, MI, were the forerunners of LEED in the Great Lakes states, as they are the only two of the top ten cities to have LEED-certified homes at the beginning of the LEED Homes rating system. Figure 5.2 also shows that residents of Havana, IL, Greenwood, IN, Chicago, IL, and Fulton, MI, have been more recent investors in LEED-certified homes. These cities started building homes between 2010 and 2013, and three of these four had more homes built from January 2014 to March 2015. The most interesting of these four cities is Fulton, MI, as the LEED-certified homes are being built by the Nottawaseppi Huron Band of the Potawatomi, a Native American government.

Table 5.1: Number of Certified LEED Homes by State and Time Period

	Early Years: 2008-2009	Middle Years: 2010-2013	Recent Years: 2014-2015
Illinois	0	24	51
Indiana	4	81	49
Michigan	25	226	37
Minnesota	4	35	13
Ohio	15	383	75
Wisconsin	2	13	5

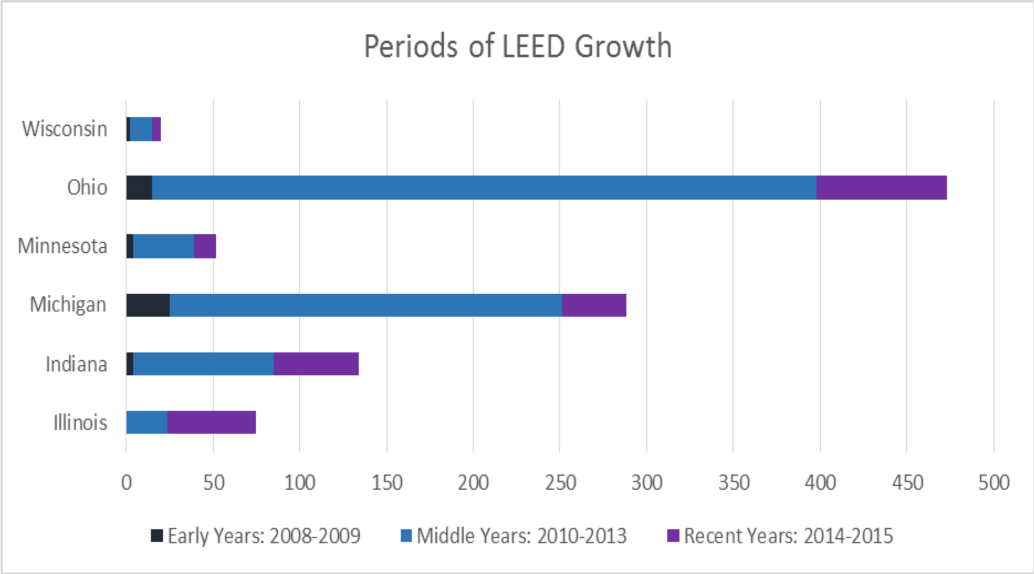

Figure 5.1: Number of LEED Homes by State and Time Period.

Table 5.2: Number of LEED Homes by City and Time Period

Table of the 10 cities with the most LEED homes organized by time period.

	Early Years: 2008-2009	Middle Years 2010-1013	Recent Years: 2014-1015
Columbus, OH	0	218	1
Cinicinati, OH	13	122	57
Grand Rapids, MI	15	75	15
East Lansing, MI	0	67	0
Havana, IL	0	0	40
Gambier, OH	0	16	12
Linton, IN	0	21	0
Greenwood, IN	0	1	17
Chicago, IL	0	8	9
Fulton, MI	0	8	6

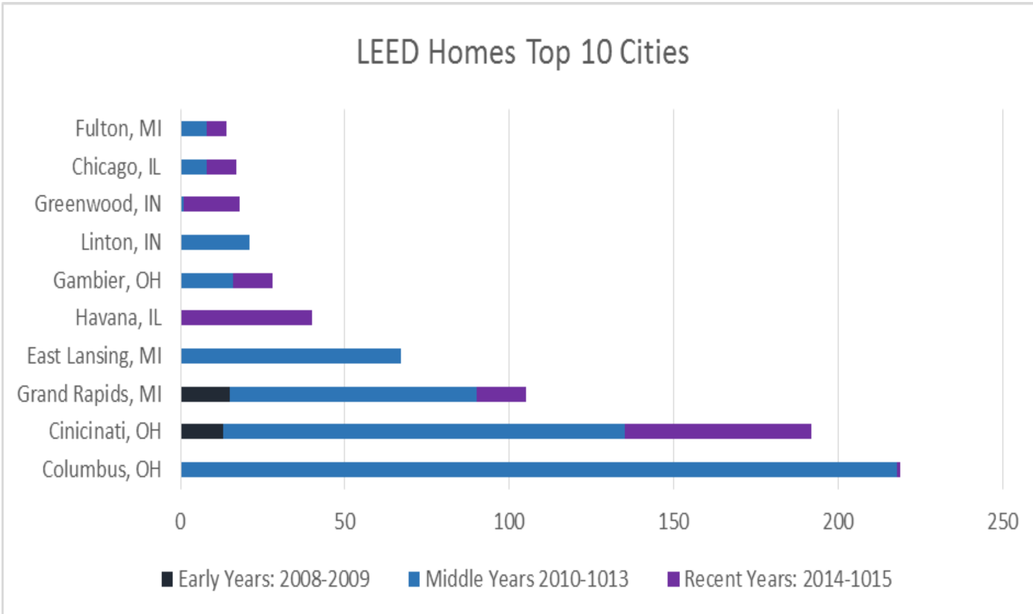

Figure 5.2: Number of LEED Homes by City and Time Period

Tables 5.3 and 5.4 show the descriptive statistics of acquired data for individual buildings and city-level respectively. Table 5.3 includes both individual level data and city level data while all of the data in table 5.4 is at the city level. These tables show the mean, maximum, minimum, and standard deviation of the two datasets for each variable.

Table 5.3: Individual Building Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
population	1039	152.00	2695598.00	318247.43	426335.74
Total_area_per_sqmi	1039	0.19	373.05	83.56	88.56
Water_area_per_sqmi	1039	0.00	118.32	2.43	6.20
Percent_water	1039	0.00	0.68	0.03	0.05
Land_area_per_sqmi	1039	0.18	366.46	81.12	86.20
Pop_density_per_sqmi	1039	7.60	11841.80	3286.13	1664.76
Housing_density_per_sqmi	1039	4.20	5246.70	1493.99	802.99
Average_Annual_Temperature	1039	37.90	57.30	51.00	2.66
Heating_Degree_days	1039	4379.00	9974.00	5950.87	799.97
Cooling_Degree_days	1039	44.00	1576.00	792.68	257.64
Certification_Year	1039	2008	2015	2012	1.46
Certification_Level	1039	1.00	4.00	2.34	0.76

Table 5.4: City-level Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Number_LEED_Houses	144	1.00	219.00	7.28	26.22
Average_Certification_Level	144	1.00	4.00	2.83	0.86
Average_Certification_Year	144	2008	2015	2012	1.53
Population	144	152.00	2695598.00	82345.90	257560.01
Leed_Buildings_per1000population	144	0.00	12.12	0.66	1.73
Total_area_per_sqmi	144	0.19	373.05	27.33	48.89
Water_area_per_sqmi	144	0.00	118.32	2.14	11.07
Percent_water	144	0.00	0.68	0.05	0.10
Land_area_per_sqmi	144	0.18	366.46	25.19	45.61
Pop_density_per_sqmi	144	7.60	11841.80	2484.03	1876.94
Housing_density	129	4.20	5246.70	1087.31	856.01
Elevation	143	132.60	500.80	245.12	56.89
Average_Annual_Temperature	143	37.90	57.30	48.88	3.33
Heating_Degree_days	143	4379.00	9974.00	6613.80	1003.89
Cooling_Degree_days	143	44.00	1576.00	695.35	264.00
Leed_Buildings_per_sqmi	144	0.01	29.79	0.92	2.94
Leed_Buildings_per_sqmTOTAL	144	0.01	29.79	0.90	2.91

A one-way ANOVA analysis for comparison of means for a series of independent variables at the state level was used to compare seven state dependent variables and their relationship with the LEED homes with respect to location in each of the six states (Cronk, 2010). Table 5.5 shows that each of the seven variables used in the analysis has a significance level of 0.0001 so there is a difference in the density of LEED homes across the states. For all seven of these variables, there are clear differences across these variables. LSD post-hoc tests were performed to identify which states within each variable were significant when compared against the other states. The results of the LSD post-hoc tests can be found as Appendix B.

Table 5.5: One-way ANOVA Results Table

		Sum of Squares	df	Mean Square	F	Sig.
Percent_water	Between	0.18	5.00	0.04	15.09	.000
	Within	2.48	1033.00	0.00		
	Total	2.66	1038.00			
Population_density	Between	398023365.32	5.00	79604673.06	33.18	.000
	Within	2478704046.88	1033.00	2399519.89		
	Total	2876727412.21	1038.00			
Housing_density	Between	111421549.68	5.00	22284309.94	41.26	.000
	Within	557880848.61	1033.00	540058.90		
	Total	669302398.29	1038.00			
Average_Annual_ Temperature	Between	5346.45	5.00	1069.29	555.13	.000
	Within	1989.75	1033.00	1.93		
	Total	7336.20	1038.00			
Heating_Degree_days	Between	509062091.87	5.00	101812418.37	677.61	.000
	Within	155211451.07	1033.00	150253.10		
	Total	664273542.94	1038.00			
Cooling_Degree_days	Between	16181190.20	5.00	3236238.04	63.41	.000
	Within	52719259.49	1033.00	51035.10		
	Total	68900449.69	1038.00			
Certification_ year	Between	122.85	5.00	24.57	12.22	.000
	Within	2076.90	1033.00	2.01		
	Total	2199.76	1038.00			

An OLS multiple linear regression was generated using the 144 city sample to predict LEED housing per square mile values based on temperature, heating degree days, certification year, population density and housing density. OLS linear multivariate regression was performed at the city level to compare five independent variables and their relationship with LEED homes density per square mile. These variables were selected based on my review of the literature as well as my own ideas regarding the distribution of LEED-certified homes. The multiple regression differences in means that resulted in an F value of 4.940 which is statistically significant at 0.0001 (Table 5.6). Each of the predictor variables are all significant at the 0.05 level or better, but the OLS regression model only has an adjusted R Square value of 0.134 (Table 5.7). This shows that only 13.4% of differences in LEED housing rates per square mile can be explained by these five variables. All five of these predictors were significant as the model was built to incorporate only significant variables (Cronk, 2010). The model is as follows: Number of LEED-certified homes per square mile = -679.674 + -1.546(Temperature) + -0.006(Heating degree days) + 0.394(Certification Year) + 0.002(Population density) + -0.006(Housing density).

Comparing the standardized coefficients for these variables also show several interesting results. The two most influential variables when standardized betas are compared are heating degree days and temperature (-1.891 and -1.734 respectively) (Table 5.8). The result from temperature shows that as the average temperature increases the density of LEED houses decreases, as they are inversely related. Heating degree days also shows an inverse relationship with LEED home density, but this variable shows the average number of days used to heating homes. These two variables predict that LEED home density will be in mild climate regions where the temperature and heating degree day variables intersect. Another interesting result of the standardized variables relate to the population density and housing density of the 144 cities included in the analysis. Housing density has an inverse relationship to LEED home density with a standardized coefficient of -1.550, but population density has a positive relationship with LEED home density with a standardized coefficient of 1.400. LEED home density locations seem to be higher in locations with multifamily complexes, allowing for a higher population density with a lower housing density.

Table 5.6: City-level Regression

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	200.421	5	40.084	4.940	.000[b]
	Residual	989.933	122	8.114		
	Total	1190.354	127			

a. Dependent Variable: Leed_Buildings_per_sqmTOTAL

b. Predictors: (Constant), Housing_un, Average_Certification_Year, Heat_Deg_day, pop_per_sq, Ave_Ann_T

Table 5.7: City-level Regression Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.410[a]	.168	.134	2.84854

a. Predictors: (Constant), Housing_un, Average_Certification_Year, Heat_Deg_day, pop_per_sq, Ave_Ann_T

b. Dependent Variable: Leed_Buildings_per_sqmTOTAL

Table 5.8: City-level Regression Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-679.674	353.101		-1.925	.057
	Ave_Ann_T	-1.546	.711	-1.734	-2.175	.032
	Heat_Deg_	-.006	.002	-1.891	-2.375	.019
	Average_Certification_Y	.394	.174	.192	2.262	.025
	pop_per_sq	.002	.001	1.400	3.406	.001
	Housing_un	-.006	.001	-1.550	-3.786	.000

a. Dependent Variable: Leed_Buildings_per_sqmTOTAL

Crosstabulation analysis using the χ^2 test statistic at the city level was also conducted to determine if LEED-certified homes were constructed in different time periods for each state. The cities were assigned a time period based on the average year of LEED home construction, for example a city in period 2 had an average construction year of 2010 or 2011. This analysis did not show any statistically significant results (see Appendix C). Figure 5.3 shows the number of cities within each time period and are color coded by state. The time periods were split every two years, starting in 2008 and ending in 2015 (2008-09 = 1, 2010-11=2, 2012-13=3, 2014-15=4).

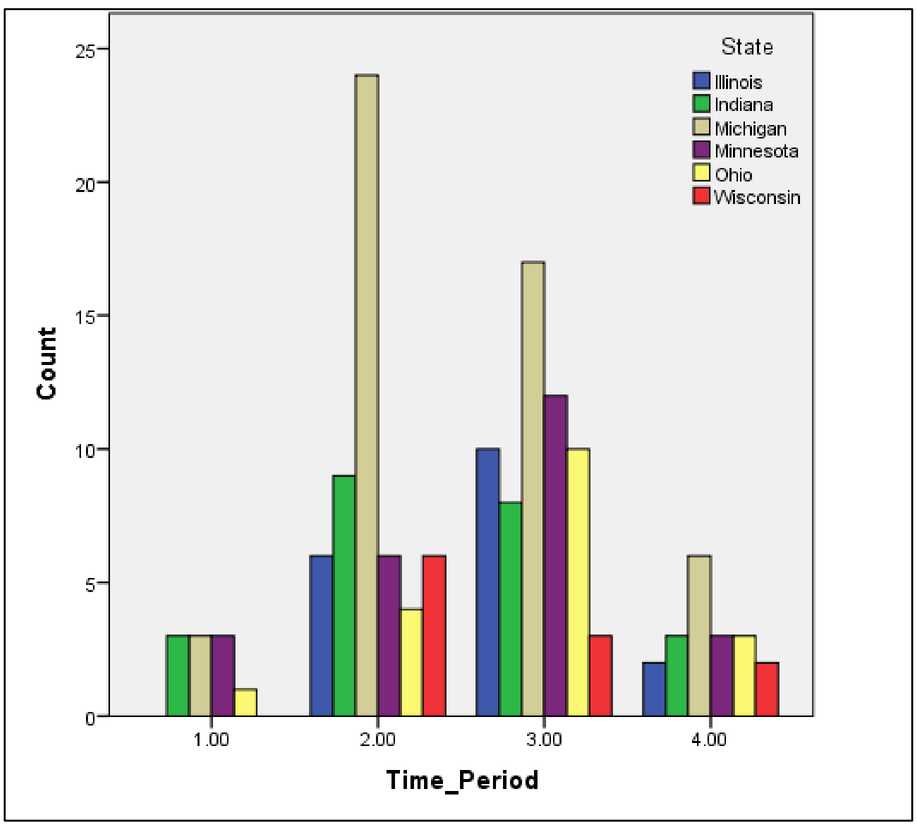

Figure 5.3: Number of Cities LEED Homes by State and Time Period.

The building-level crosstabs analysis using the χ^2 test statistic was conducted twice with state location being the constant factor in both tests. Certification level and year of certification were the two variables that were paired with state location for the crosstabulation analyses (Tables 5.9 and 5.11). Pearson's χ^2 test was performed with each of these crosstabulations to identify statistical significance. The state and certification level χ^2 test showed a significance value of 0.0001 with 15 degrees of freedom (Table 5.10). The actual and expected values from the crosstabulation showed some interesting results (Table 5.9). For the state of Michigan the expected value for level 1 certification is about five times higher than what is reported in the dataset. At the highest level of certification Michigan is only expected to have 28 homes, but the state has 48 level four homes. In contrast Ohio has 63 homes at level 1 certification, while the expected is 35, and 15 level 4 homes with the expected value being 47. The extreme contrast between these two states could be because of how strict the standards are within the states or if the state wants to have a higher quality of LEED homes rather than a higher quantity.

The χ^2 test for the state and certification year was also statistically significant with 35 degrees of freedom and a significance value of 0.0001 (Table 5.12). In the crosstabulation table for certification year, table 5.10, there the numbers do not show too many surprising results. The two most surprising results from this table are from Illinois and Indiana. In both of these states the expected number of LEED homes in 2012 are much higher than the actual numbers, and both have much higher numbers of LEED homes in 2014 over the expected value. These results show that both of these states took much longer to build LEED homes than what was expected. Figure 5.4 shows the number of homes at each certification level organized by state. Figure 5.5 shows the counts for homes certified by year and split up by state.

Table 5.9: Pearson's χ^2 Test for Certification Level

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	177.260[a]	15	.000
Likelihood Ratio	180.378	15	.000
Linear-by-Linear Association	40.229	1	.000
N of Valid Cases	1039		

a. 4 cells (16.7%) have expected count less than 5. The minimum expected count is 1.48.

Table 5.10: Pearson's χ^2 Test for Certification Year

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	459.570[a]	35	.000
Likelihood Ratio	447.833	35	.000
Linear-by-Linear Association	6.662	1	.010
N of Valid Cases	1039		

a. 17 cells (35.4%) have expected count less than 5. The minimum expected count is .13.

Table 5.11: Crostabulation for Certification Level

			Cert_lvl				Total
			1	2	3	4	
State_ID	Illinois	Count	2	51	12	10	75
		Expected	5.6	45.5	16.5	7.4	75.0
	Indiana	Count	5	91	27	11	134
		Expected	9.9	81.3	29.5	13.3	134.0
	Michigan	Count	4	130	102	49	285
		Expected	21.1	172.8	62.8	28.3	285.0
	Minnesota	Count	2	20	19	11	52
		Expected	3.9	31.5	11.5	5.2	52.0
	Ohio	Count	63	333	62	15	473
		Expected	35.1	286.8	104.3	46.9	473.0
	Wisconsin	Count	1	5	7	7	20
		Expected	1.5	12.1	4.4	2.0	20.0
Total		Count	77	630	229	103	1039
		Expected	77.0	630.0	229.0	103.0	1039.0

Table 5.12: Crosstabulation for Certification Year

			year_								
			2008	2009	2010	2011	2012	2013	2014	2015	Total
State_ID	Illinois	Count	0	0	1	6	10	7	50	1	75
		Expected	.5	3.0	7.4	7.8	23.5	16.3	14.9	1.7	75.0
	Indiana	Count	0	4	31	24	3	23	49	0	134
		Expected	.9	5.3	13.2	13.9	41.9	29.1	26.7	3.0	134.0
	Michigan	Count	5	18	40	40	38	107	36	1	285
		Expected	1.9	11.2	28.0	29.6	89.1	62.0	56.8	6.3	285.0
	Minnesota	Count	0	4	3	9	8	15	9	4	52
		Expected	.4	2.1	5.1	5.4	16.3	11.3	10.4	1.2	52.0
	Ohio	Count	2	13	24	24	263	72	58	17	473
		Expected	3.2	18.7	46.4	49.2	148.0	102.9	94.2	10.5	473.0
	Wisconsin	Count	0	2	3	5	3	2	5	0	20
		Expected	.1	.8	2.0	2.1	6.3	4.4	4.0	.4	20.0
Total		Count	7	41	102	108	325	226	207	23	1039
		Expected	7.0	41.0	102.0	108.0	325.0	226.0	207.0	23.0	1039.0

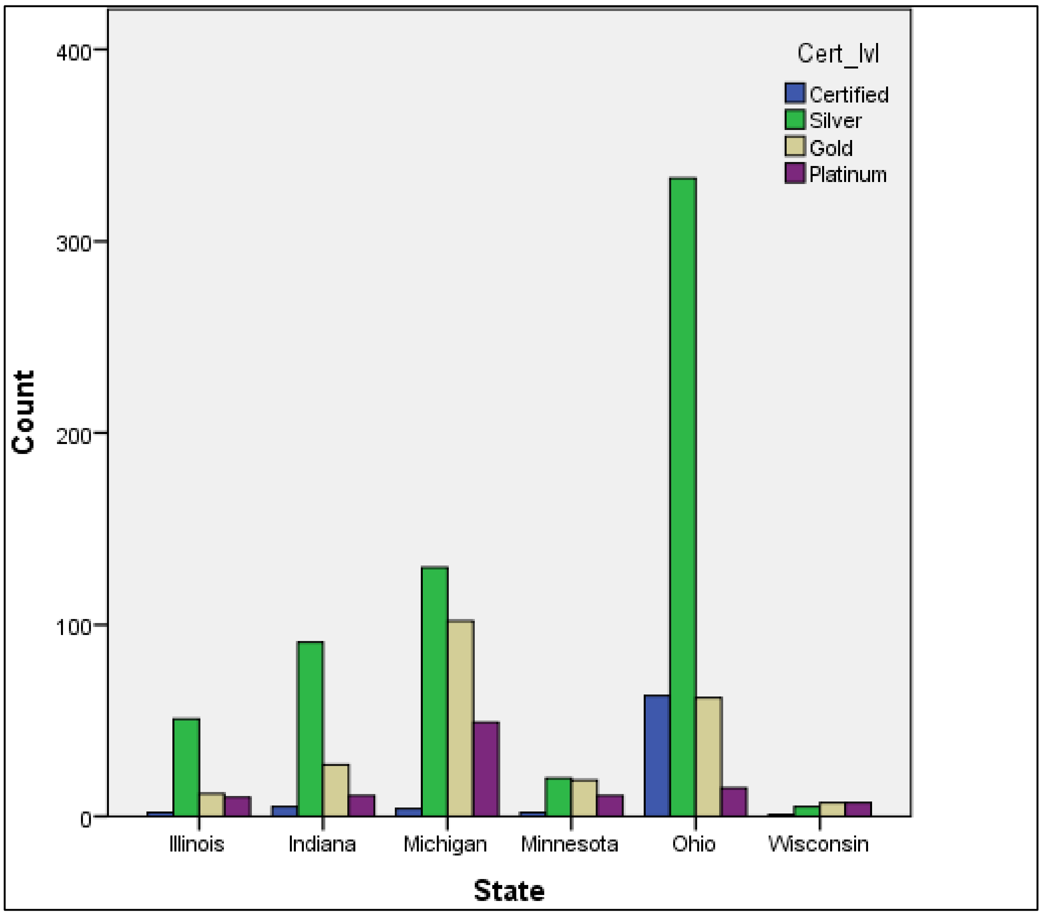

Figure 5.4: Number of Homes by Certification Level and State

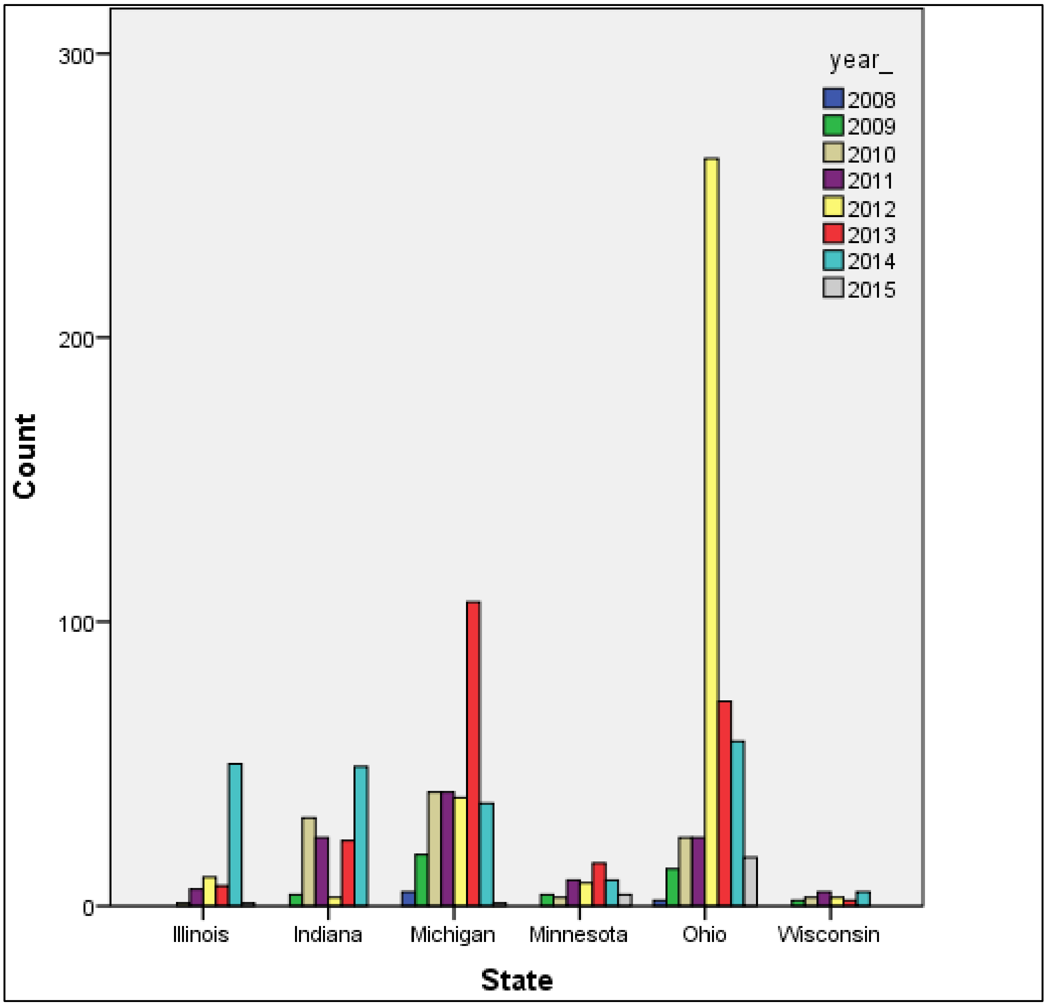

Figure 5.5: Number of Homes by Certification Year and State

Correlation analysis at the city level was also performed to identify any significant relationships between variables especially those not included in the regression analysis. With the city dataset there were three possible dependent variables LEED_Buildings_ per_sqmi, LEED_Buildings_per_sqmTotal, and LEED_Buildings_per1000_population. This analysis showed a strong relationship between the three variables as expected (Table 5.13). An interesting result found during analysis is that the average annual temperature has a slightly positive correlation, but the cooling degree days and heating degree days both showed a negative correlation with the dependent variables. This is an interesting result because a higher average temperature should correlate with more cooling degree days. Housing unit density and population density also showed slight negative correlation which is understandable as LEED Homes seems to be more focused in suburban growing areas and less on renovating houses within the city limits.

Table 5.13: Correlations at City-level (Full Table in Appendix D)

		Leed_Buildings_per_sqmi	Leed_Buildings_per_sqmTOTAL	Leed_Buildings_per1000_population
Leed_Buildings_per_sqmi	Pearson	1	.999**	.857**
	Sig. (2-		.000	.000
	N	144	144	144
Leed_Buildings_per_sqmTOTAL	Pearson	.999**	1	.850**
	Sig. (2-	.000		.000
	N	144	144	144
Leed_Buildings_per1000_population	Pearson	.857**	.850**	1
	Sig. (2-	.000	.000	
	N	144	144	144
Elevation	Pearson	-.022	-.016	-.010
	Sig. (2-	.793	.852	.907
	N	143	143	143
Ave_Ann_T	Pearson	.097	.097	.034
	Sig. (2-	.247	.249	.689
	N	143	143	143
Heat_Deg_day	Pearson	-.112	-.111	-.047
	Sig. (2-	.184	.187	.577
	N	143	143	143
Cool_Deg_day	Pearson	-.004	-.003	-.081
	Sig. (2-	.962	.973	.335
	N	143	143	143
Average_Certification_Year	Pearson	.140	.138	.146
	Sig. (2-	.094	.099	.081
	N	144	144	144
Housing_units_per_sqmi	Pearson	-.118	-.117	-.235**
	Sig. (2-	.182	.187	.007
	N	129	129	129
pop_per_sq	Pearson	-.066	-.064	-.223**
	Sig. (2-	.434	.450	.007
	N	144	144	144

Finally, a residual analysis using the OLS multivariate regression standardized residuals from the model reported earlier, was performed for the purpose of qualitatively seeking possible explanations for the patterns seen in the data. For this analysis only the city-level dataset was used. Table 5.14 shows the residual statistics for the dependent variable of LEED_Buildings_per_sqmTOTAL. The maximum residual for this variable is 23.17, but because it is so high there is a chance of this dataset having at least one outlier. Figure 5.6 shows a scatterplot of the residuals identifying that there are two possible outliers in this dataset. A histogram was created after dropping the two highest values (14.6 and 29.79) as they are considered as outliers (Figure 5.7). Figure 5.8 depicts the mapped residuals in the study area to better identify patterns (residuals table in Appendix E). Figure 5.8 shows four distinct clusters of LEED homes showing that there are some variables that effect LEED home adoptions that are spatially dependent. The cluster of cities in central Illinois contains mainly negative residuals meaning that these homes are above the average and require a decrease in value to reach the expected value. The cluster in eastern Minnesota is composed of mostly positive residuals showing that these homes are below the expected rates of adoption. The cluster in eastern Michigan is composed of two main groups, one with mainly positive residuals and other with negative residuals. Finally the cluster on the west coast of Michigan also shows a mix for expected values of LEED homes with some above and some below expected values. This study has a mix of surprising and expected results, and although these results do not help to identify major drivers in LEED-certified home locations, they can be utilized in future research in this field.

Table 5.14: Residual Statistics

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-2.8605	6.6132	.9275	1.25623	128
Residual	-3.11307	23.17402	.00000	2.79191	128
Std. Predicted Value	-3.015	4.526	.000	1.000	128
Std. Residual	-1.093	8.135	.000	.980	128
a. Dependent Variable: Leed_Buildings_per_sqmTOTAL					

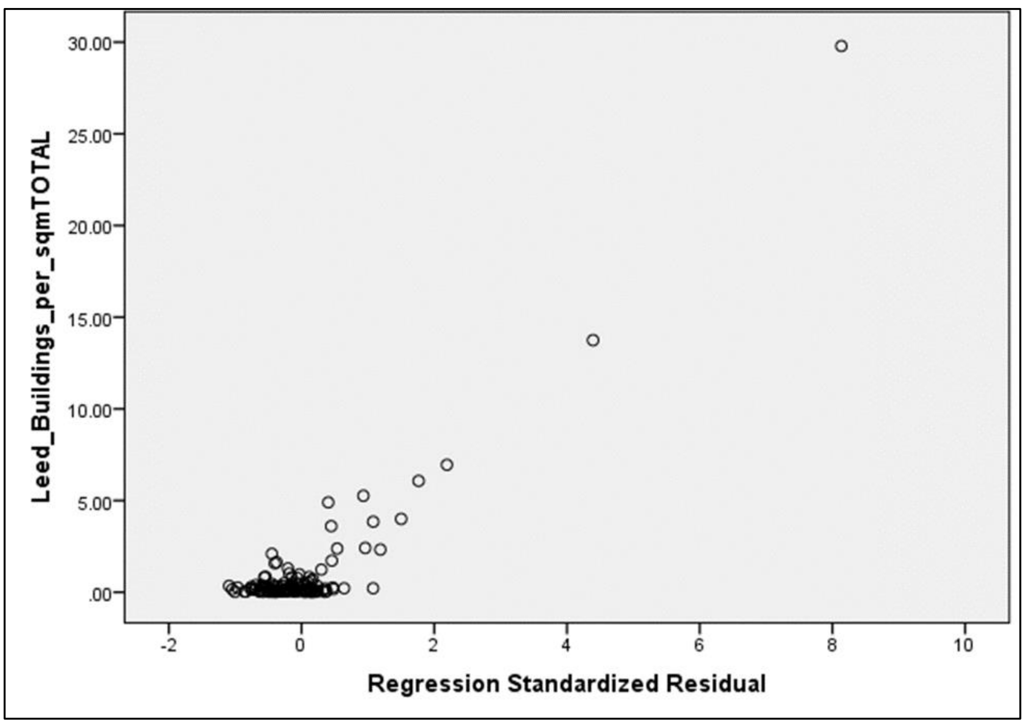

Figure 5.5: Residuals Scatterplot (14.6 and 29.79 outliers excluded)

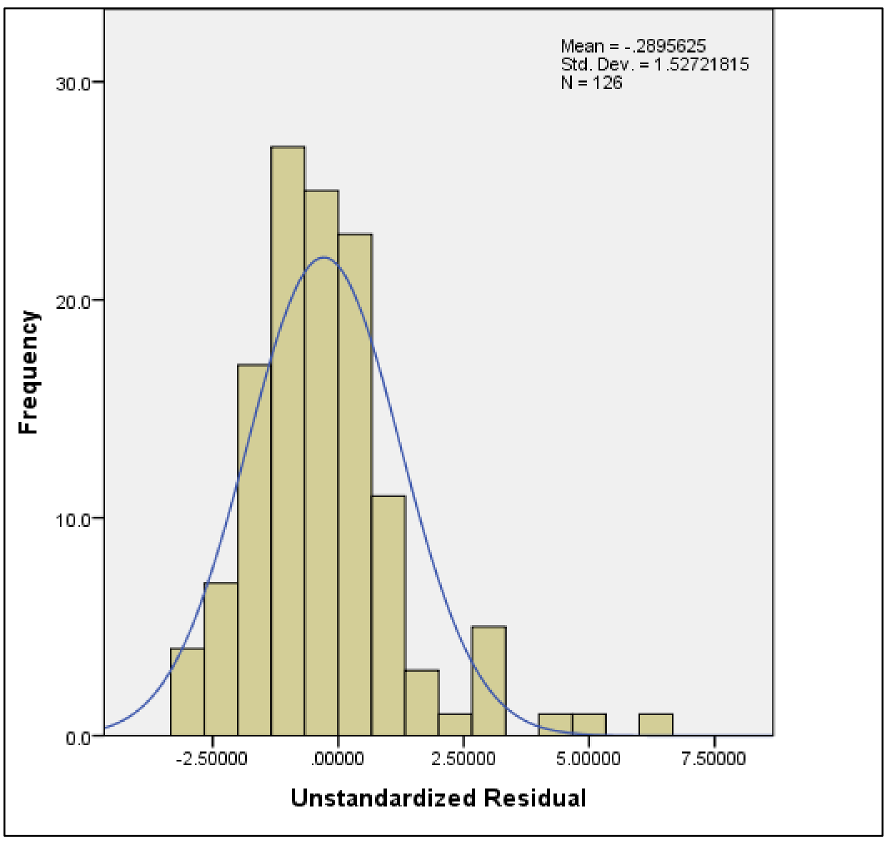

Figure 5.6: Residuals Histogram (14.6 and 29.79 outliers excluded)

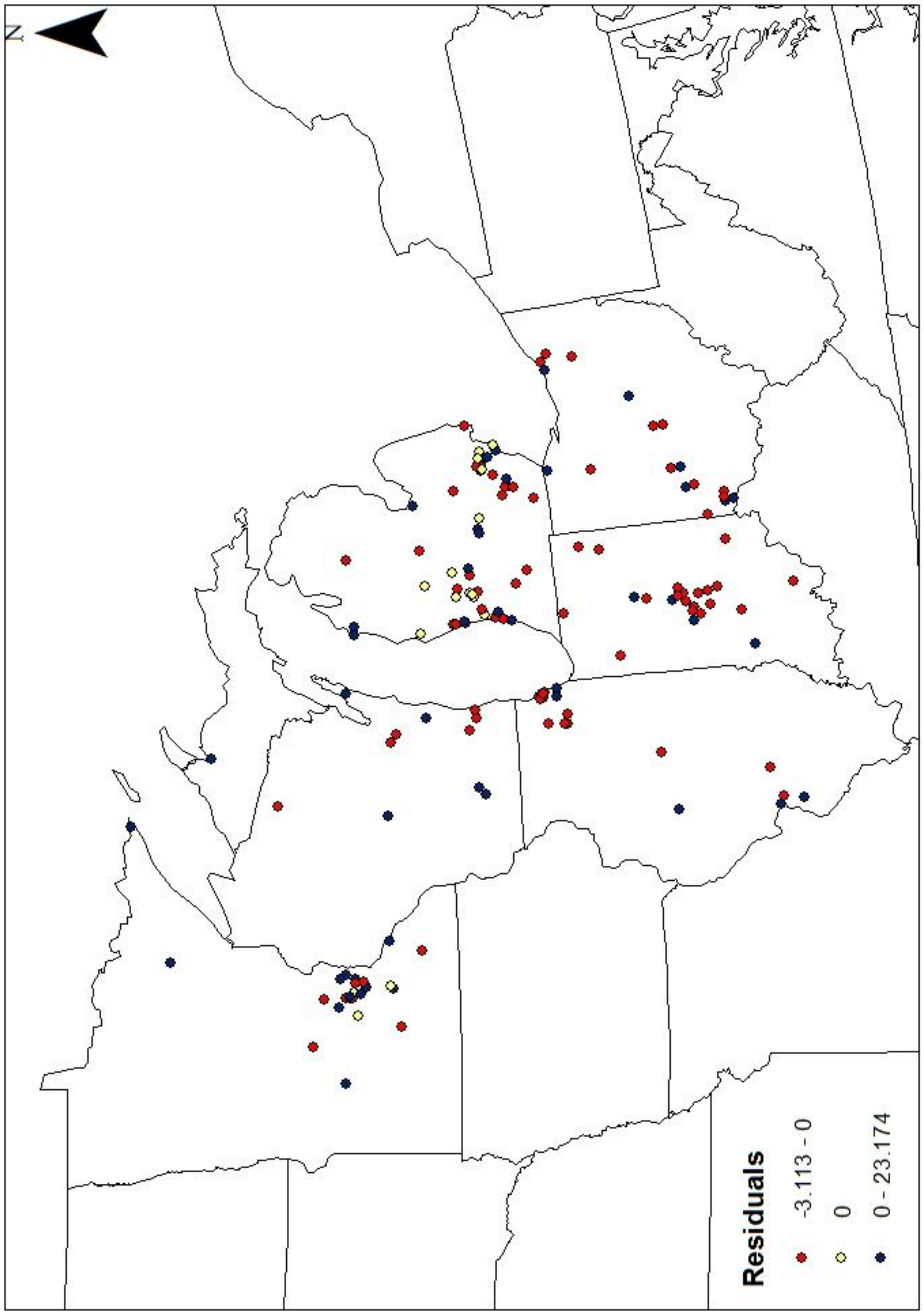

Figure 5.8 Map of Residuals
Projection: USA Contiguous Lambert Conformal Conic

CHAPTER 6

DISCUSSION AND CONCLUSION

6.1 Discussion

This study has shown that, at least for the Great Lakes states, climate does not have the significant impact on LEED home locations that has been suggested in the literature, but different results could be found at a different location or at on a different scale. Although the climate of an area is one way to earn credits for LEED certification, the climatic factors of average annual temperature, heating degree days, and cooling degree days do not have statistical significance at the building level, and minimal significance at the city level when all the LEED-certified homes are aggregated to the city level. The socio-environmental factors related to population and home density per square mile show a statistically significant impact on LEED home locations, but these and the climate variables only explain around 13% of the total spatial-temporal variance of the location of LEED homes in the Great Lakes region. While knowing that these two factor groups have minimal significance on LEED-certified home locations as a whole, the residuals show that there is a spatial pattern of LEED home adoption at the city level. This could be explained by local tax incentives and other government promotions that have been put in place at the state and city level. Political factors might also explain the extreme growth of LEED homes that started a couple years after the system was launched as political regulations take time to be adopted.

As with all research there are factors that could have influenced the results of this study. One of these problems is the completeness and accuracy of the dataset. Data from USGBC.org are maintained mainly by construction firms seeking LEED certification for homes they construct or renovate. This is a problem because there could be many more homes added to the dataset that have been certified, but other potential LEED homes were either not added to the database or the database was not updated once certification was issued. Not knowing if the uncertified homes are actually certified causes problems when performing research on certified buildings. Combining data from multiple sources also creates problems with complete data. When combining data, the problem of having missing data for an area is a concern as it requires a decision to be made as to whether to use that observation or to remove it from the dataset. When merging three different datasets into one dataset, this problem becomes a real concern and this issue can be seen within my statistical analysis as not all homes could be included for every analysis because of missing information. Another possible issue when building the dataset was the calculations that had to be made throughout the process. As the dataset grows, the chances of researcher error increases. It is uncertain what errors there could be within the dataset, but any error that was not found throughout the process potentially effected the overall outcome of the study.

Future research in this area could analyze the effect of climate and socio-environmental factors using different rating systems, different climate variables, at different scales, or in different regions of the United States. Also incorporating other potential variables, such as tax policies and other economic or socio-cultural factors, and education, within this same region could identify additional possible predictors of LEED homes that have a greater effect than the two groups of variables used in this study.

6.2 Conclusion

In closing, this study shows that LEED home adoptions in the Great Lakes region are not driven by climatic factors, and are minimally affected by socio-environmental factors. Through ANOVA, multivariate regression, Pearson's product moment correlation, and crosstabulation analysis, the variables were tested to identify the significance of each variable to LEED home density as well as what percent of the LEED home locations can be predicted by these variables. Through multivariate regression it was found that the most important variables identified through my literature search only explain about 13% of the location of LEED homes in the Great Lakes region. Even though the effect of these variables is small the residuals show that there is, however, a pattern. These two groups of factors have minimal weight in LEED home locations, but this shows that there are other factors have a greater influence on LEED home locations, with political or policy incentives being possible variables.

APPENDICES

Appendix A: Variable Definitions

Fields	Description	Units
FID	Field ID number	
State_Dummy_1	If State = Illinois: 1 All else: 0	
State_Dummy_2	If State = Indiana: 1 All else: 0	
State_Dummy_3	If State = Michigan: 1 All else: 0	
State_Dummy_4	If State = Minnesota: 1 All else: 0	
State_Dummy_5	If State = Ohio: 1 All else: 0	
State_ID	ID number given for each state (Illinois=1, Indiana=2, Michigan=3, Minnesota=4, Ohio=5, Wisconsin=6)	
City_ID	ID number for each city within the state (1-_)	
Project_ID	ID number for each project within the state (1-_)	
ID	ID number for each individual project (merges State_ID, City_ID, and Project_ID	
project_na	Name of Project on USGBC.org	
Address	Location of the project	
Certificat	Date of Certification	
Certification Year	Year of Certification	
City	City that the project is located in	
State	State that the project is located in	
Country	Country pojects are located in (United States)	
Latitude	Latitudinal coordinates of each project	
Longitude	Longitudinal coordinates of each project	
Certific_1	Certification Level achieved (Certified=1, Silver=2, Gold=3, Platinum=4)	
population	Population of the City	
Total_area	Total area of the City	Sqmi
Water_area	Cities total water area	Sqmi
Percent_wa	Percent of city area that is water	Percent
Land_area_	Cities total land area	Sqmi
pop_per_sq	Population per Land_Area	Sqmi
Pop_densit	Population density	Sqmi
Housing_un	Housing unit density	Sqmi
Station	Weather station number	
Lat	Latitudinal coordinates of station	degrees
Long_	Longitudinal coordinates of station	degrees
Elevation	Elevation of the station	feet
Location	City that the station is located in	
Ave_Ann_T	Average Annual Temperature	Fahrenheit
Heat_Deg_day	Average Annual Heating Degree Days	kWh
Cool_Deg_day	Average Annual Cooling Degree Days	kWh

Appendix B: LSD Post-hoc Test Results

Multiple Comparisons

LSD

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Percent_water	Illinois	Indiana	.03253*	.00707	.000	.0187	.0464
		Michigan	.00788	.00636	.216	-.0046	.0204
		Minnesota	-.02490*	.00885	.005	-.0423	-.0075
		Ohio	.01839*	.00609	.003	.0064	.0303
		Wisconsin	-.01991	.01234	.107	-.0441	.0043
	Indiana	Illinois	-.03253*	.00707	.000	-.0464	-.0187
		Michigan	-.02465*	.00514	.000	-.0347	-.0146
		Minnesota	-.05743*	.00801	.000	-.0731	-.0417
		Ohio	-.01415*	.00480	.003	-.0236	-.0047
		Wisconsin	-.05244*	.01175	.000	-.0755	-.0294
	Michigan	Illinois	-.00788	.00636	.216	-.0204	.0046
		Indiana	.02465*	.00514	.000	.0146	.0347
		Minnesota	-.03278*	.00739	.000	-.0473	-.0183
		Ohio	.01051*	.00368	.004	.0033	.0177
		Wisconsin	-.02779*	.01134	.014	-.0500	-.0055
	Minnesota	Illinois	.02490*	.00885	.005	.0075	.0423
		Indiana	.05743*	.00801	.000	.0417	.0731
		Michigan	.03278*	.00739	.000	.0183	.0473
		Ohio	.04329*	.00716	.000	.0292	.0573
		Wisconsin	.00499	.01290	.699	-.0203	.0303
	Ohio	Illinois	-.01839*	.00609	.003	-.0303	-.0064
		Indiana	.01415*	.00480	.003	.0047	.0236
		Michigan	-.01051*	.00368	.004	-.0177	-.0033
		Minnesota	-.04329*	.00716	.000	-.0573	-.0292
		Wisconsin	-.03829*	.01119	.001	-.0603	-.0163
	Wisconsin	Illinois	.01991	.01234	.107	-.0043	.0441
		Indiana	.05244*	.01175	.000	.0294	.0755
		Michigan	.02779*	.01134	.014	.0055	.0500
		Minnesota	-.00499	.01290	.699	-.0303	.0203
		Ohio	.03829*	.01119	.001	.0163	.0603

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Pop_density	Illinois	Indiana	2398.80517*	223.38412	.000	1960.4668	2837.1436
		Michigan	1071.58281*	201.02977	.000	677.1095	1466.0561
		Minnesota	881.51244*	279.53213	.002	332.9968	1430.0280
		Ohio	659.14599*	192.52683	.001	281.3577	1036.9343
		Wisconsin	1463.77667*	389.83278	.000	698.8222	2228.7311
	Indiana	Illinois	-2398.80517*	223.38412	.000	-2837.1436	-1960.4668
		Michigan	-1327.22237*	162.25361	.000	-1645.6066	-1008.8381
		Minnesota	-1517.29274*	253.08393	.000	-2013.9100	-1020.6755
		Ohio	-1739.65918*	151.59105	.000	-2037.1207	-1442.1977
		Wisconsin	-935.02851*	371.32581	.012	-1663.6675	-206.3896
	Michigan	Illinois	-1071.58281*	201.02977	.000	-1466.0561	-677.1095
		Indiana	1327.22237*	162.25361	.000	1008.8381	1645.6066
		Minnesota	-190.07037	233.58934	.416	-648.4341	268.2934
		Ohio	-412.43682*	116.15657	.000	-640.3666	-184.5071
		Wisconsin	392.19386	358.32299	.274	-310.9301	1095.3178
	Minnesota	Illinois	-881.51244*	279.53213	.002	-1430.0280	-332.9968
		Indiana	1517.29274*	253.08393	.000	1020.6755	2013.9100
		Michigan	190.07037	233.58934	.416	-268.2934	648.4341
		Ohio	-222.36645	226.31304	.326	-666.4522	221.7193
		Wisconsin	582.26423	407.57896	.153	-217.5129	1382.0414
	Ohio	Illinois	-659.14599*	192.52683	.001	-1036.9343	-281.3577
		Indiana	1739.65918*	151.59105	.000	1442.1977	2037.1207
		Michigan	412.43682*	116.15657	.000	184.5071	640.3666
		Minnesota	222.36645	226.31304	.326	-221.7193	666.4522
		Wisconsin	804.63068*	353.62265	.023	110.7300	1498.5314
	Wisconsin	Illinois	-1463.77667*	389.83278	.000	-2228.7311	-698.8222
		Indiana	935.02851*	371.32581	.012	206.3896	1663.6675
		Michigan	-392.19386	358.32299	.274	-1095.3178	310.9301
		Minnesota	-582.26423	407.57896	.153	-1382.0414	217.5129
		Ohio	-804.63068*	353.62265	.023	-1498.5314	-110.7300

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Housing_unit Density	Illinois	Indiana	1045.35870*	105.97677	.000	837.4044	1253.3130
		Michigan	554.33116*	95.37153	.000	367.1871	741.4752
		Minnesota	418.02236*	132.61423	.002	157.7983	678.2464
		Ohio	123.33581	91.33761	.177	-55.8926	302.5642
		Wisconsin	643.35967*	184.94251	.001	280.4538	1006.2655
	Indiana	Illinois	-1045.35870*	105.97677	.000	-1253.3130	-837.4044
		Michigan	-491.02754*	76.97554	.000	-642.0738	-339.9813
		Minnesota	-627.33634*	120.06681	.000	-862.9390	-391.7337
		Ohio	-922.02289*	71.91706	.000	-1063.1431	-780.9027
		Wisconsin	-401.99903*	176.16253	.023	-747.6763	-56.3218
	Michigan	Illinois	-554.33116*	95.37153	.000	-741.4752	-367.1871
		Indiana	491.02754*	76.97554	.000	339.9813	642.0738
		Minnesota	-136.30880	110.81828	.219	-353.7634	81.1458
		Ohio	-430.99535*	55.10642	.000	-539.1286	-322.8621
		Wisconsin	89.02851	169.99379	.601	-244.5440	422.6011
	Minnesota	Illinois	-418.02236*	132.61423	.002	-678.2464	-157.7983
		Indiana	627.33634*	120.06681	.000	391.7337	862.9390
		Michigan	136.30880	110.81828	.219	-81.1458	353.7634
		Ohio	-294.68655*	107.36630	.006	-505.3675	-84.0056
		Wisconsin	225.33731	193.36156	.244	-154.0890	604.7636
	Ohio	Illinois	-123.33581	91.33761	.177	-302.5642	55.8926
		Indiana	922.02289*	71.91706	.000	780.9027	1063.1431
		Michigan	430.99535*	55.10642	.000	322.8621	539.1286
		Minnesota	294.68655*	107.36630	.006	84.0056	505.3675
		Wisconsin	520.02386*	167.76388	.002	190.8270	849.2207
	Wisconsin	Illinois	-643.35967*	184.94251	.001	-1006.2655	-280.4538
		Indiana	401.99903*	176.16253	.023	56.3218	747.6763
		Michigan	-89.02851	169.99379	.601	-422.6011	244.5440
		Minnesota	-225.33731	193.36156	.244	-604.7636	154.0890
		Ohio	-520.02386*	167.76388	.002	-849.2207	-190.8270

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Ave_Ann_T	Illinois	Indiana	.39785*	.20014	.047	.0051	.7906
		Michigan	3.30484*	.18011	.000	2.9514	3.6583
		Minnesota	6.76800*	.25045	.000	6.2766	7.2594
		Ohio	-.76329*	.17250	.000	-1.1018	-.4248
		Wisconsin	6.06300*	.34927	.000	5.3776	6.7484
	Indiana	Illinois	-.39785*	.20014	.047	-.7906	-.0051
		Michigan	2.90699*	.14537	.000	2.6217	3.1923
		Minnesota	6.37015*	.22675	.000	5.9252	6.8151
		Ohio	-1.16114*	.13582	.000	-1.4277	-.8946
		Wisconsin	5.66515*	.33269	.000	5.0123	6.3180
	Michigan	Illinois	-3.30484*	.18011	.000	-3.6583	-2.9514
		Indiana	-2.90699*	.14537	.000	-3.1923	-2.6217
		Minnesota	3.46316*	.20929	.000	3.0525	3.8738
		Ohio	-4.06813*	.10407	.000	-4.2723	-3.8639
		Wisconsin	2.75816*	.32104	.000	2.1282	3.3881
	Minnesota	Illinois	-6.76800*	.25045	.000	-7.2594	-6.2766
		Indiana	-6.37015*	.22675	.000	-6.8151	-5.9252
		Michigan	-3.46316*	.20929	.000	-3.8738	-3.0525
		Ohio	-7.53129*	.20277	.000	-7.9292	-7.1334
		Wisconsin	-.70500	.36517	.054	-1.4216	.0116
	Ohio	Illinois	.76329*	.17250	.000	.4248	1.1018
		Indiana	1.16114*	.13582	.000	.8946	1.4277
		Michigan	4.06813*	.10407	.000	3.8639	4.2723
		Minnesota	7.53129*	.20277	.000	7.1334	7.9292
		Wisconsin	6.82629*	.31683	.000	6.2046	7.4480
	Wisconsin	Illinois	-6.06300*	.34927	.000	-6.7484	-5.3776
		Indiana	-5.66515*	.33269	.000	-6.3180	-5.0123
		Michigan	-2.75816*	.32104	.000	-3.3881	-2.1282
		Minnesota	.70500	.36517	.054	-.0116	1.4216
		Ohio	-6.82629*	.31683	.000	-7.4480	-6.2046

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Heat_Deg_day	Illinois	Indiana	31.100	55.899	.578	-78.59	140.79
		Michigan	-769.819*	50.305	.000	-868.53	-671.11
		Minnesota	-2054.985*	69.949	.000	-2192.24	-1917.73
		Ohio	426.140*	48.177	.000	331.60	520.68
		Wisconsin	-1695.623*	97.550	.000	-1887.04	-1504.20
	Indiana	Illinois	-31.100	55.899	.578	-140.79	78.59
		Michigan	-800.919*	40.602	.000	-880.59	-721.25
		Minnesota	-2086.085*	63.331	.000	-2210.36	-1961.81
		Ohio	395.040*	37.934	.000	320.60	469.48
		Wisconsin	-1726.723*	92.919	.000	-1909.05	-1544.39
	Michigan	Illinois	769.819*	50.305	.000	671.11	868.53
		Indiana	800.919*	40.602	.000	721.25	880.59
		Minnesota	-1285.166*	58.452	.000	-1399.86	-1170.47
		Ohio	1195.959*	29.067	.000	1138.92	1253.00
		Wisconsin	-925.804*	89.665	.000	-1101.75	-749.86
	Minnesota	Illinois	2054.985*	69.949	.000	1917.73	2192.24
		Indiana	2086.085*	63.331	.000	1961.81	2210.36
		Michigan	1285.166*	58.452	.000	1170.47	1399.86
		Ohio	2481.125*	56.632	.000	2370.00	2592.25
		Wisconsin	359.362*	101.991	.000	159.23	559.49
	Ohio	Illinois	-426.140*	48.177	.000	-520.68	-331.60
		Indiana	-395.040*	37.934	.000	-469.48	-320.60
		Michigan	-1195.959*	29.067	.000	-1253.00	-1138.92
		Minnesota	-2481.125*	56.632	.000	-2592.25	-2370.00
		Wisconsin	-2121.763*	88.489	.000	-2295.40	-1948.12
	Wisconsin	Illinois	1695.623*	97.550	.000	1504.20	1887.04
		Indiana	1726.723*	92.919	.000	1544.39	1909.05
		Michigan	925.804*	89.665	.000	749.86	1101.75
		Minnesota	-359.362*	101.991	.000	-559.49	-159.23
		Ohio	2121.763*	88.489	.000	1948.12	2295.40

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Cool_Deg_day	Illinois	Indiana	172.506*	32.578	.000	108.58	236.43
		Michigan	435.473*	29.318	.000	377.94	493.00
		Minnesota	411.754*	40.767	.000	331.76	491.75
		Ohio	270.063*	28.078	.000	214.97	325.16
		Wisconsin	520.497*	56.853	.000	408.94	632.06
	Indiana	Illinois	-172.506*	32.578	.000	-236.43	-108.58
		Michigan	262.967*	23.663	.000	216.53	309.40
		Minnesota	239.248*	36.909	.000	166.82	311.67
		Ohio	97.557*	22.108	.000	54.18	140.94
		Wisconsin	347.990*	54.154	.000	241.73	454.25
	Michigan	Illinois	-435.473*	29.318	.000	-493.00	-377.94
		Indiana	-262.967*	23.663	.000	-309.40	-216.53
		Minnesota	-23.719	34.066	.486	-90.57	43.13
		Ohio	-165.410*	16.940	.000	-198.65	-132.17
		Wisconsin	85.024	52.257	.104	-17.52	187.57
	Minnesota	Illinois	-411.754*	40.767	.000	-491.75	-331.76
		Indiana	-239.248*	36.909	.000	-311.67	-166.82
		Michigan	23.719	34.066	.486	-43.13	90.57
		Ohio	-141.691*	33.005	.000	-206.46	-76.93
		Wisconsin	108.742	59.441	.068	-7.90	225.38
	Ohio	Illinois	-270.063*	28.078	.000	-325.16	-214.97
		Indiana	-97.557*	22.108	.000	-140.94	-54.18
		Michigan	165.410*	16.940	.000	132.17	198.65
		Minnesota	141.691*	33.005	.000	76.93	206.46
		Wisconsin	250.434*	51.572	.000	149.24	351.63
	Wisconsin	Illinois	-520.497*	56.853	.000	-632.06	-408.94
		Indiana	-347.990*	54.154	.000	-454.25	-241.73
		Michigan	-85.024	52.257	.104	-187.57	17.52
		Minnesota	-108.742	59.441	.068	-225.38	7.90
		Ohio	-250.434*	51.572	.000	-351.63	-149.24

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Certificate_Year	Illinois	Indiana	1.188*	.204	.000	.79	1.59
		Michigan	1.402*	.184	.000	1.04	1.76
		Minnesota	1.014*	.256	.000	.51	1.52
		Ohio	1.106*	.176	.000	.76	1.45
		Wisconsin	1.610*	.357	.000	.91	2.31
	Indiana	Illinois	-1.188*	.204	.000	-1.59	-.79
		Michigan	.214	.149	.150	-.08	.51
		Minnesota	-.175	.232	.451	-.63	.28
		Ohio	-.082	.139	.554	-.35	.19
		Wisconsin	.422	.340	.215	-.25	1.09
	Michigan	Illinois	-1.402*	.184	.000	-1.76	-1.04
		Indiana	-.214	.149	.150	-.51	.08
		Minnesota	-.388	.214	.070	-.81	.03
		Ohio	-.296*	.106	.005	-.50	-.09
		Wisconsin	.208	.328	.526	-.44	.85
	Minnesota	Illinois	-1.014*	.256	.000	-1.52	-.51
		Indiana	.175	.232	.451	-.28	.63
		Michigan	.388	.214	.070	-.03	.81
		Ohio	.092	.207	.655	-.31	.50
		Wisconsin	.596	.373	.110	-.14	1.33
	Ohio	Illinois	-1.106*	.176	.000	-1.45	-.76
		Indiana	.082	.139	.554	-.19	.35
		Michigan	.296*	.106	.005	.09	.50
		Minnesota	-.092	.207	.655	-.50	.31
		Wisconsin	.504	.324	.120	-.13	1.14
	Wisconsin	Illinois	-1.610*	.357	.000	-2.31	-.91
		Indiana	-.422	.340	.215	-1.09	.25
		Michigan	-.208	.328	.526	-.85	.44
		Minnesota	-.596	.373	.110	-1.33	.14
		Ohio	-.504	.324	.120	-1.14	.13

Appendix C: Time Period Crosstabulation

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Time_Period * State	144	100.0%	0	0.0%	144	100.0%

		State						Total
		Illinois	Indiana	Michigan	Minnesota	Ohio	Wisconsin	
Time_Period	1.00	0	3	3	3	1	0	10
	2.00	6	9	24	6	4	6	55
	3.00	10	8	17	12	10	3	60
	4.00	2	3	6	3	3	2	19
Total		18	23	50	24	18	11	144

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.943[a]	15	.607
Likelihood Ratio	14.616	15	.479
N of Valid Cases	144		

a. 13 cells (54.2%) have expected count less than 5. The minimum expected count is .76.

Appendix D: Correlation Analysis

Correlations

		Leed_Buildings_per_sqmi	Leed_Buildings_per_sqmTOTAL	Leed_Buildings_per1000_population	Elevation	Ave_Ann_T	Heat_Deg_day	Cool_Deg_day	Average_Certification_Year	Housing_un	pop_per_sq
Leed_Buildings_per_sqmi	Pearson	1	.999**	.857**	-.022	.097	-.112	-.004	.140	-.118	-.066
	Sig. (2-		.000	.000	.793	.247	.184	.962	.094	.182	.434
	N	144	144	144	143	143	143	143	144	129	144
Leed_Buildings_per_sqmTOTAL	Pearson	.999**	1	.850**	-.016	.097	-.111	-.003	.138	-.117	-.064
	Sig. (2-	.000		.000	.852	.249	.187	.973	.099	.187	.450
	N	144	144	144	143	143	143	143	144	129	144
Leed_Buildings_per1000_population	Pearson	.857**	.850**	1	-.010	.034	-.047	-.081	.146	-.235**	-.223**
	Sig. (2-	.000	.000		.907	.689	.577	.335	.081	.007	.007
	N	144	144	144	143	143	143	143	144	129	144
Elevation	Pearson	-.022	-.016	-.010	1	-.561**	.557**	-.400**	.102	-.306**	-.318**
	Sig. (2-	.793	.852	.907		.000	.000	.000	.224	.000	.000
	N	143	143	143	143	143	143	143	143	128	143
Ave_Ann_T	Pearson	.097	.097	.034	-.561**	1	-.994**	.603**	-.047	.228**	.227**
	Sig. (2-	.247	.249	.689	.000		.000	.000	.576	.010	.006
	N	143	143	143	143	143	143	143	143	128	143
Heat_Deg_day	Pearson	-.112	-.111	-.047	.557**	-.994**	1	-.562**	.050	-.221*	-.212*
	Sig. (2-	.184	.187	.577	.000	.000		.000	.554	.012	.011
	N	143	143	143	143	143	143	143	143	128	143
Cool_Deg_day	Pearson	-.004	-.003	-.081	-.400**	.603**	-.562**	1	-.029	.180*	.221**
	Sig. (2-	.962	.973	.335	.000	.000	.000		.728	.042	.008
	N	143	143	143	143	143	143	143	143	128	143
Average_Certification_Year	Pearson	.140	.138	.146	.102	-.047	.050	-.029	1	.207*	.198*
	Sig. (2-	.094	.099	.081	.224	.576	.554	.728		.018	.018
	N	144	144	144	143	143	143	143	144	129	144
Housing_units_per_sqmi	Pearson	-.118	-.117	-.235**	-.306**	.228**	-.221*	.180*	.207*	1	.979**
	Sig. (2-	.182	.187	.007	.000	.010	.012	.042	.018		.000
	N	129	129	129	128	128	128	128	129	129	129
pop_per_sq	Pearson	-.066	-.064	-.223**	-.318**	.227**	-.212*	.221**	.198*	.979**	1
	Sig. (2-	.434	.450	.007	.000	.006	.011	.008	.018	.000	
	N	144	144	144	143	143	143	143	144	129	144

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix E: Residuals Table

Unstandardized Residual					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-3.11307	1	.7	.8	.8
	-2.98071	1	.7	.8	1.6
	-2.86126	1	.7	.8	2.3
	-2.74121	1	.7	.8	3.1
	-2.45922	1	.7	.8	3.9
	-2.39375	1	.7	.8	4.7
	-2.18837	1	.7	.8	5.5
	-2.1604	1	.7	.8	6.3
	-2.14963	1	.7	.8	7.0
	-2.04271	1	.7	.8	7.8
	-1.98071	1	.7	.8	8.6
	-1.95944	1	.7	.8	9.4
	-1.82159	1	.7	.8	10.2
	-1.81464	1	.7	.8	10.9
	-1.80103	1	.7	.8	11.7
	-1.70868	1	.7	.8	12.5
	-1.66395	1	.7	.8	13.3
	-1.65609	1	.7	.8	14.1
	-1.65595	1	.7	.8	14.8
	-1.60421	1	.7	.8	15.6
	-1.55076	1	.7	.8	16.4
	-1.54771	1	.7	.8	17.2
	-1.45492	1	.7	.8	18.0
	-1.44402	1	.7	.8	18.8
	-1.44076	1	.7	.8	19.5
	-1.43087	1	.7	.8	20.3
	-1.3891	1	.7	.8	21.1
	-1.28678	1	.7	.8	21.9
	-1.28252	1	.7	.8	22.7
	-1.27373	1	.7	.8	23.4
	-1.26314	1	.7	.8	24.2
	-1.21892	1	.7	.8	25.0
	-1.21336	1	.7	.8	25.8
	-1.20766	1	.7	.8	26.6
	-1.1815	1	.7	.8	27.3
	-1.1808	1	.7	.8	28.1

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-1.15662	1	.7	.8	28.9
	-1.15474	1	.7	.8	29.7
	-1.1496	1	.7	.8	30.5
	-1.11179	1	.7	.8	31.3
	-1.08812	1	.7	.8	32.0
	-1.07531	1	.7	.8	32.8
	-1.04468	1	.7	.8	33.6
	-1.044	1	.7	.8	34.4
	-0.95475	1	.7	.8	35.2
	-0.93025	1	.7	.8	35.9
	-0.92525	1	.7	.8	36.7
	-0.91547	1	.7	.8	37.5
	-0.85759	1	.7	.8	38.3
	-0.82373	1	.7	.8	39.1
	-0.78162	1	.7	.8	39.8
	-0.7435	1	.7	.8	40.6
	-0.73783	1	.7	.8	41.4
	-0.7332	1	.7	.8	42.2
	-0.72044	1	.7	.8	43.0
	-0.63896	1	.7	.8	43.8
	-0.62876	1	.7	.8	44.5
	-0.584	1	.7	.8	45.3
	-0.56778	1	.7	.8	46.1
	-0.52832	1	.7	.8	46.9
	-0.50323	1	.7	.8	47.7
	-0.44226	1	.7	.8	48.4
	-0.44007	1	.7	.8	49.2
	-0.4216	1	.7	.8	50.0
	-0.41016	1	.7	.8	50.8
	-0.40526	1	.7	.8	51.6
	-0.40031	1	.7	.8	52.3
	-0.37821	1	.7	.8	53.1
	-0.35737	1	.7	.8	53.9
	-0.35165	1	.7	.8	54.7
	-0.29162	1	.7	.8	55.5
	-0.27424	1	.7	.8	56.3
	-0.24128	1	.7	.8	57.0
	-0.20172	1	.7	.8	57.8
	-0.18968	1	.7	.8	58.6
	-0.18965	1	.7	.8	59.4
	-0.13351	1	.7	.8	60.2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	-0.10738	1	.7	.8	60.9
	-0.09669	1	.7	.8	61.7
	-0.02693	1	.7	.8	62.5
	0.13022	1	.7	.8	63.3
	0.14737	1	.7	.8	64.1
	0.16551	1	.7	.8	64.8
	0.19188	1	.7	.8	65.6
	0.21531	1	.7	.8	66.4
	0.22585	1	.7	.8	67.2
	0.2381	1	.7	.8	68.0
	0.29044	1	.7	.8	68.8
	0.3279	1	.7	.8	69.5
	0.3433	1	.7	.8	70.3
	0.3579	1	.7	.8	71.1
	0.37431	1	.7	.8	71.9
	0.3828	1	.7	.8	72.7
	0.39766	1	.7	.8	73.4
	0.41165	1	.7	.8	74.2
	0.41237	1	.7	.8	75.0
	0.42123	1	.7	.8	75.8
	0.42463	1	.7	.8	76.6
	0.43721	1	.7	.8	77.3
	0.47173	1	.7	.8	78.1
	0.48478	1	.7	.8	78.9
	0.56746	1	.7	.8	79.7
	0.59661	1	.7	.8	80.5
	0.67854	1	.7	.8	81.3
	0.68009	1	.7	.8	82.0
	0.70294	1	.7	.8	82.8
	0.85047	1	.7	.8	83.6
	0.93861	1	.7	.8	84.4
	0.99289	1	.7	.8	85.2
	1.0212	1	.7	.8	85.9
	1.07591	1	.7	.8	86.7
	1.14782	1	.7	.8	87.5
	1.2735	1	.7	.8	88.3
	1.29744	1	.7	.8	89.1
	1.33227	1	.7	.8	89.8
	1.37396	1	.7	.8	90.6
	1.52813	1	.7	.8	91.4
	1.82599	1	.7	.8	92.2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2.6533	1	.7	.8	93.0
	2.73327	1	.7	.8	93.8
	3.07328	1	.7	.8	94.5
	3.07364	1	.7	.8	95.3
	3.3847	1	.7	.8	96.1
	4.27538	1	.7	.8	96.9
	5.02606	1	.7	.8	97.7
	6.2404	1	.7	.8	98.4
	12.51227	1	.7	.8	99.2
	23.17402	1	.7	.8	100.0
	Total	128	88.3	100.0	
Missing	System	17	11.7		
Total		145	100.0		

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