THE EFFECT OF LEED CERTIFICATION ON URBAN HEAT ISLANDS

A Thesis

by

DONGHWAN GU

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Chair of Committee,	Galen D. Newman
Committee Members,	Jun Hyun Kim
	Hwanyong Kim
	Charles Culp
Head of Department,	Forster Ndubisi

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ABSTRACT

Sustainable building performance has become one of the most critical concerns recently, in architecture and urban planning disciplines. Leadership in Energy and Environmental Design (LEED) certification studies have proven that the LEED badge provides certain types of ownership benefits. However, it has not been shown whether or not a LEED certified building also enhances environmental benefits to its surroundings. For example, if LEED certification promises a standard for an environment-friendly building, then a group of these certificates should imply greater environmental benefits to the society. This is the main question of this study. The author answers this question through examining possible relationships of LEED certificates and their influence on outdoor temperature of surroundings. Overall results suggest that both LEED certification levels and the mass effect of LEED buildings do not have significant influence on regional climates in the Texas and Florida States. It should be noted that, however, the State of California resulted in an interesting output as it showed higher negative coefficients for the LEED concentration areas, and all the coefficients showed negative correlation with the regional climate. The modeling results by California State indicate that LEED certified buildings could lower the outdoor temperature by 0.3 Celsius, with Gold and Platinum certifications showing even better reduction capability.

NOMENCLATURE

GIS	Geographic Information System
LEED	Leadership in Energy and Environmental Design
OLS	Ordinarily Least Squares
UHI	Urban Heat Island
USGBC	U.S. Green Building Council
USGS	U.S. Geological Survey

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1. INTRODUCTION

Recently, sustainable building performance has become a critical concern in urban and architectural planning disciplines. A building, including its construction and maintenance, intersects with various professional fields, and because of the interdisciplinary nature of architecture, efficiency and energy-effective performance largely determines the measure of a structure's sustainability. To this extent, the Leadership in Energy and Environmental Design (LEED) has proven that their certification system can become a new guideline and resource for more sustainable urbanism and architecture. Building owners have adopted LEED standards rapidly due to the reduced operational costs, demands of city legislation, and market demand by

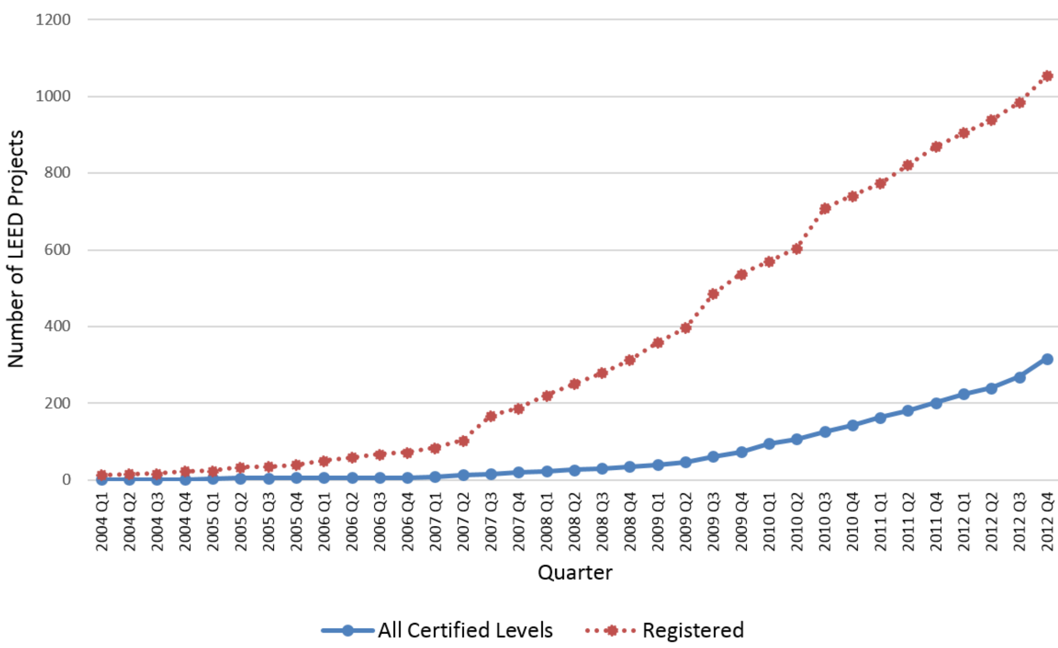

Figure 1 Number of LEED Projects in the U.S.

tenant expectations. Figure 1 shows the increasing tendency of LEED projects in U.S. since 2004. Only 2% of nonresidential building is green building in 2005 while it was increased to 41% in 2012 (Construction, 2012). The LEED is announced by the U.S. Green Building Council (USGBC) which is not a governmental agency. However, accompanied by many projects and its range of checklists, LEED has a strong influence on the standards for a sustainable building and has played an iconic role in energy-efficient architecture.

Past studies articulated a LEED certificate's effect on land price (Eichholtz, Kok, & Quigley, 2010; Fuerst & McAllister, 2011; Miller, Spivey, & Florance, 2008; Wiley, Benefield, & Johnson, 2010) or cost saving aspects (Kats et al., 2008; Singh, Syal, Korkmaz, & Grady, 2010; Tatari & Kucukvar, 2011). These studies show that LEED certifications provide certain types of benefits to the structure's owners and users. However, it is still unclear as to whether or not an LEED certified building enhances environmental benefits to its surroundings. If an LEED certification promises a baseline for an environment-friendly building, then a group of these structures should ensure significant environmental benefits to the society. This is the main interest of this study, and the author explores this hypothesis by examining the relationship of LEED certificates and their influence on outdoor temperature, especially in terms of urban heat island effect. If LEED truly is an effective system to help with environmental sustainability, then its grouping should illustrate better energy and environmental performance when compared with its counterparts.

2. BACKGROUND*

LEED was developed by the U.S. Green Building Council (USGBC) to certify high-performance buildings and sustainable neighborhoods (USGBC, 2009). Since its beginning in 1998, LEED certification effectiveness has been studied widely by various scholars. For example, one study's results showed that LEED buildings consume an average of 25-30% less energy than the national average (USGBC, 2010). Higher certification level of buildings (such as Gold and Platinum) use up to 45% less energy than non-LEED buildings (Turner, Frankel, & Council, 2008). Newsham, Mancini, and Birt (2009) also determined that LEED certificates save about 25-30% more energy in comparison with their conventional counterparts. In contrast, some studies are skeptical about the benefits that an LEED certificate provides in the aspect of energy conservation (Gifford, 2008; Lstiburek, 2008; Richter et al., 2008; Scofield, 2009a, 2009b). Regardless, the LEED standard is still widely considered a highly effective strategy for owners and users to reduce energy consumption.

There are currently four levels of LEED certification based on a 100-point scale with an additional 10-bonus point. The four certificate classifications are "Certified" with 40-49 points, "Silver" with 50-59 points, "Gold" with 60-79 points, and finally, "Platinum" with 80+ points (USGBC, 2009). This LEED score is also based on several categories:

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Sustainable Site (26 possible points), Water Efficiency (10 possible points), Energy and Atmosphere (35 possible points), Materials and Resources (14 possible points), Indoor Environmental Quality (15 possible points), Innovation in Design (6 possible points), and Regional Priority (4 possible points) (USGBC, 2010). Previous literature about post-occupancy evaluation investigates the total energy use intensity (EUI) generally by measuring the Energy and Atmosphere credit (Gifford, 2008; Lstiburek, 2008; Newsham et al., 2009; R. Diamond, M. Opitz, T. Hicks, B. Vonneida, & Herrera, 2006; Richter et al., 2008; Scofield, 2009a; Turner et al., 2008). However, there are two possible problems with these studies. First, although the Energy and Atmosphere credit accounts for 35% of the base points, it is just one agenda among many LEED certifications. Thus, a more comprehensive evaluation on the LEED buildings, such as Sustainable Site, Water Efficiency, and Indoor Environmental Quality are necessary. Second, these studies have clarified that the benefits of LEED certification mostly fall to the owners. If energy saving is only one part of the greater environmental benefits, then LEED certification should promote a diverse aspect of sustainability, such as its interactions with the surrounding environment.

As a response, some studies examined the LEED buildings in a broader context. The expansion of a high density built environment results in the change of heat balance, also known as the heat island effect (M Santamouris, 2013). The heat island effect is determined by factors such as urban canyons, material properties, anthropogenic heat, and the lack of evaporating surface with the increase of stored solar radiation (Oke, Johnson, Steyn, & Watson, 1991). Accordingly, energy consumption of a building is directly affected by increased urban temperature (Hassid et al., 2000; M Santamouris et al., 2001). More specifically, material property of buildings, such as the albedo and solar reflectance index (SRI), is correlated with the air temperature in urban areas and plays a crucial role in reducing the heat island effect (Heidt & Neef, 2008; Mat Santamouris, Synnefa, & Karlessi, 2011). Numerous researchers have developed methodologies to improve building energy performance and have earned meaningful results (Machairas, Tsangrassoulis, & Axarli, 2014). However, compared to those in suburban areas, buildings in urban environments consume more energy for air conditioning due to the high temperature of the surroundings. This suggests that the effort to reduce heat island effect in terms of LEED certification systems should be accompanied by corresponding research projects.

To reduce the heat island effect, the USGBC encourages building owners to utilize paving materials with a SRI of at least 29 for a minimum of 50% of the site's hardscape, including roads, sidewalks, courtyards, and parking lots. It is also encouraged to use low-sloped roofing with an SRI of at least 78 or steep-sloped roofing with an SRI of at least 29 for a minimum of 75% of the roof surface (USGBC, 2010). Concerning the LEED certification process, "Sustainable Sites Credit 7.1: Heat Island Effect" was applied to 62% of LEED projects, making it the 23rd most commonly earned point. Additionally, "Sustainable Sites Credit 7.2: Heat Island Effect" was the 31st most commonly earned point, and was applied to 53% of LEED projects (Marceau & Van

Geem, 2007). Over 50% of LEED projects have earned points through the heat island measures, meaning that these buildings are expected to lower the heat island effect with the materials or technologies they have utilized in their construction.

The heat island credits in LEED are categorized into local and regional environmental sectors. The current practices, however, do not distinguish such regional differences, and a unified standard is utilized to determine the credits. As mentioned earlier, material property of buildings is correlated with the air temperature, thus influencing the heat island effect (Heidt & Neef, 2008; Mat Santamouris et al., 2011). Therefore, in order to reflect the different local climates, and to provide a more accurate measurement, geographical standards should be customized depending on regions (Cavanaugh, 2008; Kumar, 2002). Although LEED addresses building material issues as well as regional issues in categories such as Sustainable Site, its analysis between the heat island credit and its impact on urban temperature is rather sparse and yet unreliable.

The goal of this paper is to analyze the influence of LEED certification on urban temperatures as an indicator of regional interactions. If an LEED certificate is regarded as a strong contributor to a sustainable built environment, then a group of these certificates should result in greater benefits to society. To this extent, the author questions if there is any possible relationship between a large concentration of LEED certified sites and the temperature of their surroundings. As previously described, there certainly are credits geared toward regional context. If these are made to be truly effective measures, then the regional credits (such as Sustainable Site or Heat Island Effect) will provide more solid groundwork for the success in LEED evaluation process.

3. RESEARCH FRAMEWORK*

The following two statements specify the author's main research questions:

Q1) How much outdoor temperature change can an LEED certified building induce?

Q2) Is there any difference in heat reduction capability among the various levels of LEED certifications?

Figure 2 shows conceptual step of this research. The phase 1 presents the relationship

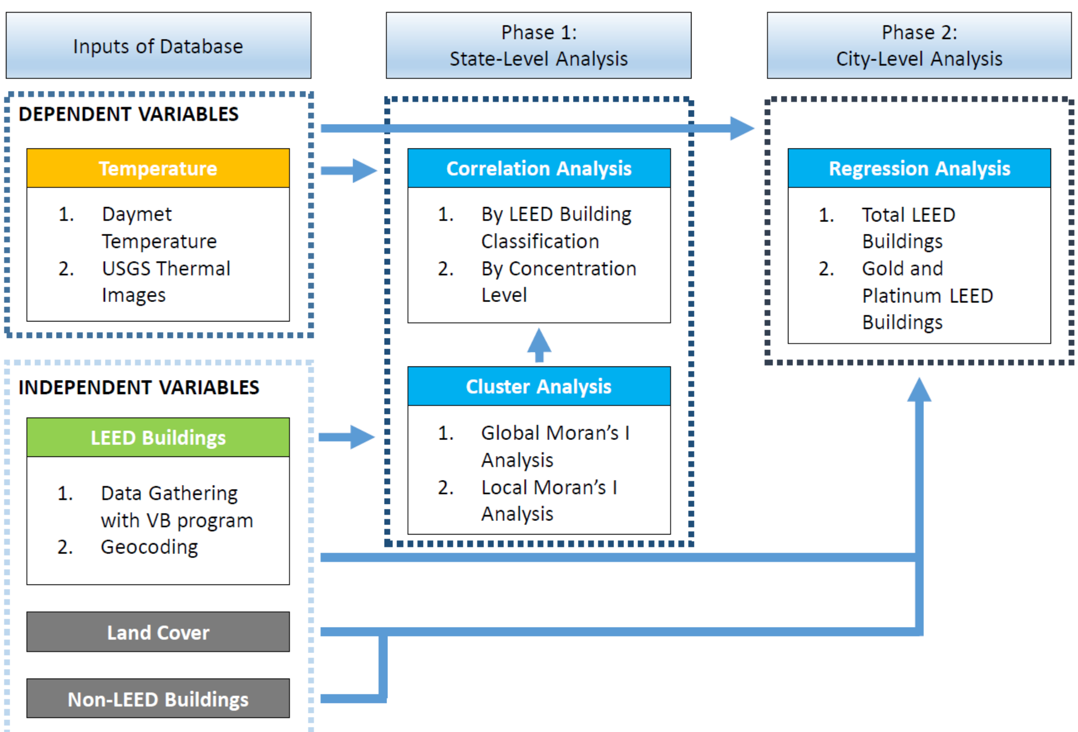

Figure 2 Research Framework

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between the urban temperature and LEED buildings using the GIS-based cluster analysis and correlation analysis for three States: California, Texas, and Florida. For the phase 2, the statistical significance is presented by the regression analysis from three independent variables: 1) number of LEED buildings; 2) land cover and 3) number of non-LEED buildings in city of Los Angeles.

3.1 State-level Analysis

This paper uses Moran's Index (I) and correlation analysis to confirm the urban temperature changes by LEED buildings. Moran's I measures the spatial autocorrelation of geographic features based on locations and number of clusters. The result presents whether the pattern of LEED buildings is spatially clustered, dispersed, or random. It is essential to check the pattern of LEED buildings since urban heat island is mainly derived from the aggregation of buildings. Also, correlation analysis is useful to identify the connection between temperature and the level of LEED clusters.

Table 1 Number of LEED Buildings by Year, States, and Certification Levels

Year	**~2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
No.	44	74	101	197	279	586	1,413	1,988	2,487	7,169

States	**CA**	**TX**	**NY**	**FL**	**IL**	**PA**	**MA**	**WA**	**Others**	**Total**
No.	1,091	448	360	323	296	291	268	267	3,825	7,169

Levels	**Certified** (40~49points)	**Silver** (50~59points)	**Gold** (60~79points)	**Platinum** (80 and above)	**Total**
No.	1,287 (18%)	2,533 (35%)	2,600 (36%)	749 (11%)	7,169

USGBC provides each LEED building's address, certification level, certification date, and rating system. It has 47,946 building information in the U.S. as of January 2014. However, the USGBC only provides each building's physical address through their website, not in a downloadable spreadsheet format. Hence, the challenge was collecting physical addresses of more than 40,000 LEED certified buildings and make them available for geocoding. The author created an MS Excel MACRO that automatically download all the physical addresses of LEED buildings and put it into a blank Excel sheet (the Appendix A contains full source code).

After data clearing process, 13,273 building data are left. Table 1 shows the summary of LEED buildings built prior to the year 2012. As can be seen, the number of LEED

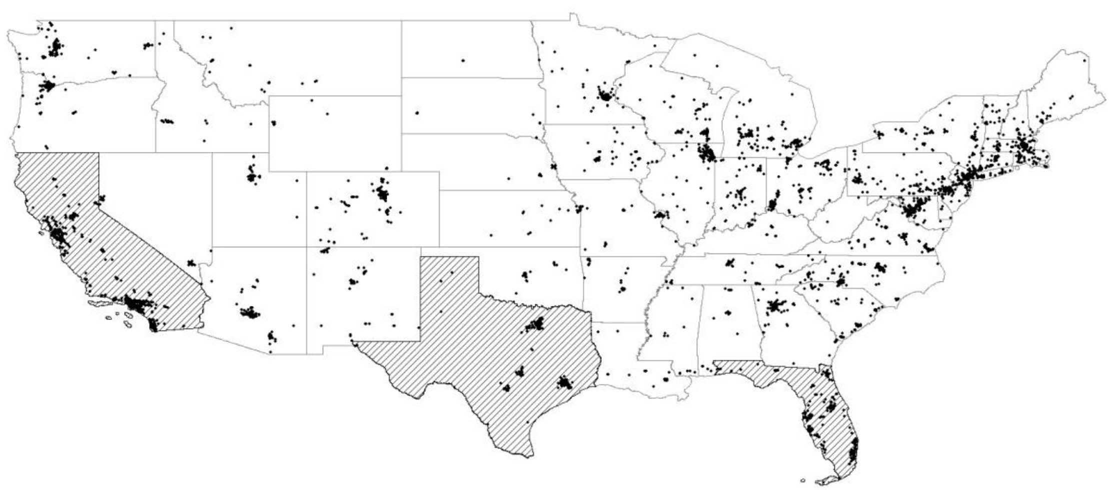

Figure 3 LEED Building Distribution

buildings has grown dramatically in the later years. Figure 3 shows the LEED distribution across the states and most of the certifications concentrate on urban areas. The study boundaries of this study are the States of California, Texas, and Florida. The primary reason for choosing them is because they represent the LEED buildings in the Sun Belt States and their annual temperature shows more consistency compared to other states such as, New York or Illinois. Table 1 also shows the number of LEED buildings by their certification levels. As mentioned briefly, there are four criteria of green buildings on the basis of 100 possible points.

Temperature dataset is another requirement to calculate the correlation coefficient between the level of LEED cluster and its annual temperature. The Daymet data supported by the National Aeronautics and Space Administration (NASA) Earth Science Data and Information System (ESDIS), and the Terrestrial Ecosystem Program provides 1km by 1km gridded estimates of daily weather parameters for North America from 1980 to 2012 (Thornton et al., 2014). It offers 7 different types of information: daily

Table 2 Summary of Temperature for the Study Areas (°C)

	California				Texas				Florida			
	Jan 1	Apr 1	Jul 1	Oct 1	Jan 1	Apr 1	Jul 1	Oct 1	Jan 1	Apr 1	Jul 1	Oct 1
Min	-11	-9.5	1.5	-4	8.5	18	25.5	17	22	24.5	30	25
Max	30.5	33.5	44.5	44.5	27.5	37	42.5	36.5	27.5	31.5	36.5	33
Mean	16.6	15.1	29.2	33.3	22.1	31.6	34.7	25.9	24.9	28.6	33.6	31.1
Std dev.	5.3	7.5	6.8	5.4	3.1	2.1	2.2	2.5	1.3	1.7	1.0	1.4

minimum and maximum temperature; precipitation occurrence and amount; humidity level; shortwave radiation; snow water equivalent; and day length. In this study, daily maximum temperatures on January 1st, April 1st, July 1st, and October 1st in 2012 are used for temperature data point as they represent possible seasonal transitions. Table 2 summarizes the temperature changes in the study area. Well known for its natural assets, the three states have a larger number of distinct climate zones such as, desert, grasslands, mountains, inland, and coaster areas. Accordingly, the mean temperature in the summer season for the three states show higher figure compared to the national average. Therefore, if LEED buildings have a temperature mitigation effect, especially in the summer, then it is more advantageous in the study area to make greater environmental benefits.

3.2 City-level Analysis

The author used the ordinarily least squares (OLS) regression analysis to properly assess the possible relationship between LEED certificates and their effects on urban temperature in selected urban area. Accordingly, the dependent variable is outdoor temperature of the study site, and there are four independent variables: 1) the number of LEED certified buildings; 2) the number of non-LEED buildings; 3) the presence of impervious land covers; and 4) the level of LEED certificates. The study boundary was set to the city of Los Angeles in the state of California. Well known for its natural and cultural assets, Los Angeles is one of the most populous metropolitan areas in the world. Based on the number of LEED buildings in the U.S. and the results of correlation analysis of the three states (California, Texas, and Florida), California showed the highest number of LEED buildings and their correlation coefficients with its annual temperature. Also, the three counties selected in the state of California (Los Angeles, San Diego, and San Francisco) presented the highest correlation results with their monthly temperature, especially in January and April. Based on these preliminary results, the study boundary was set to the City of Los Angeles, where the author expected the most distinctive outcome.

Another practical reason for selecting Los Angeles is because of the city's strong preference towards environment-friendly policies. In 2002, the Los Angeles City Council voted for a requirement of LEED certification to all public construction where the gross square footage is greater than 7,500. Also, in 2003, the Council required that all projects sponsored by the city comply with the LEED certificate standards (Everblue, 2009). This is the main reason Los Angeles is among cities in the U.S. with the most LEED certified buildings.

The United States Geological Survey (USGS) provides Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) sensor thermal band images. The guideline for the selection of a satellite image is based on the percentage of cloud coverage and the filming date. There are two basic rules of thumb. First, the percentage of cloud coverage should be minimal because the amount of cloud cover reduces UHI magnitude (Morris, Simmonds, & Plummer, 2001). This paper features the image that has the lowest cloud coverage option in USGS; it is lower than 10%. In addition, the selected image should have been taken between January and April to generate the best outcome according to the Environmental Protection Agency research outcomes about atmospheric UHI (Wong & Hogen, 2011). Thus, the satellite image captured on March

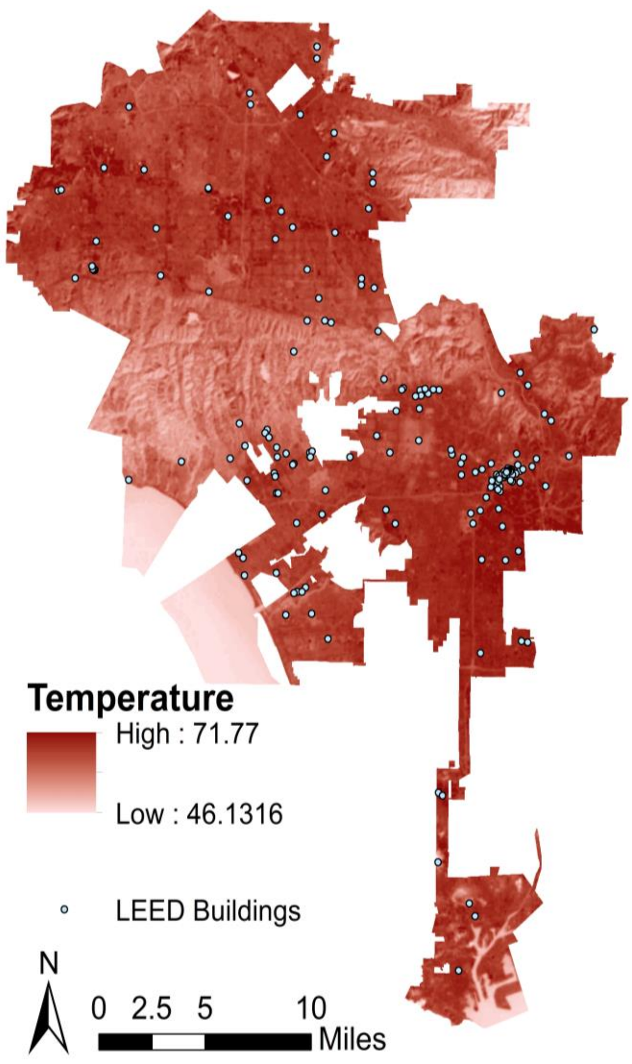

Figure 4 Los Angeles Temperature and LEED Buildings Distribution

13, 2014 is selected because it corresponds well with the conditions described above. The image contains 1,376,820 cells, and the resolution is in 30m x 30m. Figure 4 and Table 3 show the temperature image and the descriptive data summary of the study site.

Non-LEED buildings and LEED certified buildings are the two main predictors for the urban temperature. For information regarding the LEED certified buildings, the USGBE database was utilized. For the non-LEED buildings, the Los Angeles County GIS Data Portal was utilized as it provides building outlines collected in January through April 2008, measuring all the buildings with size greater than 400 square-feet. Overall, Los Angeles has 1,143,945 non-LEED buildings and 197 LEED certified buildings within its city limits.

Land cover data is another predictor and is used as a dummy variable. Since the temperature data is collected in 30m x 30m cells, the author selected the same cell size for their examination; the land cover data provided by the USGS Land Cover Institute (LCI) also matches the same resolution (The USGS Land Cover Institute, 2014). Using the same resolution is advantageous because it is closer to measuring whether an impervious cover is present or not present within the 30 meters boundary. Having a land cover dummy is an important variable because it provides the grounds for whether or not the final outcome is reliable; it is a reliable measure if the LEED certificates and impervious cover coefficient directions illustrate the same result. Finally, the author decided to test if there is any difference among the certification levels. Accordingly, the certification levels are grouped to two types for more effective modeling: 1) buildings with all levels of LEED certificates, and 2) buildings with gold and platinum LEED certifications. Table 3 shows the descriptive statistics of non-LEED buildings, LEED certified buildings, land cover types, and certification level differences.

As noted, urban temperature is the dependent variable and it is examined in 30m x 30m cells. Accordingly, the number of observation (1,376,820) is the same number as the total number of cells. The respective totals of non-LEED buildings and LEED buildings within the 30m distances are calculated based on each cell. Land cover is converted into a dummy variable to indicate the imperviousness of each cell; it is paired with one cell for each temperature value. To verify the effectiveness of the LEED certification levels, two models are designed. The first model includes all certification levels of LEED buildings, whereas the second model only contains the platinum and gold certification levels as an independent variable.

Table 3 Summary of Dependent and Independent Variables

Dependent Variable		Independent Variables							
Temperature (℃)		No. of LEED Buildings		%	No. of Buildings	%	Land Cover	No. of Cells	%
Min	46.13	Total	197	100%	1,143,945	100%	Total	1,376,820	100%
Max	71.77	Certified	39	20%			Pervious	959,271	70%
Mean	64.48	Silver	54	27%			Impervious	417,549	30%
Std. dev.	4.54	Gold	78	40%					
		Platinum	26	13%					

4. ANALYSIS AND RESULTS*

4.1 Spatial Distribution of LEED buildings

Table 4 lists the result from Global Moran's I analysis. Moran's I is to test whether LEED buildings are randomly distributed across the states. If this paper can reject the null hypothesis with the statistical significance, then this paper could argue that LEED buildings have tendency to cluster or disperse across the study boundary. The p-value shows a statistically significant level with a 99% confidence except for the State of Florida, and z-scores resulted in positive values. Thus, the States of California and Texas are able confirm that the patterns of the LEED buildings are spatially clustered. The State of Florida, on the other hand, could be marginally accepted for its spatial clustering effect in LEED buildings with an 80% confidence level. This is an interesting result and partially expected because the metropolitan areas have more possibility to construct LEED certified buildings and the rural areas are less likely to have the same

Table 4 Summary of Global Moran's I Analysis by Three States

	California	Texas	Florida
Moran's Index	0.003	0.005	0.001
z-score	12.367	9.505	1.255
p-value	0.000	0.000	0.209

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opportunities. Nevertheless, Moran's I results confirmed this clustered pattern of LEED in the study boundary. Then the next questions become where clustering happens and what are their possible connections to annual temperature.

4.2 State-Level Correlation Analysis

To answer these two questions, a correlation between daily maximum temperatures and the number of LEED buildings by the LEED certification level is calculated first, and table 5 summarizes the coefficient results. Considering the conventionally accepted coefficients, above 0.3, the results show relatively low correlation results. The influence of temperature change among the certification levels is indistinct across the three states. Thus, it could be noted that the maximum temperature does not vary significantly based on certification levels.

Table 5 Summary of Correlation by the Level of LEED Certification

Certification Level	California				Texas				Florida			
	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
Certified, Silver, Gold, Platinum	0.01	-0.02	-0.06	-0.03	-0.08	-0.04	0.05	0.02	-0.03	-0.01	0.01	-0.01
Silver, Gold, Platinum	0.01	-0.02	-0.05	-0.02	-0.12	-0.06	0.07	0.02	-0.02	0.01	0.00	-0.05
Gold, Platinum	0.01	-0.02	-0.04	-0.02	-0.11	-0.06	0.06	0.02	-0.02	-0.01	0.02	-0.06
Platinum	0.02	-0.01	-0.01	0.00	-0.04	-0.02	0.01	-0.01	-0.01	0.02	0.03	0.01

The primary purpose of correlation analysis is to find the temperature change caused by possible regional credits in LEED certificate system. However, table 5 showed there is no significant difference between the levels of certification. Then, how about LEED concentrated areas? Will they show the same level of insignificance? Or will they imply a different relationship with the annual temperature? To define the clusters, the author selects the census tracts with statistically significant (HH census tracts) areas in the Anselin Moran's I analysis result. Anselin Moran's I analysis defines clusters at a local level, whereas the Global Moran's I analysis produces a single statistics to summarize the entire study area. A unit with high positive z-score suggests that the surrounding units have similar values. Thus, statistically significant values in Anselin Moran's I analysis are selected to define LEED concentrated areas.

Another dimension on concentration is also added. High concentrated census tracts in Los Angeles, San Diego, and San Francisco counties in California; Dallas, and Harris counties in Texas; and Miami-Dade, Palm Beach, and Sarasota counties in Florida were selected to run the differences between the urban and rural areas. Those counties are selected based on the number of LEED buildings in each county to represent an urbanized environment with LEED buildings. Top three counties in each state are designated while the State of Texas has only two counties and those two contain more than 71% of LEED buildings. Table 6 illustrates the number of LEED buildings by the level of LEED certification, and the level of concentration in the selected counties. The concentration of LEED buildings in HH area shows a tendency to increase in the

Table 6 Summary of the Number of LEED Buildings and Classifications

No. of LEED Buildings	California		Texas		Florida	
Total	1,091	100%	448	100%	323	100%
in Certified level	207	19%	128	29%	82	25%
in Silver level	311	29%	152	34%	107	33%
in Gold level	419	38%	136	30%	116	36%
in Platinum level	154	14%	32	7%	18	6%
Total	1,091	100%	448	100%	323	100%
in HH census tracts	472	43%	372	83%	147	46%
in Non-HH census tracts	619	57%	76	17%	176	54%
Total in selected counties	461	100%	317	100%	112	100%
in HH census tracts	206	45%	317	100%	81	72%
in Non-HH census tracts	255	55%	0	0%	31	28%

selected counties, rather than the whole state areas. Texas HH area has about 83% of LEED certificates and 100% of LEED buildings are located in the selected counties. Similarly, the State of Florida has 46% and 72%, and California has 43% and 45% respectively.

The negative coefficient suggests that the LEED cluster is associated with lower urban temperature, implying that the LEED concentrations may have reduced their

Table 7 Summary of Correlation by the Target Areas

Target Areas	California				Texas				Florida			
	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct	Jan	Apr	Jul	Oct
All census tracts	-0.13	-0.14	-0.17	-0.11	-0.08	-0.12	-0.06	0.02	0.09	0.03	-0.09	-0.02
Census tracts in the selected counties	-0.24	-0.22	-0.20	-0.17	-0.05	0.06	0.05	0.08	-0.07	-0.21	-0.01	0.13

surroundings' temperature. As seen in table 7, the coefficient for the general census tracts in the State of California shows negative correlations, ranging from -0.11 to -0.17. However, the correlation result in the high concentrated areas illustrates higher values of negative correlation, meaning that the LEED concentrated areas have relatively lower urban temperature than other regions. Unlike California, the State of Texas and Florida show weak correlation results, indicating that the LEED focused areas may not have significant influence on the temperature. Despite the fact that the three states present slightly different results, by looking at the variances in coefficients, it can still be said that the temperature change is more distinct when the LEED certificates are clustered.

4.3 Regression Analysis in Los Angeles

Tables 8 and 9 list the results from the OLS regression analysis in selected research area; Los Angeles. The total number of all LEED buildings is used for Model 1, and the number of only Gold and Platinum LEED buildings is used for Model 2. As can be seen, the R-square and p-values show very similar results ($R2=0.3895$, $p<0.01$) across the two models. All of the p-values for the independent variables indicate statistically significant results at a 99% confidence level (p<0.01), and the f-values for the overall model fit also illustrate a significant result (f=292,839.1, p<0.01).

For Model 1, land cover shows the coefficient of negative 4.6, meaning that if the cell boundary (30m x 30m) is mainly made with pervious covers such as open spaces or natural vegetation covers, it could lower the outdoor temperature by -4.5 degrees Celsius. The non-LEED buildings' coefficient of 0.128 illustrates that within the 30m x 30m boundary, one non-LEED building may increase the surrounding outdoor temperature by 0.128 degrees Celsius. Lastly, the LEED buildings' coefficient shows that one LEED certified building within the 30m boundaries, regardless of its certification levels, could lower the surrounding air temperature by -0.35 degree Celsius. This is a noteworthy

Table 8 Summary of the Model 1 - All LEED Buildings

Model 1	Observations		R^2	F		P
	1,376,820		0.3895	292,839.1		0.000
Predictors	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Land Cover	-4.5995	0.0060	-770.60	0.000	-4.6112	-4.5878
Non-LEED Buildings	0.1281	0.0008	151.28	0.000	0.1264	0.1297
LEED Buildings	-0.3524	0.1022	-3.45	0.001	-0.5527	-0.1521
Constant	66.1409	0.0042	16000.00	0.000	66.1327	66.1492

result as it proves that the LEED certified buildings do have an effect on lowering the temperature of their surroundings. It also means that the regional credits of the LEED certification system, such as Sustainable Sites or Urban Island, may deliver even greater environmental benefits to the overall environment.

Coefficients for both the numbers of LEED buildings and the number of Gold and Platinum LEED buildings revealed negative values, indicating that the areas with more LEED building units have higher probability to have lowered outdoor air temperature. In addition, the coefficients for the LEED certified buildings in Model 2 show a slightly higher result than the coefficient of the LEED buildings in Model 1. This means that the higher levels of LEED certification tend to have more of a mitigation effect on the outdoor temperature. Table 9 summarizes the Model 2 results. As can be seen, the presence of a Gold or Platinum LEED building within the 30m boundaries could lower the outdoor temperature by -0.51 degrees Celsius. Compared to the overall effect of any LEED building, this is an improvement of about 0.16 degrees Celsius. Therefore, it can be said that the higher levels of the LEED certification system provide more effective results in terms of a broader environmental context.

This is a particularly interesting result given that the maximum points for the LEED Heat Island credit is two points regardless of a building’s certification levels. This means that regardless of whether a building earns a Bronze or a Platinum certification, the consideration given to heat island effect is the same. The possibility of earning a higher

Table 9 Summary of the Model 2 - Gold & Platinum LEED Buildings

Model 2	Observations		R^2		F		P
	1,376,820		0.3895		292,837.7		0.000
Predictors	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]		
Land Cover	-4.5994	0.0060	-770.62	0.000	-4.6111	-4.5877	
Non-LEED Buildings	0.1281	0.0008	151.31	0.000	0.1264	0.1297	
Gold & Platinum LEED Buildings	-0.5163	0.1695	-3.05	0.002	-0.8485	-0.1840	
Constant	66.1408	0.0042	16000	0.000	66.1325	66.1490	

certification, however, will likely involve obtaining the maximum credits and thus, Gold and Platinum projects have a higher probability to fully satisfy the Heat Island credit. This could possibly be the primary explanation for the resulting higher coefficient for LEED buildings in Model 2 and should be examined by future studies accordingly.

5. SUMMARY AND CONCLUSIONS

Based on results, it seems that both the LEED certification levels and the mass effect of LEED buildings do not have significant influence on regional climate in the state level. The results shows that the relationship of LEED clusters and their effects on regional heat has minimal interactions and thus, the author may possibly question the effectiveness of LEED's regional credit process, such as Sustainable Sites or Heat Island Effect credit. It should be noted that, however, the State of California resulted in an interesting output as it showed higher negative coefficients for the LEED concentration areas, and all the coefficients showed negative correlation with the regional climate. The degrees of coefficients for the States of Texas and Florida resulted in less predictable outcome, but the coefficient differences between the normal areas and LEED concentrated areas in Texas, and the negative correlation between regional temperature and LEED building areas in Florida are noteworthy findings.

It should be noted that correlation is one of many ways to diagnose possible relationship but it does not indicate causation. Also, measuring correlation coefficient provides a possible foundation to the research questions, but it does not give an affirmative answer about whether or not the relationship is reliable. In other words, just calculating correlation coefficient does not assure that a group of LEED certificates does not have any influence on the greater environmental benefits, the degree of urban heat in this case, nor does it prove whether the LEED certificates do have positive influences. Finally, capturing the heat of the first day of four months as a proxy for the annual temperature may have simplified the weather variation and thus, more thorough measurements should be taken into account for the future research works.

To overcome these limitations and to determine whether the LEED certification system has effective regional measurements in the urban area, the author questioned the system on two aspects. First, if LEED is a good indicator for energy saving and sustainability at large, then how much could outdoor air temperature be lowered by having the certification? Second, if LEED does help lower the surrounding air temperature, will the level of the certification make a difference in how much it is lowered? Using GIS and OLS regression analysis, the author observed that constructing an LEED certified building in a 30m boundary could possibly lower the heat of the surroundings by 0.3 degrees Celsius. Also, having a higher certification level (such as Gold or Platinum) could increase the lowering effect by 0.16 degree Celsius. This is a meaningful result, as not many previous studies have articulated the relationship of LEED certifications and their effects on a regional context.

Two things should be noted, however. First, as the R-square values for both models show relatively low scores ($R^2=0.39$), interpretation of the results should be carried out carefully. Possible considerations for other factors affecting heat could be wind, building orientation, density, and so forth. This means that there may be other possible concerns involved in the heat island effect. Also, although the satellite image for the heat data was obtained by following convention, the analysis results could vary to a certain degree depending on the quality of the satellite data. Future studies should improve on minimizing such limitations.

Nonetheless, the main point of this paper addresses a meaningful attempt that could imply possible directions for future research. As mentioned earlier, the main purpose of this paper is to address the LEED certificate and credit system's effectiveness in terms of its broader environment. We have enough studies about owner benefits of LEED buildings, such as cost savings and energy savings. But not many have been directed under the domain of benefits to users. In this extent, the author thinks the analysis in this study indicates a possible development direction for both USGBC and other proponents of the LEED certification system. Based on the analysis results, it can be said that the LEED certification system not only saves costs in energy usage for the users and the owners, it also provides significant environmental benefits to the surroundings. In addition, the LEED certification system's regional credits (such as Sustainable Site and Heat Island Effect) contribute overall to environmental justice regardless of their possible maximum points. If the LEED could become a more interactive measurement with its regional context, which is indeed a required perspective in a broader context of sustainability, it would become a true sustainable building standard as it actively considers architecture a semi-public asset. Also, LEED will become a more comprehensible measurement due to the fact that it enhances the relationship of urban environmental problems with the architectural performance.

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APPENDIX A

PROGRAM SOURCE CODE

```
Sub Macro1()

Dim wSU As Worksheet
Dim wSR As Worksheet
Dim wSS As Worksheet

Dim iForRow As Integer
Dim iLastRow As Integer
Dim sURL As String

Set wSU =
ThisWorkbook.Sheets("URLs")
Set wSR =
ThisWorkbook.Sheets("Results")
Set wSS =
ThisWorkbook.Sheets("Scrape")

Application.ScreenUpdating = False

iLastRow =
wSU.Cells(wSU.Rows.Count,
"a").End(xlUp).Row
For iForRow = 1 To iLastRow Step 1
sURL$ = wSU.Cells(iForRow,
"a").Value
With
wSS.QueryTables.Add(Connection:= _
"URL;" & sURL,
Destination:=wSS.Range("A1"))
.Name = ""
    .FieldNames = True
    .RowNumbers = False
    .FillAdjacentFormulas = False
    .PreserveFormatting = True
    .RefreshOnFileOpen = False
    .BackgroundQuery = True
    .RefreshStyle = xlInsertDeleteCells
    .SavePassword = False
```

```
        .SaveData = True
        .AdjustColumnWidth = True
        .RefreshPeriod = 0
        .WebSelectionType = xlEntirePage
        .WebFormatting =
xlWebFormattingNone
        .WebPreFormattedTextToColumns
= True
        .WebConsecutiveDelimitersAsOne
= True
        .WebSingleBlockTextImport =
False
        .WebDisableDateRecognition =
False
        .WebDisableRedirections = False
        .Refresh BackgroundQuery:=False
End With
wSR.Cells(iForRow + 1, "a").Value =
wSS.Range("a107").Value
wSR.Cells(iForRow + 1, "b").Value =
wSS.Range("a110").Value
wSR.Cells(iForRow + 1, "c").Value =
wSS.Range("b109").Value
Next iForRow
Application.ScreenUpdating = True
MsgBox "Process Completed"

End Sub
```