Effect of LEED Ratings and Levels on Office Property Assessed and Market Values

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Abstract This study examines the effect of Leadership in Energy and Environmental Design (LEED) ratings and certification levels on Assessed (AV) and Market Values (MV), while controlling for a property's characteristics and its location. The overall dataset was developed by combining information from CoStar Group, U.S. Green Building Council (USGBC), and local Assessors/Treasurer. The results indicate that ENERGY STAR designation increases AV and MV substantially. The effect of LEED rating/level on both of these values (AV and MV) can be differentiated based on the level of geographic aggregation. LEED-Existing Building (EB) designation at the Gold level has a strong positive effect on AV, while LEED-EB at the Silver level has a similar effect on both AV and MV. This effect is absent among all LEED-EBs, when controlling only for MSAs. LEED-New Construction at the Gold level has a strong positive effect on MV, while LEED-Core & Shell at the Gold and Silver levels almost doubles that effect on AV, when controlling for MSAs.

Scientists raised their concerns over the environment for many years, but climate changes (IPCC, 2007) and improved green technologies have increased the top-down political and bottom-up civic engagement in enhancing the protection of our planet. Real estate is among the many industries increasingly pursuing green technologies, because it affects both the environment (natural[1] and built) and the occupants it houses. The real estate industry in the United States currently uses three primary sustainable rating systems, with the goal of decreasing the environmental impact of a facility through improved efficiency: ENERGY STAR (launched by the U.S. Environmental Protection Agency and the Department of Energy in 1992), Leadership in Energy and Environmental Design—LEED [launched by U.S. Green Building Council (USGBC) in 1998], and Green Globes (initiated by the Canadian Standards Association and evolved through time with the participation of multiple private and public organizations).

The interest of property owners and managers on environmentally-friendly interventions for existing buildings and green development of new buildings is mushrooming throughout the U.S., due to the cost savings realized in the short and long run Return On Investment (ROI) (Denise, 2007; Burr, 2008; IBT, 2008; Turner 2008). The growing professional interest combined with the data availability is leading to a growing amount of academic research in this area

(Eichholtz, Kok, and Quigley, 2009; Fuerst and McAllister, 2008; Miller, Jay, and Florance, 2008). Departing from other studies, this paper analyzes assessor determined values (market values and assessed values) of LEED office buildings based on their certification rating (New Construction, Existing Building, Core & Shell, and Commercial Interior) and levels (Platinum, Gold, Silver, and Certified). The only restrictions imposed on the dataset were on the building size (above 50,000 sq. ft. of rentable building area) and classification (only A or B). This new perspective on the performance of LEED office buildings as evaluated by a third party (assessor) will provide an additional benchmark for the evaluation of their future performance.

Literature Review

The combination of publicly accessible information on both ENERGY STAR and LEED certified buildings, along with the establishment of a critical data mass for research purposes, has led to an increasing volume of academic research on the effect of ENERGY STAR rating and LEED on property rents and sales prices. A series of three recent studies in the U.S. focused on controlled experiments with a "green" group of LEED and ENERGY STAR buildings and a controlled group of buildings with similar, but "non-green" characteristics. Eichholtz, Kok, and Quigley (2009) find that rents/sq. ft. and sales prices were roughly 3% and 16% respectively higher for their "green" group. Miller, Jay, and Florance (2008) find similar trends on average rent/sq. ft. levels (control group $28, LEED $42.15, and ENERGY STAR $30.5) and building values (LEED 9.9% and ENERGY STAR 5.3%). Fuerst and McAllister (2008) derive similar results on the significance of their "green" group for rent/sq. ft. (control group $24.68, LEED $27.07, and ENERGY STAR $29.34) and sales price.

In addition to the academic research field, a number of organizations are surveying executives on sustainability and green development. A global survey by Jones Lang LaSalle and CoreNet Global (JLL, 2008) in 2008 clearly shows the increasing interest in sustainable buildings, which will eventually pressure buildings currently not pursuing green technologies to reevaluate their future strategy to remain competitive. Two key findings were that: "a) three-quarters of companies consider energy and sustainability issues as a "major" or "tie-breaker" factor in making location decisions; b) corporate tenants report greater scarcity of green space that meets their needs today than a year ago." Turner Construction (2008) interviewed commercial real estate executives after the credit market crises began and the results of their survey showed a sustained interest in the benefits of green buildings even in this difficult economic environment, because of the "lower ongoing costs (energy, operating costs)" and market performance (values, rents). The vast majority of executives also indicated their interest to pursue LEED certification for new construction. IBT's (2008) survey of financial institution executives had similar results for new construction as the Turner survey. They also highlighted a number of sustainable initiatives currently in place by the executives' organizations (e.g., energy efficient lighting, recycling, etc.) leading to decreased operating costs. Among the cases highlighting the LEED effect on Return on Investment (ROI) by USGBC is that of Adobe Towers, with an ROI of 120% and a 9.5-month payback (Denise, 2007). A more general reference on a survey conducted by the Building Owners & Managers Association (BOMA/International), USGBC, and the Real Estate Forum found that 65% of respondents acknowledged a 5% increase in their ROI compared to the year before due to their green investments (Burr, 2008).

Data

This study uses assessor-generated values (total assessed values[2] and market values[3]) of LEED office buildings throughout the U.S. for three reasons. The first is the difficulty in obtaining the actual transaction prices of properties throughout the U.S. with certain characteristics. In addition, properties constructed recently might have not transacted at all. The use of assessor-generated values is, therefore, the closest proxy one can use for a property's valuation. The third reason this route was chosen was the lack of any work we are aware of on this area and the creation of a benchmark to which future studies can compare their results to and evaluate changes in the way properties are assessed.

The study's focus on assessors' valuations required information gathering from multiple sources. Although some aggregations were available on LEED ratings, levels and general property information, market values, and assessed values required extensive research of local (county and city) assessor/treasurer offices throughout the U.S. The sources of information included:

- CoStar Group: This was the first source used to extract information on buildings with rentable building area of 50,000 sq. ft. or more with Class A & B classification and LEED designation throughout the U.S. The data fields gathered included: the building's geocoding (longitude and latitude), number of stories, building class (A or B), Rentable Building Area (RBA), year built, type of tenant (single vs. multi), owner (private or public (government or educational), ENERGY STAR status, and LEED certification. Information was partially available and gathered on property valuation and it was compared with the information gathered from the local assessors' records.
- U.S. Green Building Council (USGBC): The second source verifying and enriching the CoStar Group data with specific information on the LEED rating[4] and certification[5] levels achieved by each building.
- County/City Assessors and Treasurers websites across the U.S.: They provided information on property assessment levels for 2008. Total Assessed Values (AV) were available in most cases, as well as Fair Market Values (MV). In the cases where AVs[6] were available without MVs, additional research was done to identify the appropriate assessment ratio used and backtracked to the MV. In forty-two cases, the property was tax exempt, but the MV was recorded by the assessor and, therefore, the dataset with MVs are slightly larger from the one with AVs.

It should be noted that a number of states, counties, and cities offer a variety of property and other tax-related incentives (Nellen and Miles, 2007) promoting green development and renovation. The Database of State Incentives for Renewables & Efficiency (DSIRE) offers the most comprehensive aggregation of all incentives at the state and local level throughout the U.S. As of July 2009, DSIRE reported state-related property tax exemptions or special assessments for renewables in 24 states. Local governments in three states (Virginia, New Hampshire, and Vermont) are authorized to offer exemptions and five states (Colorado, Iowa, Maryland, New York, and Rhode Island) offer state level exemptions or special assessments and local government options. In addition to DSIRE, USGBC publishes a quarterly report named ''Summary of Government LEED Incentives,'' which provides updates on LEED incentives in counties, cities and towns throughout the U.S.

The data were gathered from February of 2009 through the summer of 2009 with the overall dataset reaching 351 office buildings across 36 states (Exhibit 1). This overall dataset was then divided into two subgroups: MVD included properties with available market values (275, also shown broken down in Exhibit 1 in parentheses) and AVDs included other properties with assessed values (266). Regardless of overall dataset or subgroup, Class A properties dominate the data gathered (Exhibit 1). The vast majority of property is privately owned (mainly due to CoStar Group, which concentrates on private properties) (Exhibit 1). The distribution among the different LEED designations shows that 200 buildings were LEED-New Construction, 85 were LEED-Existing Buildings, 51 were LEED-Core & Shell, 6 were LEED-Commercial Interiors, and 9 were not specified. The certification level of the 351 buildings ranged from Platinum (highest) to Certified (lowest), with 24 Platinum properties, 120 Gold, 124 Silver, one Bronze (not currently used by USGBC), and 82 Certified.

Methodology

The main goal of this study is to examine the effect of certain property characteristics (ENERGY STAR designation, rentable building area, year built, property class, type of tenant, and owner) and LEED designations (rating and level) on their assessed and market values. The initial overview in Exhibits 1–10, which allocates selected property characteristics and LEED designations (rating and level) by state. is complemented with Exhibits 11–13, which provide the average values of: rentable building area, year built, assessed, and market values by LEED rating and level.

A few[7] regression models were considered, but three were finally used: a robust OLS regression (Equation 1, Exhibit 14), a maximum likelihood spatial error regression (Equation 1-1), and a fixed effects regression (Equation 2, Exhibit 14).

Exhibit 1 | Overview of Key Data by U.S. State

			Class		LEED Certification Type					LEED Certification Level					Type of Owner		
State	Totals	EN. STAR	A	B	NC	EB	CS	CI	NA	Platinum	Gold	Silver	Bronze	Certified	Private	Government	Education
AL	3 (2)	0 (0)	0 (0)	3 (2)	3 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (2)	0 (0)	0 (0)	3 (2)	0 (0)	0 (0)
AR	2 (1)	0 (0)	2 (1)	0 (0)	2 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	1 (0)	0 (0)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)
AZ	3 (2)	2 (1)	3 (2)	0 (0)	2 (1)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	2 (1)	3 (2)	0 (0)	0 (0)
CA	59 (33)	16 (14)	46 (27)	13 (6)	28 (7)	24 (20)	6 (5)	0 (0)	1 (1)	9 (5)	20 (12)	17 (13)	0 (0)	13 (3)	46 (32)	13 (1)	0 (0)
CO	22 (20)	7 (7)	14 (13)	8 (7)	13 (11)	7 (7)	2 (2)	0 (0)	0 (0)	1 (1)	7 (6)	7 (6)	0 (0)	7 (7)	14 (13)	8 (7)	0 (0)
DC	7 (7)	1 (1)	5 (5)	2 (2)	0 (0)	3 (3)	4 (4)	0 (0)	0 (0)	0 (0)	4 (4)	3 (3)	0 (0)	0 (0)	6 (6)	1 (1)	0 (0)
DE	1 (1)	0 (0)	1 (1)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
FL	4 (3)	1 (1)	3 (3)	1 (0)	3 (2)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)	1 (1)	0 (0)	1 (1)	4 (3)	0 (0)	0 (0)
GA	6 (6)	2 (2)	5 (5)	1 (1)	2 (2)	1 (1)	3 (3)	0 (0)	0 (0)	0 (0)	3 (3)	2 (2)	0 (0)	1 (1)	5 (5)	1 (1)	0 (0)
ID	2 (1)	1 (0)	2 (1)	0 (0)	1 (1)	1 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	1 (0)	0 (0)	0 (0)	1 (1)	1 (0)	0 (0)
IL	13 (10)	4 (3)	9 (7)	4 (3)	4 (2)	6 (6)	3 (2)	0 (0)	0 (0)	1 (1)	6 (4)	5 (4)	0 (0)	1 (1)	10 (7)	2 (2)	1 (1)
KS	4 (3)	0 (0)	4 (3)	0 (0)	4 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)	2 (2)	2 (2)	2 (1)	0 (0)
KY	1 (1)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)	0 (0)	0 (0)
LA	1 (1)	0 (0)	1 (1)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
MA	22 (21)	8 (8)	16 (15)	6 (6)	11 (10)	7 (7)	1 (1)	1 (1)	2 (2)	1 (1)	9 (9)	7 (6)	0 (0)	5 (5)	20 (19)	0 (0)	2 (2)
MD	19 (18)	1 (1)	15 (14)	4 (4)	11 (10)	1 (1)	6 (6)	1 (1)	0 (0)	1 (1)	7 (6)	8 (8)	0 (0)	3 (3)	15 (15)	4 (3)	0 (0)
MI	19 (9)	1 (1)	16 (7)	3 (2)	15 (6)	2 (2)	1 (0)	0 (0)	1 (1)	1 (1)	2 (2)	2 (1)	0 (0)	14 (5)	18 (9)	1 (0)	0 (0)
MN	5 (5)	0 (0)	3 (3)	2 (2)	4 (4)	0 (0)	1 (1)	0 (0)	0 (0)	1 (1)	4 (4)	0 (0)	0 (0)	0 (0)	5 (5)	0 (0)	0 (0)
MO	7 (5)	0 (0)	4 (3)	3 (2)	2 (2)	3 (1)	0 (0)	1 (1)	1 (1)	1 (1)	0 (0)	2 (1)	0 (0)	4 (3)	6 (4)	0 (0)	1 (1)

Exhibit 1 | (continued)

Overview of Key Data by U.S. State

			Class		LEED Certification Type					LEED Certification Level					Type of Owner		
State	Totals	EN. STAR	A	B	NC	EB	CS	CI	NA	Platinum	Gold	Silver	Bronze	Certified	Private	Government	Education
NC	3 (2)	0 (0)	3 (2)	0 (0)	1 (0)	0 (0)	1 (1)	0 (0)	1 (1)	0 (0)	0 (0)	2 (1)	0 (0)	1 (1)	3 (2)	0 (0)	0 (0)
NE	3 (2)	0 (0)	2 (1)	1 (1)	3 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (2)	0 (0)	0 (0)	0 (0)	0 (0)	3 (2)	0 (0)
NJ	4 (4)	0 (0)	3 (3)	1 (1)	1 (1)	2 (2)	0 (0)	1 (1)	0 (0)	0 (0)	1 (1)	2 (2)	0 (0)	1 (1)	4 (4)	0 (0)	0 (0)
NM	1 (1)	1 (1)	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
NV	2 (2)	0 (0)	1 (1)	1 (1)	1 (1)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)	0 (0)	0 (0)	2 (2)	0 (0)	0 (0)
NY	13 (11)	1 (1)	9 (9)	4 (2)	7 (5)	5 (5)	1 (1)	0 (0)	0 (0)	1 (1)	2 (2)	7 (5)	0 (0)	3 (3)	9 (8)	3 (2)	1 (1)
OH	8 (7)	1 (1)	6 (5)	2 (2)	1 (0)	5 (5)	2 (2)	0 (0)	0 (0)	0 (0)	1 (1)	2 (2)	0 (0)	5 (4)	7 (6)	1 (1)	0 (0)
OR	19 (15)	3 (3)	10 (9)	9 (6)	13 (10)	2 (2)	4 (3)	0 (0)	0 (0)	1 (1)	13 (10)	4 (3)	1 (1)	0 (0)	15 (12)	4 (3)	0 (0)
PA	21 (15)	2 (1)	13 (10)	8 (5)	14 (11)	2 (1)	3 (1)	2 (2)	0 (0)	2 (0)	6 (4)	7 (7)	0 (0)	6 (4)	15 (10)	5 (4)	1 (1)
SC	5 (4)	0 (0)	5 (4)	0 (0)	5 (4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4 (3)	0 (0)	1 (1)	5 (4)	0 (0)	0 (0)
TN	2 (2)	1 (1)	0 (0)	2 (2)	1 (1)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (2)	1 (1)	1 (1)	0 (0)
TX	25 (23)	2 (2)	17 (16)	8 (7)	18 (16)	2 (2)	4 (4)	0 (0)	1 (1)	1 (1)	7 (7)	14 (13)	0 (0)	3 (2)	25 (23)	0 (0)	0 (0)
UT	3 (2)	1 (1)	1 (0)	2 (2)	2 (2)	0 (0)	1 (0)	0 (0)	0 (0)	1 (0)	1 (1)	1 (1)	0 (0)	0 (0)	2 (1)	1 (1)	0 (0)
VA	16 (13)	2 (2)	13 (11)	3 (2)	10 (8)	2 (2)	3 (2)	0 (0)	1 (1)	0 (0)	6 (5)	8 (7)	0 (0)	2 (1)	10 (8)	6 (5)	0 (0)
WA	17 (17)	2 (2)	9 (9)	8 (8)	11 (11)	3 (3)	3 (3)	0 (0)	0 (0)	0 (0)	4 (4)	9 (9)	0 (0)	4 (4)	12 (12)	5 (5)	0 (0)
WI	7 (6)	1 (1)	7 (6)	0 (0)	3 (2)	3 (3)	1 (1)	0 (0)	0 (0)	0 (2)	4 (4)	3 (0)	0 (0)	0 (0)	7 (6)	0 (0)	0 (0)
WV	2 (0)	1 (0)	1 (0)	1 (0)	2 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	2 (0)	0 (0)	0 (0)	0	2 (0)	0 (0)
Totals	351 (275)	61 (54)	251 (199)	100 (76)	200 (140)	85 (77)	51 (43)	6 (6)	9 (9)	24 (17)	120 (98)	124 (103)	1 (1)	82 (56)	281 (229)	64 (40)	6 (6)

Notes: Values in parenthesis represent the count of properties with available market values. If a property was tax exempt and did not have a market value it was excluded. An additional 34 properties were excluded because of the lack of market value information.

NA = Not Available.

Exhibit 2 | LEED-NC Distribution

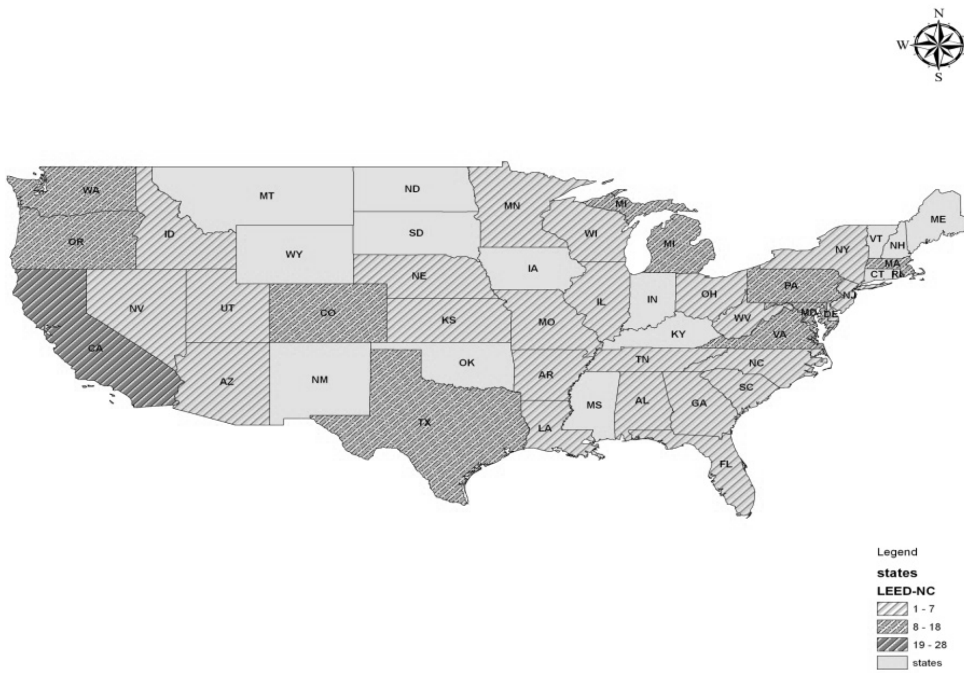


Exhibit 3 | LEED-EB Distribution

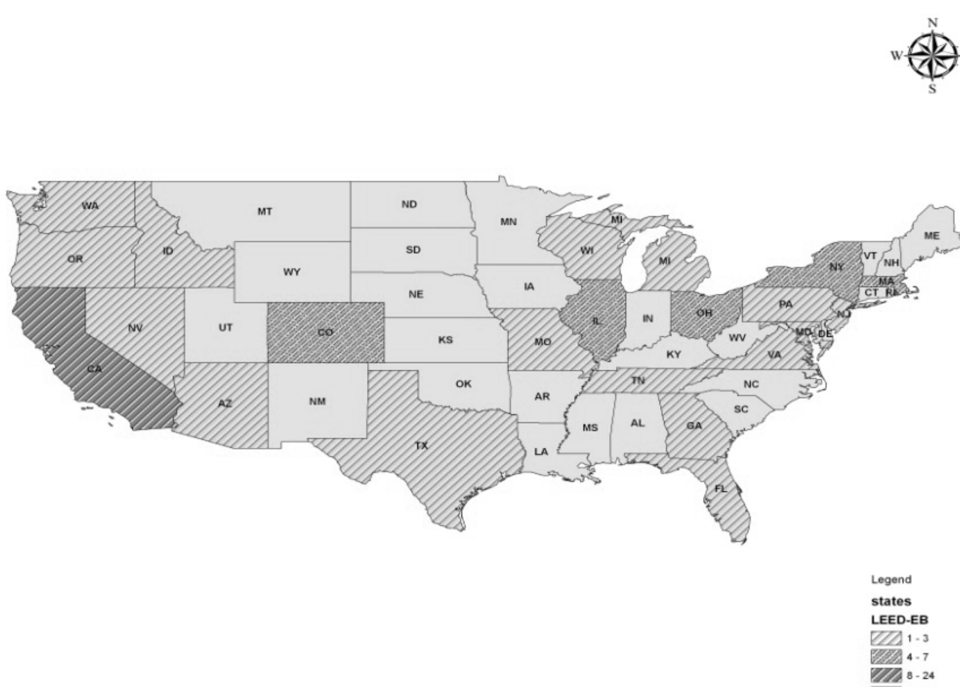


Exhibit 4 | LEED-CS Distribution

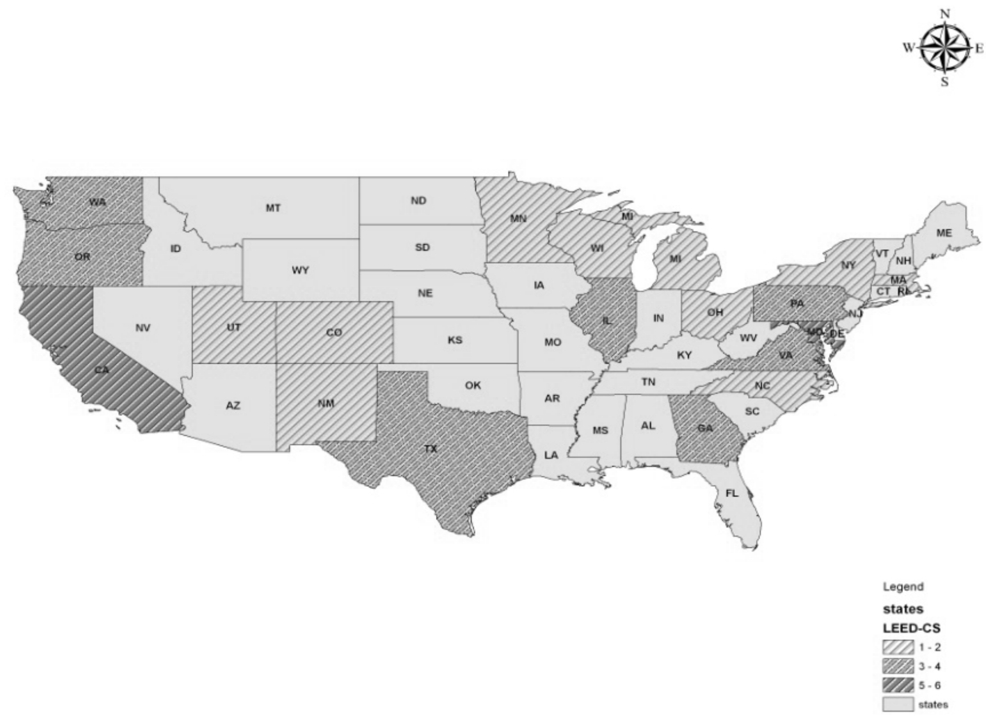


Exhibit 5 | LEED-Platinum Distribution

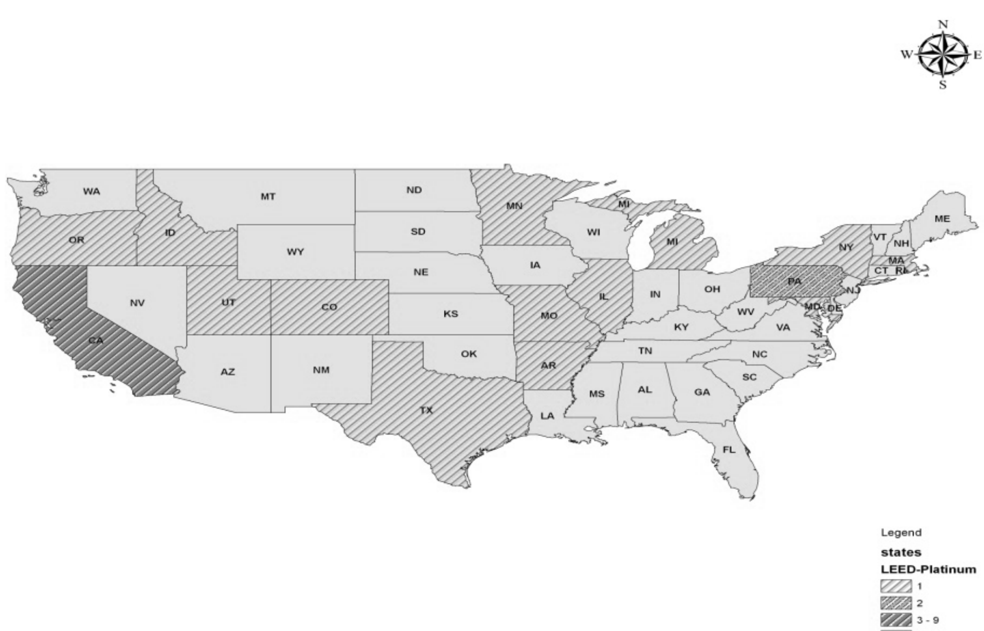


Exhibit 6 | LEED-Gold Distribution

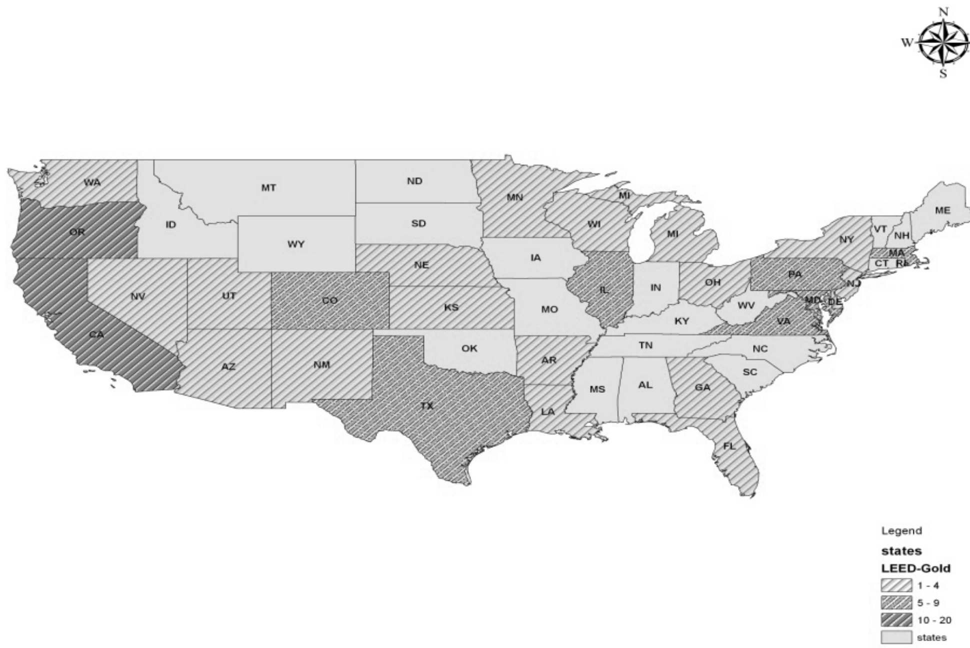


Exhibit 7 | LEED-Silver Distribution

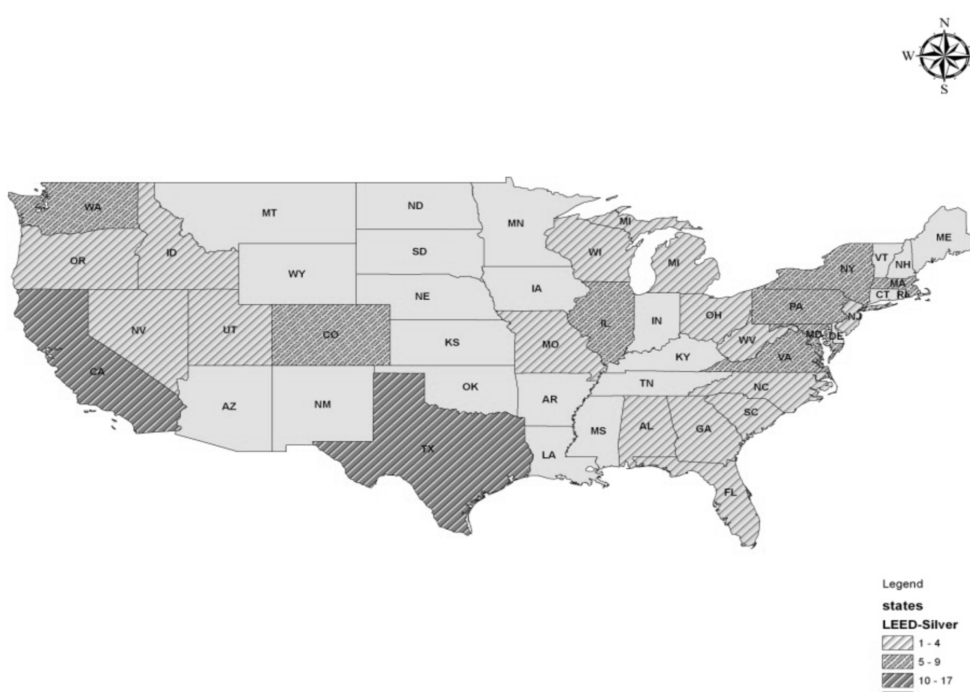
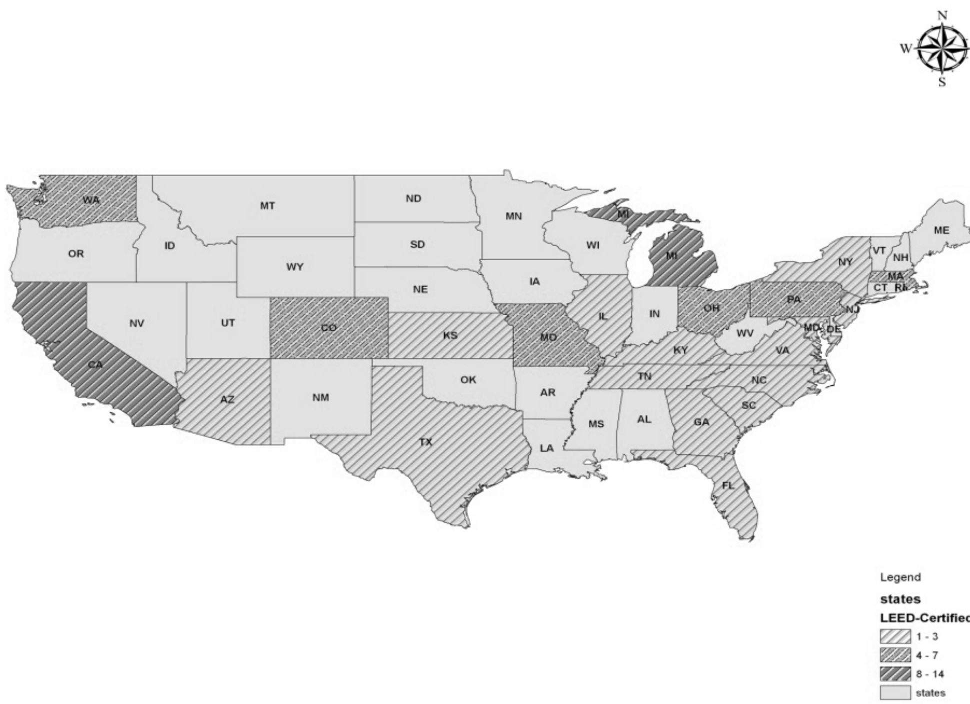


Exhibit 8 | LEED-Certified Distribution



$$Y = \alpha + \beta_1 ES + \beta_2 RBA + \beta_3 YB + \beta_4 BC + \beta_5 TE + \beta_6 OW + \gamma LEED_{(kj)} + \varepsilon. \tag{1}$$

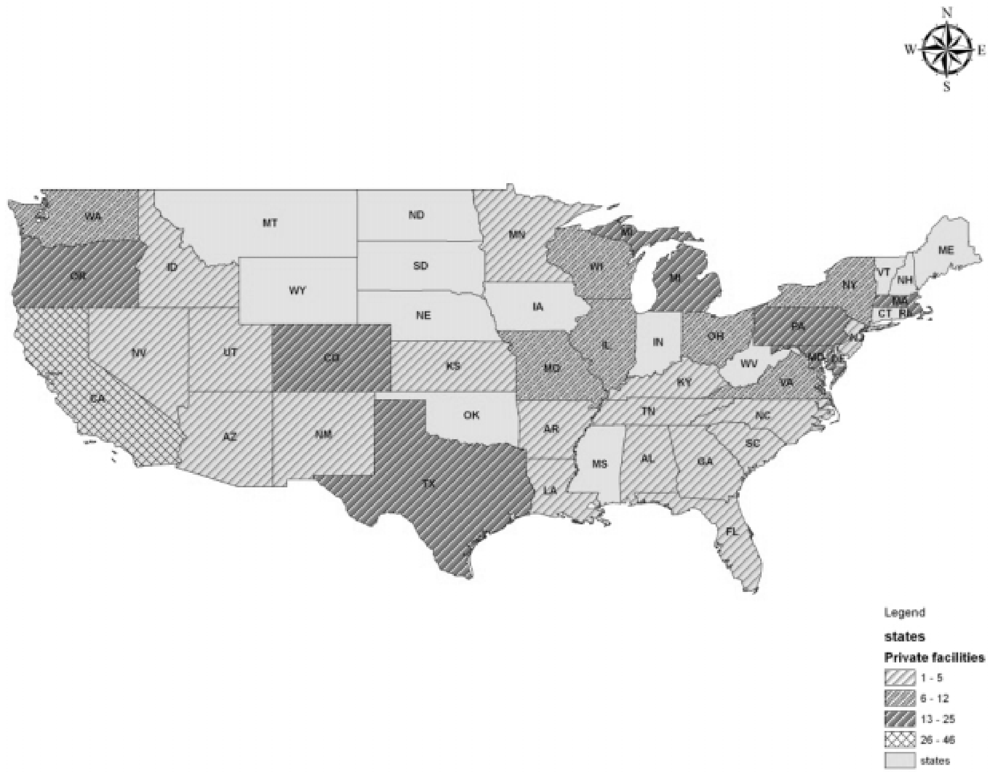
$$Y = \beta X + \lambda W_{\varepsilon} + \mu. \tag{1-1}$$ [8]

$$Y_i = \alpha + \beta_1 ES_i + \beta_2 RBA_i + \beta_3 YB_i + \beta_4 BC_i + \beta_5 TE_i + \beta_6 OW_i + \gamma LEED_{(kj)i} + \eta_i + \varepsilon_i. \tag{2}$$

Where:

- Y = The log of total assessed value or market value;
- i = Takes the values 1 through 74 representing the different MSAs included in the data;
- ES = The ENERGY STAR dummy (takes value 1 if the building is ENERGY STAR, otherwise it is 0);
- RBA = The rentable building area;
- YB = The year built;
- BC = The building classification dummy (takes value 1 if the building is Class A, otherwise it is 0);

Exhibit 9 | Distribution of Private LEED Facilities



TW = A tenant dummy (takes value 1 if the building is multi-tenant, otherwise it is 0);

OW = An owner dummy (takes value 1 if the building is private, otherwise it is 0);

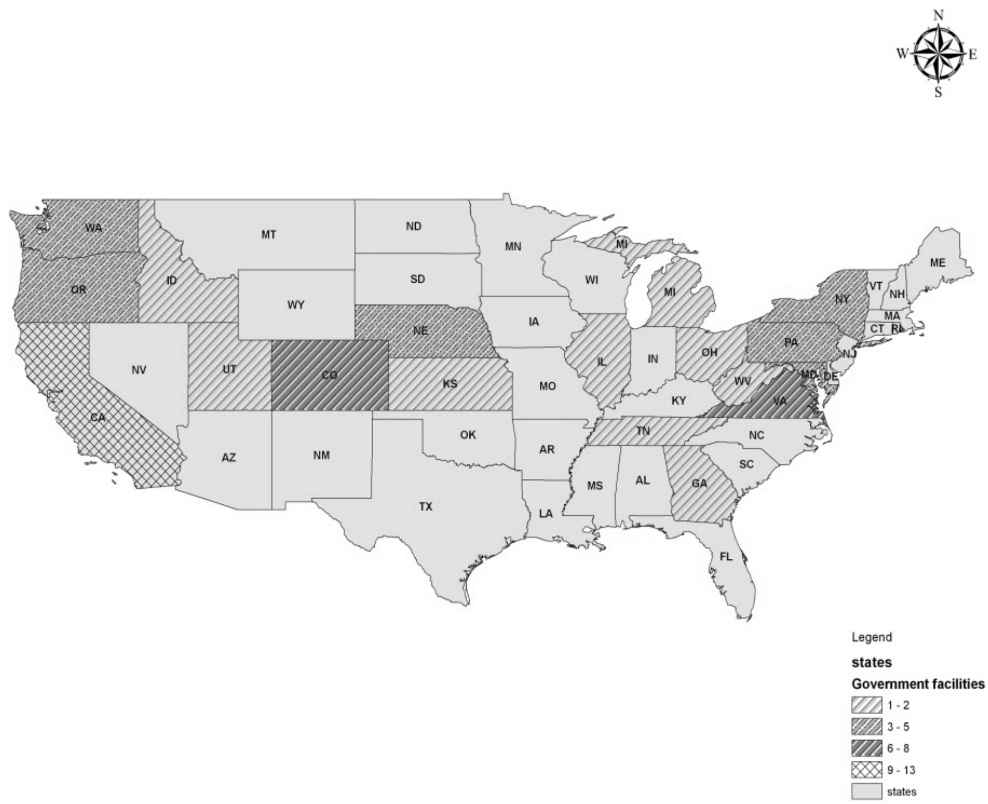
$LEED_{kj}$ = k represents the different types of LEED rating (e.g., NC, etc.) and j the different levels of designation (e.g., platinum etc.).

Based on the size of the data, the following pairs were examined:

LEED-NC & Platinum	LEED-EB & Platinum	LEED-CS & Platinum
LEED-NC & Gold	LEED-EB & Gold	LEED-CS & Gold
LEED-NC & Silver	LEED-EB & Silver	LEED-CS & Silver
LEED-NC & Certified	LEED-EB & Certified	LEED-CS & Certified

All of the $LEED_{kj}$ variables were dummies, taking the value 1 based on their designation at the time and are 0 otherwise.

Exhibit 10 | Distribution of Government LEED Facilities



β = A "vector of coefficients";
X = Represents all the independent variables from the original OLS model;
λ = The spatial autoregressive parameter;
W_ε = The spatial weight matrix;
μ = A "vector of homoscedastic and uncorrelated errors;" and
η_i = Different for each MSA accounting for the differences.

The OLS model did not include any variables accounting for the geographic location of properties such as State or Metropolitan Statistical Area (MSA) dummies, but additional testing on spatial dependence was performed. With the use of each property's geocoding information (longitude & latitude), a spatial weight matrix was determined using Euclidean distance.[9] Developing this spatial weight matrix allowed the testing of the OLS model for spatial error and lag dependence at the lowest possible geographic level (property level). Three tests of spatial error dependence were performed (Moran's I, simple Lagrange multiplier, and robust Lagrange multiplier), along with two tests of spatial lag dependence (simple Lagrange multiplier and robust Lagrange multiplier) (Anselin, Bera, Florax, and Yoon, 1996). The results from Equation 1 provide partial

Exhibit 11 | Averages of RBA & Year built Trends by LEED Certification

	Average Values											
	Platinum			Gold			Silver			Certified		
	Count	ARBA	AYB	Count	ARBA	AYB	Count	ARBA	AYB	Count	ARBA	AYB
NC	9	243,120	2003	73	218,419	1998	60	210,128	1999	57	208,705	1995
EB	12	304,071	1984	27	453,602	1978	32	478,366	1980	14	235,030	1985
CS	3	101,972	2006	17	269,425	1996	25	204,016	2003	6	127,208	1984
CI				1	100,000	2006	4	160,945	2007	1	165,000	2005
NA				2	203,467	1999	3	281,479	1984	4	258,219	1994

NA = Not Available.

Exhibit 12 | Averages of RBA & Year Built Trends by LEED Certification (with Assessed Values)

	Average Values											
	Platinum			Gold			Silver			Certified		
	Count	ARBA	AYB	Count	ARBA	AYB	Count	ARBA	AYB	Count	ARBA	AYB
NC	6	179,187	2003	51	227,072	1996	42	183,356	1997	33	266,122	1994
EB	9	271,973	1981	26	450,918	1980	29	507,850	1983	13	246,648	1983
CS	1	59,662	2006	16	272,516	2002	22	185,178	2002	4	108,621	1974
CI				1	100,000	2006	4	160,945	2007	1	165,000	2005
NA				2	203,467	1999	3	281,479	1984	4	258,219	1994

NA = Not Available.

Exhibit 13 | Average Assessed & Market Value Trends by LEED Certification (with Assessed Values and / or Market Values)

	Platinum			Gold			Silver			Certified		
	Count	AAV	AMV	Count	AAV	AMV	Count	AAV	AMV	Count	AAV	AMV
NC	6(7)	31,300,000	45,600,000	51(53)	44,200,000	52,300,000	42(45)	23,300,000	28,900,000	33(34)	23,400,000	26,900,000
EB	9(9)	53,700,000	54,700,000	24(26)	52,900,000	70,600,000	29(29)	87,600,000	105,000,000	13(13)	26,900,000	38,700,000
CS	1(1)	7,865,453	7,865,453	16(16)	43,900,000	62,100,000	22(22)	39,300,000	47,000,000	4(4)	8,986,388	14,000,000
CI				1(1)	15,000,000	15,000,000	4(4)	12,800,000	13,100,000	1(1)	135,900	434,880
NA				2(2)	7,350,003	7,350,003	3(3)	28,700,000	28,700,000	4(4)	30,000,000	32,100,000

Values per square foot of rentable building area

	Platinum			Gold			Silver			Certified		
	Count	AAV	AMV	Count	AAV	AMV	Count	AAV	AMV	Count	AAV	AMV
NC	6(7)	116.33	138.54	51(53)	182.97	221.79	42(45)	131.51	161.90	33(34)	95.04	126.55
EB	9(9)	181.61	184.69	24(26)	179.00	219.57	29(29)	240.93	286.94	13(13)	95.85	141.36
CS	1(1)	131.83	131.83	16(16)	201.86	253.41	22(22)	206.25	237.04	4(4)	58.92	106.71
CI				1(1)	150.00	150.00	4(4)	86.53	88.40	1(1)	0.82	2.64
NA				2(2)	78.30	78.30	3(3)	100.46	100.46	4(4)	155.11	167.36

Notes: The values in parenthesis represent the count of the MVD.
ARBA: Average Rentable Building Area
AYB: Average Year Built
AAV: Average Assessed Value
AMV: Average Market Value
NA = Not Available.

evidence of spatial dependence and, therefore, a spatial error model was applied (Equation 1-1) (Anselin and Hudak, 1992). Another model was also developed to test the effect of MSA level aggregation of the dataset (Equation 2). Due to concerns over contagions, multicollinearity tests were performed on all regression models derived from Equations 1 and 2 and no evidence was found. A final test performed to check for the stability of the results based on their statistical significance included the clustering of the assessed value subset by assessed values per square foot. Ten groups were determined using average-linkage[10] clustering with Euclidean distance as the dis(similarity) measure (Exhibit 15). From the 10 groups generated, the most populated were groups 1 through 3. Each of the three groups was then isolated from the overall data and the results from Equations 1 and 2 were re-estimated. These results did not have significant differences from the original assessed value subgroup dataset based on MSAs and therefore the original fixed effects regression was used.

Results

The approach offered in this study provides interesting insights on the effect of property characteristics and LEED ratings/levels on assessed and market values, even though it is a departure from the controlled experiments of the recent literature. The restricted dataset of office buildings with more than 50,000 square feet of RBA and only A or B classification allows for an in-depth look of a relatively homogenous group with properties sharing the same use and partial characteristics. Exhibit 1 is the first introduction of the full extent of the dataset to the reader with volume allocation among all the states represented. A few observations can be made based on this exhibit.[11] ENERGY STAR designation is found only on 17.4% of the overall number of properties in the dataset, which is a relatively low percentage considering their LEED designation. This low percentage shows that the full adoption of green strategies is still in its infancy. A good sign is that Class A properties are more easily embracing LEED designation (71.5% of the overall dataset) compared to Class B. This is partially expected, because Class A properties are usually newer and more likely to be constructed as LEED; they might also be more easily retrofitted to accomplish LEED designation faster than Class Bs, which might be lagging behind due to upfront cost, time required for retrofit, and payback period requirements imposed by the owner (e.g., if the owner is planning to sell the property in few years and the LEED payoff is beyond that timeframe, the owner is not motivated to pursue the retrofits). This argument is also reinforced by the analysis of the distribution of LEED ratings in the overall dataset. As expected, the LEED-NC designation outnumbers the other ratings in the overall dataset, with 56.9% when LEED-EB follows with 24.2%. The concentration of LEED-NC also indicates the commitment of the development community in accomplishing a more sustainable environment. Further examining the LEED levels, two are the most frequently accomplished in the overall dataset; Silver 35%, closely followed by Gold 34%. These levels are ranked by LEED as third and second highest. Accomplishing these levels is another indication that properties pursuing LEED designation are focused on levels beyond the minimum certification. The final element presented in Exhibit 1 is the ownership distribution, which, as expected, is skewed significantly (80% of the overall dataset) towards private ownership, because CoStar Group is mainly focused on private properties.

Exhibits 2–4 show the geographical distribution of the overall dataset's LEED ratings throughout the U.S. The comparison of these figures shows that LEED-NC is distributed more evenly throughout the country compared to the other two ratings. California, which has embraced environmental incentives throughout the years, has the highest number of buildings of all LEED ratings. The two other adjacent states of Oregon and Washington have increased concentration of LEED-NC and CS in the dataset, although LEED-CS is less prevalent in the dataset.

Exhibits 5–8 show the geographical distribution of LEED certification levels across the U.S. The number of Platinum level properties per state is very limited and, therefore, a conclusion cannot be drawn. In contrast, Gold and Silver level properties have more observations in the overall dataset, allowing for a better assessment of their distribution. Gold level properties are more evenly distributed throughout the U.S. compared to Silver-rated properties, which seem to be more concentrated along the West and East Coasts. Certified properties are more concentrated along the east and southern portion of the U.S.

Exhibits 9 and 10 show the geographical distribution of private and public LEED properties across the U.S. California and Oregon share a higher concentration of private LEED buildings, as does Texas and Colorado. Other adjacent states with similar levels of concentration in the public sector are Wisconsin, Illinois, and Missouri. Although the data are skewed towards the private sector, because one of the main sources is CoStar Group, some government facilities are also included. Their distribution is more linear from one coast to the other in our dataset compared to a more diversified allocation in the private sector.

Exhibits 11–13 offer additional insight on the dataset beyond aggregate counts by highlighting the average Rentable Building Area (RBA) and Year Built by LEED rating and level. Exhibit 11, which refers to the overall dataset of 351 properties, shows that LEED-EB buildings are larger in size on average compared to all other LEED ratings followed by LEED-NC (Gold level is the only exception). A further comparison between LEED-NC and EB trends for the various certification levels leads to two conclusions: (1) on average, New Construction (NC) is smaller in size compared to Existing Buildings (EB), because of the increased efficiency offered in new buildings; (2) on average, large EBs are able to accomplish LEED—Gold and Silver. This finding is another indication of the commitment and belief of owners and managers in sustainability and reduction of operating costs even for larger buildings, which will require an increased upfront investment in green technologies. Focusing on the average year built of the NCs, it is interesting to see mid to late 1990s, which is an indication that the properties included are not only the ones built after 2000, but there are older properties too, which went through major renovations with substantial retrofitting (adaptive re-use) to accomplish this rating rather than opting for LEED-EB. The Core & Shell type of LEED designation also seems to have larger in size properties in the Gold and Silver levels, but the lack of a significant number of observations in the

Platinum and Certified levels cannot help in generalizing this result. Exhibit 12's dataset overview focuses only on properties with Assessed Values (266 properties). Even though Assessed Values were not available for all properties (no data were available for 34 properties and 42 were tax exempt), the overall trends of Exhibit 11 remain almost the same. The only exception can be found on LEED-NC Silver buildings, which have a smaller on average size compared to LEED-CS of the same level of designation. Exhibit 13 focuses on the Average Assessed (AVD: 266 properties) and Market Values (MVD: 275 properties) found in the two subsets.[12] The table shows both the total value and the value per square foot, as well as the subset sizes. Comments can be made on the Gold, Silver levels of NC, EB, and CS, because of the more significant number of observations. Although the total AAV and AMV are higher for EB-Gold properties, because of the size of these properties, when the value/sq. ft. is considered, LEED-EB Gold comes in to third place compared to CS and NC at the Gold level. In contrast at the Silver level EB properties and NC and CS share the same ranking between total assessed value and value/sq. ft. This indicates that although EB properties are larger (based on Exhibit 12), their value is also high. Another observation on the value/sq. ft. comparison among NC, EB, and CS is that the CS rating seems to overshadow both NC and EB ratings at the Gold level with higher values/sq. ft. A cause might be the smaller number of properties compared to the other two categories. At the silver level, the CS rating seems to accomplish the second highest values/sq. ft. with EB being the first. Very interestingly, NC is not ranked first in either the Gold or the Silver levels. At the Gold level the property sizes (based on Exhibit 12) are smaller for NC compared to CS, which means that the value proposition offered by this properties might not be similar to those of slightly large size with other ratings. In the case of Silver NCs, their size is, on average, even smaller compared to EB and CS and their value proposition per square foot is even less.

Exhibit 14 provides the result of the regression modeling (Equations 1, 1-1, and 2). Columns 1 through 6 show the results of the spatial dependence analysis (Equation 1), while controlling for the property's location through its geocoding information. The *p*-values, which are zero in some cases, are indicative of strong spatial effects (Equation 1, columns 1 through 6). Equation 1-1 was developed to address the spatial dependence issues, by also analyzing the effect of property characteristics[13] and LEED ratings/levels on AV and MV (columns 1-1 through 6-1). The focus, therefore, shifts on analyzing the results of LEED rating and level, based on Equation 1-1 and Equation 2. The results of Equation 1-1 indicate that MV decreases by 36% [exp(−0.45)-1] for LEED-NC at the Silver level compared to the other LEED properties. Although this result was not expected, looking in Exhibits 12 and 13 we see that the values registered for LEED-NC Silver were the lowest compared to all other ratings and levels. In contrast, LEED-EB Gold and Silver properties have a positive and statistically significant effect on AV and MV. LEED-EB properties at the Gold level are associated with a 77% increase in AV compared to other LEED properties, while LEED-EB at the Silver level are associated with a 118% increase in AV and a 95% increase in MV compared to the other LEED properties. LEED-CS does not seem to have a statistically significant effect on AV or MV, with properties at the Certified level

Exhibit 14 | Regression Modeling

	Equation 1 Models						Equation 1-1 Models						Equation 2 Models					
	1	2	3	4	5	6	1-1	2-1	3-1	4-1	5-1	6-1	7	8	9	10	11	12
	AV1	MV1	AV1	MV1	AV1	MV1	AV1	MV1	AV1	MV1	AV1	MV1	AV2	MV2	AV2	MV2	AV2	MV2
Property Characteristics																		
ENERGY STAR[a]	0.98	0.90	0.79	0.79	0.99	0.92	0.83	0.78	0.63	0.64	0.79	0.79	0.83	0.75	0.74	0.61	0.97	0.73
	3.66**	4.31**	2.71**	3.42**	3.89**	4.50**	3.38**	3.7**	2.51**	2.94**	3.26**	3.82**	3.35**	3.39**	2.73**	2.53**	4.05**	3.26**
Rentable Building Area	1.45E-06	1.50E-06	1.28E-06	1.39E-06	1.46E-06	1.53E-06	1.61E-06	1.54E-06	1.42E-06	1.40E-06	1.56E-06	1.56E-06	1.75E-06	1.51E-06	1.74E-06	1.54E-06	1.58E-06	1.53E-06
	3.28**	3.86**	2.93**	3.56**	3.25**	3.84**	5.07**	5.75**	4.41**	5.08**	4.89**	5.72**	5.71**	5.29**	5.48**	5.13**	5.06**	5.02**
Year Built	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	1.86***	1.77***	2.01**	1.91**	1.52	1.49	2.42**	2.18**	2.75**	2.47**	2.12**	1.96**	2.21**	1.57	2.47**	1.83***	1.81***	1.50
Building Class[a]	0.27	0.34	0.31	0.36	0.27	0.34	0.19	0.26	0.24	0.30	0.21	0.28	0.15	0.23	0.14	0.21	0.11	0.19
	1.10	1.7***	1.21	1.73***	1.09	1.67***	0.93	1.45	1.18	1.65***	1.01	1.54	0.69	1.14	0.62	1.01	0.52	0.93
Type of Tenant[a]	0.08	0.17	0.04	0.14	0.08	0.16	−0.07	0.02	−0.10	0.00	−0.02	0.06	−0.10	0.01	−0.06	−0.03	−0.12	−0.02
	0.34	0.90	0.21	0.79	0.39	0.90	−0.35	0.10	−0.52	0.00	−0.10	0.34	−0.46	0.06	−0.31	−0.18	−0.60	−0.12
Type of Owner[a]	0.51	0.09	0.44	0.06	0.43	0.05	0.28	0.00	0.25	0.00	0.25	0.01	0.09	0.02	0.13	0.01	0.01	−0.03
	1.65***	0.37	1.45	0.28	1.43	0.21	1.05	0.00	0.96	0.00	0.95	0.06	0.36	0.10	0.49	0.03	0.03	−0.13
LEED Type & Level of Certification																		
LEED-NC & Platinum[a]	−0.46	−0.12					0.06	0.06					0.42	0.49				
	−0.64	−0.29					0.10	0.12					0.63	0.88				
LEED-NC & Gold[a]	0.28	0.25					0.27	0.16					0.08	0.41				
	1.04	1.21					1.06	0.77					0.33	1.72***				
LEED-NC & Silver[a]	−0.31	−0.32					−0.44	−0.45					−0.72	−0.56				
	−0.97	−1.14					−1.61	−1.97**					−2.48**	−2.08**				
LEED-NC & Certified[a]	−0.18	−0.14					0.04	−0.07					−0.14	0.08				
	−0.58	−0.54					0.12	−0.25					−0.45	0.28				
LEED-EB & Platinum[a]			0.21	−0.08					0.18	−0.03					0.54	0.32		
			0.36	−0.15					0.31	−0.07					0.78	0.49		
LEED-EB & Gold[a]			0.54	0.38					0.57	0.43					0.35	0.32		
			1.63	1.43					1.7***	1.54					1.03	1.05		

Exhibit 14 | (continued)

Regression Modeling

	Equation 1 Models						Equation 1-1 Models						Equation 2 Models					
	1	2	3	4	5	6	1-1	2-1	3-1	4-1	5-1	6-1	7	8	9	10	11	12
	AV1	MV1	AV1	MV1	AV1	MV1	AV1	MV1	AV1	MV1	AV1	MV1	AV2	MV2	AV2	MV2	AV2	MV2
LEED-EB & Silver[a]			0.63	0.44					0.78	0.67					0.36	0.21		
			1.86***	1.52					2.49**	2.44**					1.04	0.66		
LEED-EB & Certified[a]			−0.30	−0.08					−0.32	−0.13					0.38	0.14		
			−0.55	−0.16					−0.79	−0.35					0.82	0.34		
LEED-CS & Platinum[a]					−0.02	−0.38					−0.43	−0.59					−0.92	−0.48
					−0.11	−2.02**					−0.31	−0.48					−0.74	−0.40
LEED-CS & Gold[a]					0.25	0.24					0.02	0.02					0.59	0.14
					0.64	0.76					0.04	0.06					1.67***	0.42
LEED-CS & Silver[a]					0.32	0.23					0.01	0.08					0.82	0.13
					0.77	0.70					0.03	0.27					2.53**	0.43
LEED-CS & Certified[a]					−1.69	−0.57					−1.47	−0.42					−2.51	−0.71
					−1.82***	−0.99					−2.03**	−0.66					−2.69**	−0.78
Constant	−2.64	2.29	−4.59	0.70	0.59	4.02	−2.20	2.56	−5.03	0.27	−0.15	3.66	−0.87	4.69	−4.26	1.89	2.31	4.97
	−0.28	0.30	−0.47	0.09	0.06	0.51	−0.31	0.41	−0.68	0.04	−0.02	0.58	−0.12	0.65	−0.53	0.24	0.31	0.66
MSA fixed effects	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic (fixed effects)													3.65	2.27	3.42	2.06	3.85	2.08
Lamda							0.56	0.42	0.55	0.43	0.54	0.40						
							7.85	5.14	7.93	5.45	7.41	4.76						

Exhibit 14 | (continued)

Regression Modeling

	Equation 1 Models						Equation 1-1 Models						Equation 2 Models					
	1	2	3	4	5	6	1-1	2-1	3-1	4-1	5-1	6-1	7	8	9	10	11	12
	AV1	MV1	AV1	MV1	AV1	MV1	AV1	MV1	AV1	MV1	AV1	MV1	AV2	MV2	AV2	MV2	AV2	MV2
Spatial error:																		
Moran's I	6.99	4.89	7.46	5.34	6.81	4.63												
	0.00	0.00	0.00	0.00	0.00	0.00												
Lagrange multiplier	44.09	21.15	49.71	24.99	42.44	19.15												
	0.00	0.00	0.00	0.00	0.00	0.00												
Robust Lagrange multiplier	2.79	0.86	6.33	2.42	0.78	0.13												
	0.00	0.00	0.01	0.00	0.38	0.72												
Spatial lag:																		
Lagrange multiplier	42.12	21.64	43.39	22.87	44.10	21.58												
	0.00	0.00	0.00	0.00	0.00	0.00												
Robust Lagrange multiplier	0.82	1.35	0.01	0.30	2.44	2.56												
	0.37	0.24	0.93	0.59	0.12	0.11												
R^{2b}	20.31%	25.86%	20.62%	25.49%	20.81%	25.05%	19.10%	25.10%	20.10%	24.90%	19.90%	24.50%	52.88%	43.70%	51.28%	40.70%	54.66%	40.63%

Notes: The dependent variable is log(total property assessed or market value). Values in the second line of each variable represent *t*-statistics. Multicollinearity testing of all models presented in this table were negative. For AV1 and AV2, N = 266; for MV1 and MV2, N = 275.

AV: Assessed Value.

MV: Market Value.

[a] Dummy variable.

[b] Adj. R^2 for FE regressions.

** Statistically significant at the 5% level.

*** Statistically significant at the 10% level.

being the only exception. The negative effect at the Certified level is biased, because of the small number of observations (see Exhibits 12 and 13).

The model in Equation 2 was then developed to analyze the effect of the property and LEED independent variables while accounting for the location of properties at the MSA level (columns 7 through 12 in Exhibit 14). The designation of a building as ENERGY STAR (ES) has a positive effect on both Assessed and Market Values (AV and MV) in all cases. Although a relatively small portion of the dataset had an ES designation (almost 20% for the AVD and MVD), it seems to be affecting the valuation process significantly among LEED properties, as a distinctive feature, adding to AV and MV. An increase in the RBA is also associated with a small increase in AV and MV in all cases. The year built is the only property variable without a consistent effect on MV in four out of the six cases. The results indicate that an increase of the Year Built (YB) by one year is associated with a 1% increase in AV or MV, when controlling for LEED-NC, EB properties. YB is not statistically significant in the LEED-NC and LEED-CS cases. Very interestingly, building class and tenant and owner types were consistently not statistically significant in all cases. Focusing on the LEED-NC results of columns 7 and 8, we see that LEED-NC properties at the Gold level are associated with a 50.7% increase in MV, while their AV is not affected and is statistically significant. In contrast, the AV and MV of LEED-NC properties at the Silver level are affected negatively by 51.3% and 42.8% respectively. Although on the surface this result might be not expected, going back to Exhibits 12 and 13 we see that the values registered for LEED-NC Silver were the lowest compared to all other ratings and levels (this effect is consistent with column 2-1). This effect requires additional research in the future to determine if it is a lasting trend for buildings with similar characteristics as those gathered in this study. In the case of LEED-EB buildings (columns 9 and 10), none of the levels seem to have a statistically significant effect on AV or MV, which is surprising and needs to be examined in future studies. Columns 11 and 12 focus on LEED-CS at the different certification levels. Although AV is affected by properties at the different designation levels (column 11), there is no a statistically significant effect on MV. LEED-CS at the Gold level is associated with an 80.4% increase in AV and a 127% increase at Silver level. In contrast, LEED-CS at the Certified level is associated with a decrease of 91.8% in AV [this result is biased, because of the small number of observations and is consistent with column 5-1 (see Exhibits 12 and 13)]. Exhibit 14 also reports the F-statistic of the fixed effect regressions, which indicates that the MSA dummies are jointly significant in all cases. Comparing the results of Equation 1-1 and Equation 2, a few differences can be identified. LEED-NC at the Silver level and LEED-CS at the Certified level do not have a statistically significant effect on AV or MV accordingly (based on Equation 1-1). In contrast, LEED-EB Gold and Silver have a statistically significant effect on AV and MV (only at the Silver level) based on Equation 1-1. The results indicate that the level of geographic aggregation we use can affect the significance of a LEED rating on AV or MV.

Finally, Exhibit 15 identifies the clusters generated based on the AV subset. These groupings were used instead of the MSAs in Equation 2, but because of the

Exhibit 15 | Clustering Results Based on Assessed Values / Sq. Ft.

Group	Count	Average	Std. Dev.	Min	Max
1	111	28.94	21.30	0.26	77.43
2	69	119.36	23.59	81.01	161.46
3	44	218.74	37.26	170.97	291.61
4	30	360.78	27.59	304.02	410.51
5	7	498.15	50.56	447.70	583.52
6	1	668.46		668.46	668.46
7	1	1,226.53		1,226.53	1,226.53
8	1	1,318.02		1,318.02	1,318.02
9	1	1,111.76		1,111.76	1,111.76
10	1	2,856.94		2,856.94	2,856.94

similarity results with the MSA, the models do not appear in the study. The table of clusters is included because it provides some descriptive statistics on the prices/ sq. ft. seen in the AV subset. Forty-one percent of the AVD have low values/sq. ft. ($0.3/sq. ft. to $77/sq. ft.). The second lowest values/sq. ft. (25.9% of AVD) range from $81/sq. ft. − $161/sq. ft. The other two most populated groups are almost evenly distributed with 16% ($171/sq. ft. to $292/sq. ft.) and 11% ($304/ sq. ft. to $410/sq. ft.) of the overall AVD. The table also shows some outliers.

Conclusion

Research conducted by companies, associations, and now academics are pointing out that green is here to stay, due to the cost savings and the increased ROI obtained by the owners. The most prevalent LEED rating in the dataset is LEED-NC, followed by LEED-EB. In terms of LEED designation level, Silver is followed by Gold as the most popular in the dataset. A first overview of the average values of the dataset shows that smaller (approximately 100,000 square feet) LEED-NCs at the Silver level have lower assessed and market values per square foot compared to the other LEED ratings. In the case of LEED-NC at the Gold and Certified levels, their values are among the second lowest for medium-sized properties (approximately 220,000 square feet). LEED-CS properties of medium size are valued relatively high compared to other properties within the Gold and Silver level. On average, medium- and large-sized LEED-EB properties at the Silver and Certified level are valued at the highest level of both assessed and market value per square foot. The regression modeling indicates the impact of ENERGY STAR designation, RBA, and in some cases, the year the building was built are statistically significant. LEED-EB has a statistically significant effect on either assessed value or market value, when controlling for the property's location at the geocoding level and not the MSA. LEED-NC at the Gold level has a statistically positive effect on the property's market value, while LEED-CS Gold and Silver have a similar effect on assessed values, when controlling for MSAs. These findings are a first step in understanding the effect of LEED certification levels on valuation and addition research is needed in the future to identify long-term trends.

Endnotes

1 The USGBC reports that ''U.S. buildings are responsible for: 38% of carbon dioxide emissions, 71% of electricity consumption, 39% of energy use, 12% of water consumption and 40% of non-industrial waste,'' (USGBC, A Natural Green Building Research Agenda, February 2008).

2 Total Assessed Value (AV) in general is the amount (for both land and structure) assigned by the local assessor for tax purposes. In the majority of areas a ratio is applied to estimate AV based on the full cash or fair market value of the property. This paper uses the AVs as estimated by each county/city based on their own definition.

3 Fair Market Value (MV) is estimated again by the local assessors and it usually is a competitive sale price for the property considering existing market conditions. Similar to AV, for the purposes of this paper, it represents the definitions given by the various local assessors.

4 LEED ratings used in this paper include: LEED-New Construction (LEED-NC), LEED-Existing Building (LEED-EB), LEED-Core & Shell (LEED-CS), and LEED-Commercial Interiors (LEED-CI) (USGBC, 2009).

5 LEED certification levels include: Platinum 80 points and above, Gold 60–79 points, Silver 50–59 points, Certified 40–49 points (USGBC, 2009).

6 Properties in California were the most difficult in determining their MVs, due to the formula used in calculating their AV, which does not allow an easy backtrack to MV. In this case, their MV was determined by backtracking to their most recent sale or construction year information. Sale information for 18 properties was not available and their AV was also used as their MV.

7 A model analyzing the effect of property characteristics & LEED rating (NC, EB, CS) on Assessed Value (AV) and Market Value (MV) was considered, but the results were not statistically significant for the LEED ratings considered. Another model focused on the effect of property characteristics and LEED levels (Platinum, Gold, Silver, Certified) and the results were also similar. State dummy variables were also used, with similar results, as were clusters based on assessed values per square foot.

8 Equation 1-1 is based on Anselin and Hudak, 1992.

9 Euclidean distance: $\sqrt{(minlatitude - maxlatitude)^2 + (minlontitude - maxlontitude)^2}$.

10 Average linkage was used because of ''the closest two groups are determined by the average (dis)similarities between the observations of two groups,'' (Stata Manual, release 10, 2007).

11 The observations made will reflect the overall dataset (351 properties) and not the subgroup of properties with available market values (275).

12 Both counts are offered in Exhibit 13, because they are slightly different between the AVD and MVD subsets. The difference is caused because certain properties were tax exempt, but the local assessor made the market value estimation available.

13 The effect of property characteristics on AV and FV seems to be almost consistent across all models and will be discussed from column 7 and beyond.

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