Is Green (still) a Matter of Prime? Stylized Facts about the Location of Commercial Green Buildings

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Abstract  We investigate the status quo of commercial green building locations and changes made over time in 103 metropolitan statistical areas (MSAs) to detect indications of the maturity of the commercial green building market. The findings of the descriptive analysis, based on LEED data provided by the U.S. Green Building Council, are twofold. First, commercial green buildings are typically located in prime locations. Second, since 2006, a slight hierarchical diffusion process from prime to non-prime locations is observed, particularly among low-level certifications, which indicates an effective product differentiation, rising market transparency, and increased learning curve effects on the commercial green building market.

In order to contribute to answering the question of whether green is particularly a matter of prime location, one has to take into account the conception of the Leadership in Energy and Environmental Design (LEED label), its target customers, and their motivations. Beside the public sector, particular tenant needs and investor reactions drive the market outcome for green buildings. According to Lutzenhiser and Woolsey Biggart (2003) and Eichholtz, Kok, and Quigley (2009), tenants of the service sector, usually characterized by a high level of corporate social responsibility (CSR) and mainly situated in prime locations, are the innovators of green buildings. Their motivations for green buildings are lower lifecycle costs and a healthier working environment, in order to present an environmental and socially responsible company brand to stakeholders. In general, long-term tenant preferences define future market standards to ensure the stability of the investors’ property values and therefore are represented by developers. Since the green tenant demand is distinctive of properties in prime locations, we anticipate green buildings more in prime than in non-prime locations. On the other hand, we assume that the additional costs of sustainable design, in relation to the total investment costs, are comparatively low in prime locations and therefore, negligible to these sites. Accordingly, we expect to find green buildings initially and particularly in prime locations.

Shifting the focus from the status quo of green building locations to changes over time, we expect a declining importance of prime locations in favor of non-prime ones, in accordance with hierarchical diffusion. In other words, the question is...
whether green buildings remain in or move out of prime locations over time. The latter is assumed to be a result of rising experience-curve effects, market transparency, and the maturity of green buildings, which in turn may indicate whether green buildings are suitable for sites beyond prime locations or are limited to a (prime market) niche segment.

However, one LEED certification is not like another. In terms of a reasonable product differentiation, we expect location-specific differences based on the certification level and the LEED system used. Since the additional costs for high-level certification in relation to total investment costs are assumed to be marginal in prime locations, and tenants strive to be best-in-class with regard to highest green quality in the optimal location, we anticipate high-level certifications particularly in prime locations. Additionally, we assume that the LEED system of operations and maintenance (LEED O+M) (i.e., the system for existing buildings) is more likely to prevail in prime locations than the LEED system of building design and construction (LEED BD+C), which mainly covers new construction activities. Apart from the cost argument, this can be attributed to the lack of space in prime locations and a corresponding greater willingness for sustainability upgrades as a quasi-market requirement in prime properties.

In our study, we analyze 103 metropolitan statistical areas (MSAs) in the United States between 2000 and 2014 based on certification and registration data for LEED properties provided by the U.S. Green Building Council (USGBC). A relative definition of prime locations controls for size effects across MSAs. In order to answer both the static and the dynamic research questions, the location of green buildings is analyzed jointly as well as separately, by using subsamples based on certification level and applied LEED system.

**Literature Review**

**Spatial Diffusion of Green Buildings**

The aggregate behavior of individuals or organizations in terms of adopting an innovation is examined in the diffusion literature. Economic diffusion research (Rogers, 1962) focuses mainly on the temporal dimension, whereas the geographical counterpart, introduced by Haegerstrand (1952), analyzes the spatial diffusion patterns of innovations. The latter literature can be divided into two basic types. Expansion diffusion describes a process starting from one point, before spreading in a contiguous manner away from its origin (i.e., proximity is a requirement of contagion). In contrast, non-contiguous pathways are referred to as relocation diffusion. Hierarchical diffusion is a special form of relocation diffusion referring to a one-way, downward-spreading process from higher-order to lower-order areas. In the case of green buildings, most literature on the geography focuses on the identification of driving forces (Yudelson, 2005; Goering, 2009; Kahn and Vaughn, 2009; Simons, Choi, and Simons, 2009; Choi, 2010; Choi and Miller, 2011; Fuerst, Kok, McGraw, and Quigley, 2011; Kontokosta, 2011; Simcoe and Toffel, 2012; Malkani and Starik, 2013; Prum and Kobayashi, 2013; Kontokosta, and McAllister, 2014), whereas studies on the
pathways of spatial diffusion are scarce. On that point, Cidell (2009), Cidell and Beata (2009), Johansson (2011), and Kaza, Lester, and Rodriguez (2013) offer some initial insights. On a regional level, Cidell (2009) and Johansson (2011) identify expansion diffusion from the metropolitan areas of the Pacific Northwest and the East Coast into the interior of the U.S. Additionally, Johansson (2011) detects hierarchical diffusion trajectories on a region level. However, in changing the spatial unit of investigation from a region to a city level, hierarchical diffusion cannot be maintained. That is, green building diffusion does not necessarily take place directionally from large to small agglomerations (Johansson, 2011). However, hierarchies exist not only between agglomerations, but also within them, since institutions, businesses or even ideas are unevenly distributed within agglomerations. In contrast to Cidell (2009) and Johansson (2011), Dermisi (2013) and Kaza, McGraw, and Quigley (2013) contribute by leaving the city level (macro level) to “zoom” into metropolitan areas (micro level). In an exploratory paper, Kaza, Lester, and Rodriguez (2013) reveal green building clustering both across and within agglomerations, including spillover effects. Compared to Kaza, Lester, and Rodriguez (2013), we focus on the categorization of green building locations and their potential change over time, in accordance with Brown (1981), who argues that there is an undulating propagation of innovations from the central business district (CBD) outwards to more rural areas. First evidence is provided by Dermisi (2013), who observes a concentration of green buildings in the CBD of Chicago.

Prime Locations and Their Characteristics

According to bid-rent theory, in a monocentric city model [for an overview, see Fujita, Krugman, and Venables, (1999)], the commercial office sector in particular is situated in the CBD, in particular, tenants in the finance, insurance, and real estate (FIRE) service sectors. Due to their high level of value added per capita, these locations are characterized by a maximal intra-metropolitan rent value and therefore referred to as prime locations. Subsequently, in the case of a monocentric agglomeration such as New York City, rent values decrease radially with an increasing distance from prime locations. Since the rent level in prime locations is higher than in non-prime locations, buildings on the former sites are larger. However, due to the cost benefits and technological progress in telecommunications, the decentralization of employment in the service sector started in the 1980s, including the decentralization of office buildings (Geltner, Miller, Clayton, and Eichholtz, 2007). The concentration in commercially oriented sub-centers increases the rent level in these, formerly peripheral, locations and forms polycentric types of agglomeration (e.g., Los Angeles). In contrast to the decentralized structure of residential, manufacturing or back office service employment, high-quality service employment in office buildings is more centralized (Glaeser and Kahn, 2001), which we assume to be the predominant users of green buildings.

In sum, in contrast to non-prime locations, prime locations are characterized by tenants of the (FIRE) service sector and large, complex buildings. These characteristics of prime locations lead to location-specific framework conditions for green buildings, which affect investment decisions.
Benefits and Costs of Green Buildings

In general, a rational investor is assumed as deciding in favor of a green building, if the net present value is higher than that of alternative investments (i.e., a conventional building). Starting with the benefits, various studies reveal added value for green buildings compared to conventional properties, which is suspected by Robinson (2013). Lower lifecycle costs and superior quality increase tenant willingness-to-pay, which in turn leads to a rent premium ranging between 2% and 17%, compared to conventional buildings. Additionally, the supply of green buildings meets a strong demand, reflected in increased occupancy rates of around 10%. As a result, the average values of green buildings have a 10%–25% premium over their counterparts. Furthermore, investments in green buildings contribute to value added at the portfolio level (Eichholz, Kok, and Quigley, 2012; Geiger, Cajias, and Bienert, 2013) and company level (Cajias and Bienert, 2011; Cajias, Geiger, and Bienert, 2012; Cajias, Fuerst, McAllister, and Nanda, 2014), due to reduced risk.

In a recent study, Marker, Mason, and Morrow (2014) identify financial disincentives and difficulties in transition as the most significant barriers to LEED certification. More precisely, they reveal real costs, perceived costs, paperwork load, complexity of certification process, and confusion among green building programs as the top five LEED barriers. Particular analyses of the extra costs of green buildings yield differing results. Based on varied cost approaches and samples, the literature presents up to 8% higher construction costs for green buildings, as opposed to conventional design, an average of about 1.8%. In contrast, Matthiessen and Morris (2004) and their 2007 update (Morris and Matthiessen, 2007) do not observe significant higher construction costs for green buildings. However, additional ancillary construction costs definitely occur, which are about 1.5%–3.0% higher for LEED properties than for conventional buildings, due to registration and certification fees (McAuley, 2008; Alpha Energy & Environment, 2010).

In general, the benefits (and costs) rarely accrue to all market players, due to the heterogeneity of potential investors. Therefore, we examine green buildings in specific segments and geographical markets. In order to identify these locations, we have to investigate the investors’ motivations for green buildings in more detail. For the most part, the supply of buildings is defined by tenant needs.

The Distinctive Tenant Demand for Green Buildings

Marker, Mason, and Morrow (2014) identify lower lifecycle costs, healthier buildings, positive image, social responsibility, and marketability as the top five motivations for LEED certifications, which is in line with Nelson, Rakau, and Doerrenberg (2010). Energy-efficient technologies or the installation of renewables, both requirements of the LEED standard, reduce the energy consumption of a building and hence its energetic dependence. Therefore, green buildings provide lower lifecycle costs for tenants (Antonopoulos, 2013) and the savings in operating expenses are substantial. In addition, LEED buildings offer a healthier work environment, since factors such as indoor air quality are
enhanced. This improves employee satisfaction, which in turn is positively correlated with corporate financial performance (Edmans, 2011). According to Edwards (2006) and Nelson (2007), increased employee productivity even exceeds savings with respect to greater energy efficiency. In the age of globalization, a high-quality working environment represents a key factor in the competition for the best talent, in particular for companies characterized by high-income staff in the service sector (Eichholtz, Kok, and Quigley, 2009). This competitive advantage must be communicated to external stakeholders to attract future employees. Hence, environmentally leading or CSR-driven companies, in particular, make great efforts to recruit a highly skilled workforce (Bauer and Aiman-Smith, 1996; Turban and Greening, 1997; Greening and Turban, 2000) and thus opt for a LEED building (Gauthier and Wooldridge, 2012; Antonopoulos, 2013). That is, the image of a company, workplace included, is crucial. Labels such as LEED certification at a property level, or sustainability reports at a company level, are effective marketing tools. Specifically, the companies' sustainability reports or websites may provide business advertising, as they offer a platform for demonstrating a desire to “do good and make it known.” For example, by highlighting energy savings, accompanied by photos of these certified, mostly prime, properties. In summary, the green building market is characterized by the CSR-driven demand of service sector tenants, mostly situated in prime locations.

Arguments for Green Buildings in Prime Locations

Green Design as a Quasi-Market Requirement of Buildings in Prime Locations. In general, tenants do not realize (green) buildings; however, they often claim greening of properties in lease negotiations. On the other hand, the identification of long-ranging tenant needs is crucial for investors to ensure the long-term value retention of properties. In the case of green buildings, the investors of prime locations consider tenant demand for sustainable design as a new quasi-market requirement on these sites, which sets future product standards for competitors (Lutzenhiser and Woolsey Biggart, 2003; Dermisi, 2013). In particular, green building user requirements are addressed by developers of both the build-to-suit and the build-to-hold market (Lutzenhiser and Woolsey Biggart, 2003). The former type of developers provides tailored solutions for their users, in the knowledge of an indented purchase, which reduces investment uncertainty. The objective of large-scale developers in the build-to-hold-segment is to ensure value retention in the long term, as they own and operate the buildings for an extended period. Hence, these buildings should suit future market requirements, for example through lower lifecycle costs, as do LEED properties.

Greater Cost Effectiveness of Green Buildings in Prime Locations. Whereas this marketability component refers to the investor’s revenue side, another argument in favor of the concentration of green buildings in prime locations addresses the cost side. As mentioned, additional ancillary construction costs definitely occur for a green design. According to information from the USGBC website, registration and certification costs depend only partially on the size of the building (i.e., both size-dependent and fixed costs occur). Therefore, and since properties in prime locations are usually larger than their non-prime counterparts, the green
costs per square foot for properties in prime locations ceteris paribus are assumed to be lower than for non-prime ones. Besides, the per square foot construction costs of conventional buildings are also location-dependent. More precisely, they are comparatively high for large properties with complex structural components, characteristically located in prime locations. Consequently, the per square foot additional green costs in relation to the per square foot construction costs of conventional buildings are relatively low in prime locations, compared to those in non-prime locations. In other words, a sustainability upgrade is more cost-effective and therefore more affordable in prime than in non-prime locations. This is also backed by McAuley (2008), who specifies that the relative green extra costs of certified properties in the outskirts are higher than for labeled buildings downtown, which may also explain the heterogeneous results of existing green building cost studies.

In summary, the quasi-market requirement of green design and its more affordable cost situation in prime locations, prove the attractiveness of sustainability upgrades of buildings in prime locations, compared to properties in non-prime locations. Hence, we hypothesize that LEED-certified buildings are typically located in prime locations.

**Arguments for an Increasing Market Acceptance in Non-Prime Locations**

**Hierarchical Diffusion of Green Buildings from Prime to Non-Prime Locations.** As outlined above, we examine green buildings particularly in prime locations, which are therefore assumed to be the starting point for the diffusion of commercial LEED-certified buildings. In subsequent steps of the propagation process, we anticipate a hierarchical diffusion from prime to non-prime locations, as green buildings are assumed to become more cost-effective in general, even in non-prime locations. Kaza, Lester, and Rodriguez (2013) identify an increasing business-as-usual mentality. Accordingly, the following three experience curve effects gradually enhance transparency and minimize uncertainty in the investment decisions of all involved players. First, developers and investors become familiar with the quasi-market requirement of sustainable design, which reduces the risk of failure and hence, uncertainty in green building investment decisions. Second, the division of labor and increasing competition decreases the costs and fees of service providers. For example, this applies to architects or consultants, who offer service packages that reduce paperwork, the complexity of the certification process, and confusion among green building programs. Third, initiated by the increased demand of LEED certifications, new green technologies may be invented by suppliers, which decrease the construction costs of a sustainable design. All of this increases the general attractiveness of green buildings, which makes labeled properties even in non-prime locations more likely.

**Product-specific Differences in the Location of Green Buildings**

**Location and the Level of Certification.** Since LEED is characterized by a variety of product differentiations, this raises the question of whether the locations of the green buildings also differ in order to meet the market needs of distinct target
groups. As the technical complexity of LEED buildings and, by implication, the construction costs are assumed to increase with a rising level of certification, investors presumably calculate whether a higher level of certification is indeed profitable. The investment costs of a given level of certification are assumed to be relatively low in prime locations, compared to non-prime ones, which is in line with Dermisi (2014). We expect this also to apply to the cost situation of high-level certifications. Additionally, tenants in prime locations strive to maximize the image effect by achieving the highest possible certification levels. In other words, the objective of investors is to offer the highest (green) quality on these sites. Consequently, high-level certified LEED properties, if any, are more likely in prime than in non-prime locations.

Location and the LEED System. Besides the level of certification, the USGBC differentiates by the used LEED system: LEED for Building Design and Construction (LEED BD+C), LEED for Operations and Maintenance (LEED O+M), and LEED for Interior Design and Construction (LEED ID+C).9 Whereas, LEED BD+C mainly covers new construction projects, LEED O+M focuses on greening the operations of existing buildings and LEED ID+C applies to the tenant fit-out. We assume that different mechanisms are reflected in diverging locations. More precisely, in accordance with Dermisi’s (2013) results, we expect existing LEED buildings to be located more in prime locations, than new constructions for two reasons: (1) due to the general affordability argument in prime locations and (2) due to the limited space in prime locations. The latter means that the pressure on existing properties in prime locations is comparatively high, especially as LEED is regarded as a quasi-market requirement in prime locations. Therefore, the availability of green space in prime locations determines maximal rental yields on these sites.

Data and Research Design

Data Description

The USGBC provides a comprehensive project trajectory database with detailed data on all LEED registered and certified properties with regard to the site, the parcel of land, the building, and certificate-specific information. Furthermore, the data contain information related to the place and time of certification, which enables us to investigate the diffusion of green buildings. In a first step, the disclosed address data are geocoded using a geographic information system (GIS). As the site information is essential in small-scale spatial analysis, only buildings with a 100% accurate matching result remain in the sample, which is validated by online geocoding tools. Consequently, the LEED buildings with factual information including the registration date since 2000 are located as “dots” on the map in order to join them with the corresponding MSA or to perform distance calculations. As each investment decision is considered to be equivalent, these dots are all the same size, regardless of their gross floor area.10 The LEED projects within the 103 largest MSAs, each with more than 500,000 people, are selected for the investigation. Finally, the total sample comprises more than 13,300 LEED
registered buildings (Exhibit 1) and, as a subset, more than 7,300 certified buildings, after cleaning the initial data from the USGB, with almost 100,000 projects. We dropped properties with doubtful geocoding results, properties outside the selected MSAs, and non-classifiable buildings according to their owner-type. We focused specifically on commercially owned LEED properties.

**Research Approach**

Dermisi (2013) uses CoStar classification data for a market segmentation of Chicago. However, her approach is not realizable for all considered LEED properties in 103 MSAs. In this case, an intra-agglomeration rent differentiation is approximated by the monocentric agglomeration model, which does not completely reflect reality with regard to the decentralization of employment but is sufficient for this research purpose. According to bid-rent theory, rent is highest in the CBD, as a result of limited supply and high demand, and decreases centrifugally, as the geographical distance to the CBD rises. Therefore, LEED buildings of the innovator stage are assumed to be situated in or close to the CBD. In the subsequent steps, we assume a centrifugal development of green buildings from the CBD outwards.

**Operationalization of Prime Locations.** However, the mean distance would not accurately address the research topic with respect to prime locations. Nor would the 5%-quintile of the most centrally located green buildings depict the term “prime” correctly, since a definition of “prime” based on the location of green buildings creates a circular reference. As the scale of the CBD differs across MSAs, we define prime locations as a relative borderline, which controls for size effects and is an independent, stable operationalization. In a first step, the 103 MSAs are each subdivided into two rings, the inner and the outer. The inner ring contains the 1% of the MSA ZIP Codes that are closest to the CBD, the most central point, and the outer ring the complementary 99%. Analogously, we construct a 5% and a 10% inner ZIP Code ring to determine whether our results are robust to the aforementioned definition. In this study, prime locations are defined as those within the 1%, 5% or 10% ZIP Codes of each MSA, which are closest to the CBD. The objective is to allocate the green buildings in each MSA to its prime and non-prime locations. Exhibit 2 depicts the 5% inner and the corresponding 95% outer ZIP Code ring of Chicago. Accordingly, the density of green buildings in prime locations is obviously higher than in non-prime locations.

**Subsamples**

Since the diffusion mechanisms across the total sample of about 13,300 LEED registrations are quite heterogeneous, subsampling is necessary. According to the assumed major motive of providing optimal quality in prime locations, the highest certification level in particular is expected in prime locations. Hence, the total sample is subdivided into the categories of platinum and gold with 3,161 green buildings and silver and certified, with 4,221 LEED properties (Exhibit 3). The former includes all buildings with a platinum or gold LEED certificate, whereas the latter comprises all LEED certifications with a silver or certified rating.
### Exhibit 1 | Statistical Overview about the Green Buildings

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<td>334,748</td>
<td>288,076</td>
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<td>330,737</td>
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<td>Var</td>
<td>0.08</td>
<td>0.70</td>
<td>0.53</td>
<td>1.51</td>
<td>4.61</td>
<td>14.46</td>
<td>44.26</td>
<td>467.20</td>
<td>896.76</td>
<td>1,081.53</td>
<td>538.23</td>
<td>760.02</td>
<td>989.28</td>
<td>669.92</td>
<td>633.73</td>
<td>50,112.64</td>
</tr>
<tr>
<td>Mean GFA</td>
<td>295,048</td>
<td>184,668</td>
<td>150,928</td>
<td>147,729</td>
<td>238,962</td>
<td>193,179</td>
<td>240,830</td>
<td>202,402</td>
<td>209,465</td>
<td>205,008</td>
<td>149,993</td>
<td>155,648</td>
<td>187,642</td>
<td>223,455</td>
<td>211,250</td>
<td>195,600</td>
</tr>
</tbody>
</table>
Exhibit 2 | Definition of Prime Locations in the MSA of Chicago: Inner 5% and Outer 95% ZIP Code Ring
**Exhibit 3 | Description of Subsamples**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Subsample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registered buildings</td>
<td>Commercial (registered LEED buildings owned by companies) green building stock measured as the number of LEED registered buildings</td>
<td>13,322</td>
</tr>
<tr>
<td>Certified buildings</td>
<td>Commercial green building stock measured as the number of LEED certified buildings</td>
<td>7,382</td>
</tr>
<tr>
<td>High-level certifications</td>
<td>Platinum &amp; gold certifications</td>
<td>3,161</td>
</tr>
<tr>
<td>Low-level certifications</td>
<td>Silver &amp; certified certifications</td>
<td>4,221</td>
</tr>
<tr>
<td>LEED BD+C</td>
<td>Registered LEED buildings with a LEED system for building design and construction (new construction and core &amp; shell)</td>
<td>6,158</td>
</tr>
<tr>
<td>LEED O+M</td>
<td>Registered LEED buildings with a LEED system for operations and maintenance</td>
<td>3,588</td>
</tr>
<tr>
<td>LEED ID+C</td>
<td>Registered LEED buildings with a LEED system for interior design and construction</td>
<td>3,576</td>
</tr>
</tbody>
</table>

Although representing the largest group, the remaining registered properties, not yet certified, are dropped.

The second sample-splitting variable is the type of applied LEED system. For this purpose, the LEED registered properties are separated in 6,158 LEED BD+C, 3,588 LEED O+M, and 3,576 LEED ID+C buildings based on the categorization of the USGBC.

**Analysis**

**A Static View on the Locations of Green Buildings**

In order to examine whether LEED buildings are situated in prime locations, we use the concept of 1%, 5%, and 10% inner ZIP Code rings. According to Exhibit 4, 15.00% of all registered LEED properties are located in the 1% inner ZIP Code ring (i.e., within 1% of all ZIP Codes of the corresponding MSA), which are closest to the CBD and therefore define prime locations. Additionally, the 5% and 10% inner ZIP Code rings cover 31.50% and 39.50% of all registered buildings; 85.00%, 68.50%, and 60.50% of the registered properties are located in the 99%, 95%, and 90% outer ZIP Code rings respectively, which represent non-prime locations. Analogously, the figures with respect to certified properties confirm this statement.

In summary, aggregated to the national average, LEED buildings are particularly located in prime locations, regardless of the definition of prime location and whether certification or registration dates are used. Overall, LEED buildings are
**Exhibit 4** | Distribution of LEED Buildings in Prime Locations and Results of Cross-tabulation

<table>
<thead>
<tr>
<th></th>
<th>1% Inner ZIP Code Ring</th>
<th>5% Inner ZIP Code Ring</th>
<th>10% Inner ZIP Code Ring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>$\chi^2$</td>
<td>Cramer's V</td>
</tr>
<tr>
<td>Certified LEED buildings until 2014</td>
<td>16.07%</td>
<td>96.23***</td>
<td>0.11</td>
</tr>
<tr>
<td>Registered LEED buildings until 2014</td>
<td>15.00%</td>
<td>25.25%</td>
<td>18.65</td>
</tr>
<tr>
<td>Certified LEED platinum &amp; gold buildings until 2014</td>
<td>20.91%</td>
<td>23.37%</td>
<td>32.71%</td>
</tr>
<tr>
<td>Certified LEED silver &amp; certified buildings until 2014</td>
<td>12.44%</td>
<td>351.50***</td>
<td>0.16</td>
</tr>
<tr>
<td>Registered LEED BD+C until 2014</td>
<td>8.88%</td>
<td>21.92%</td>
<td>32.71%</td>
</tr>
<tr>
<td>Registered LEED O+M until 2014</td>
<td>18.59%</td>
<td>351.50***</td>
<td>0.16</td>
</tr>
<tr>
<td>Registered LEED ID+C until 2014</td>
<td>21.92%</td>
<td>42.70%</td>
<td>50.31%</td>
</tr>
</tbody>
</table>

**Notes:** We use the Chi-square test to analyze whether certification level and ring affiliation of green buildings or the type of the LEED system and ring affiliation are stochastically independent at a 10% (*), 5% (**), or 1% significance level (***).
not a niche product limited to prime locations, but are particularly concentrated in these sites.

**A Dynamic View on the Locations of Green Buildings**

In order to gain information on the diffusion of green buildings and deduce potential future pathways, an analysis of past developments is essential. However, the methodology with respect to the three rings remains unchanged.

As the number of LEED registered buildings in 2000 was limited to seven, individual case decisions characterize the initial stage of pilot projects. Hence, the first years require careful interpretation, due to the low sample size. In 2003, the cumulated number of LEED registered buildings exceeded 100 for the first time (Exhibit 5). Since 2006, the proportions of the cumulated number of registered properties in prime locations decreases by tendency, regardless of the ring definition. This provides evidence of a general, slight relocation effect of green buildings from prime to non-prime locations since 2006, indicating a centrifugal development within MSAs. This is in line with the assumed hierarchical diffusion process. The results for the certified properties are similar. However, the general development of proportions of green buildings in prime locations changes over time, which is more evident in broadly defined prime locations (i.e., in the 5% and 10% inner ZIP Code rings). For this purpose, a more precise consideration is necessary. Thus, the development is divided into the following five periods in order to explore the potential underlying mechanisms.
**Period of Lighthouse Effect (2000):** The period of lighthouse effect is short and characterized by a small number of LEED properties and a relatively high share of green buildings in prime locations. According to Rogers (1962), observability is assumed to play an important role in the diffusion process. From the innovation’s perspective, observability increases the communication of improved corporate image towards stakeholders. Since pilot projects receive particular attention due to their lighthouse effect and the image-driven part worth for properties in prime locations is characteristically high, innovative LEED buildings are typically in prime locations.

**Period of Trust (2001):** This period comprises LEED registered properties from the end of 2000 until 2001. It is characterized by a slightly increasing number of registrations and a decreasing share of green buildings in prime locations. We attribute this development to a lack of information about the costs and benefits of green buildings, accompanied by a high degree of uncertainty. The lack of information and market transparency is assumed to lead to partly inefficient investment decisions. On the one hand, actors that would profit most from the implementation of green buildings, omit labeling due to their late adopter mentality. On the other hand, bold decision makers invest in green buildings, although their risk of making the wrong choice is even higher. Accordingly, the first group represents investors in prime locations, whereas the latter group is characterized by investors in non-prime locations.

**Period of Awareness Raising (2002–2006):** The period of awareness raising begins at the end of 2001 and ends in 2006. It is characterized by a still slightly increasing number of LEED registrations and a return to prime locations. More information about the costs and benefits of green buildings increases transparency in the real estate market, which reduces uncertainty in investment decisions. To be more precise, CSR-driven tenants of the service sector become aware of the benefits of green buildings and address their needs to developers. Subsequently, early-adopting investors broaden their product range by providing green building products in prime locations to meet upcoming market standards and ensure the stability of property values. Additionally, the extra costs for green provisions are more negligible in prime locations. Consequently, the share of green buildings in prime locations increases in the period of awareness raising, at the expense of LEED properties in non-prime locations.

**Period of Expansion (2007–2009):** The period of expansion occurs from the end of 2006 until 2009 and demonstrates considerable expansion with respect to the number of green buildings, accompanied by relocation effects in favor of non-prime locations. A boost in the number of LEED registered properties by about 5,300 within three years can hardly be achieved exclusively in prime locations. Therefore, relocation effects to non-prime locations are predictable. For this purpose, the period is characterized by an early majority that adopts LEED as a mass product. Kaza, Lester, and Rodriguez’s (2013) explanation of an increasing business as usual mentality is in line with increased experience curve effects, which make green buildings more cost-effective ceteris paribus, even in non-prime locations. Meanwhile, developers and investors consider green buildings as a
regular feature in their business models, which reduces uncertainty in their investment decisions. A rising competition among architects and consultants, who provide transparency enhancing service products around sustainability topics, decreases their fees. Additionally, positive experiences are assumed to encourage existing and further potential adopters. Furthermore, as policies are expected to enhance the relative advantage of a green design, they may attract sustainable upgrades even in non-prime locations. However, as we could not separate policy effects, we cannot reject their additional influence on the spatial distribution of green buildings within agglomerations.

**Period of Consolidation (2010-present):** The final stage so far, the period of consolidation, started at the end of 2009. Before stabilizing, it initially was characterized by a declining number of registrations. Additionally, the period is associated with a marginal return to prime locations.

**A Detailed View on the Locations of Green Buildings**

**Certification Level.** By now, the only product-specific distinction we focus on is the difference between certification and registration. Going one step further, we examine which certification levels are linked to which locations, since the target groups of high- and low-level certifications are assumed to differ. Exhibit 4 shows that the relationship between the certification level and the ring affiliation (i.e., inner or outer ZIP Code ring) is weak (see Cramer’s V) but significant (see $\chi^2$), regardless of the considered ring definition. That is, the attributes “certification level” and “ring affiliation” of green buildings are stochastically not independent. In this case, platinum and gold certifications are more apparent in prime locations (i.e., within the corresponding inner ZIP Code ring) than lower certification levels (see mean). All this indicates that a high-level certification is a quasi-market requirement of properties in prime location to be best-in-class green tenants. Accordingly, the objective is to maximize the marketability and value of properties in prime locations. Furthermore, additional green costs are marginal in relation to total investment costs and hence negligible. In contrast, for properties in non-prime locations, a certified rating is assumed to be sufficient to improve the marketability of these buildings, especially since the costs of green features are comparatively high on these sites.

This reveals the current situation, but without considering changes over time. Since the 5% inner ZIP Code ring is more reliable in the initial years than the 1% ring, on the one hand, and applies more to the definition of prime locations than the 10% ring, the 5% ring is used in the following analysis sections. Exhibit 6 shows that the cumulated number of LEED certifications in both categories of certification developed similarly until 2007 (i.e., the demand for both groups was mostly the same size). In recent years, the number of certifications with a silver or certified rating increases faster. In 2004, the number of silver or certified LEED certifications exceeds 100 for the first time. From that point onwards, the share of properties with a low-level certification in prime locations increases until 2006, before declining. This downward tendency since the beginning of 2007, in combination with a rising number of certifications, indicates an expansion of the category to non-prime locations. This means that silver or certified certifications
gain attractiveness on these sites due to increased economies of scale. Additionally, the costs of these certifications are assumed to be relatively low in lower rent, non-prime locations, and the lack of market differentiation between the certification levels gradually seems to disappear. Slightly different, the proportions of the platinum and gold certifications in prime locations generally increase, with an interim low in 2007. Thus, the gap between high-level and low-level certifications increases from 7.09% in 2007 to 14.67% in 2014 (i.e., the results are distinct with respect to product differentiation). Prime certifications remain associated with prime locations, whereas low-level certifications increasingly are a product for investors in non-prime locations.

Type of LEED System. Although the investor’s choice of intended certification level is a conscious decision, the choice of type of certification system however is sometimes specified. For example, the LEED system differs between LEED BD+C, LEED O+M and LEED ID+C. Whereas the latter addresses tenant fit-outs, LEED BD+C is mainly focused on new construction activities and LEED O+M applies for green operations and is therefore dedicated to improvements of existing buildings. Pilot projects apart, the introductions of LEED O+M and LEED ID+C clearly start later and do not reach the same magnitude as LEED BD+C.

In general, CBD locations are scarce, which puts pressure to refurbish in prime locations. In contrast, new construction is easier in peripheral locations. Therefore, in combination with the superior motive of providing the best quality in prime locations, LEED O+M are assumed to be more likely in prime locations than LEED BD+C. The “green upgrade” of an existing building is regarded as a kind
of market requirement for properties in prime locations. Exhibit 4 distinctly confirms this hypothesis, as LEED O+M is situated more in prime locations than LEED BD+C [i.e., within the corresponding inner ZIP Code ring (see mean)]. The relationship between the used LEED system and the ring affiliation (i.e., inner or outer ZIP Code ring) is weak (see Cramer’s V) but significant, regardless of the considered ring definition.

According to Exhibit 7, the graphs depicting the development of the proportions of LEED O+M and LEED BD+C differ distinctly, particularly in the 5% inner ZIP Code ring. The gap between the proportions of LEED O+M and LEED BD+C within the 5% ring is stable at about 10%–12%, since 2007, when the cumulated number of LEED O+M initially exceeds 100.

At a glance, the figures of LEED ID+C astonish, since LEED ID+C is even more apparent in prime locations than LEED O+M, particularly as the situation does not change over time. The gap between the proportions of both systems in prime locations remains stable at about 9%–10%, when focusing on the periods with reliable subsample sizes. We address this fact to the nature of LEED ID+C. Considering the origin of our argument above, CSR-driven tenants in the service sector, mostly situated in prime locations, strive for labeling. The influence on LEED ID+C is expected to be higher than on LEED O+M or, in particular, on LEED BD+C, due to the tenant fit-out character of LEED ID+C. That is, the interior finish is directly modifiable by tenants, whereas LEED O+M or LEED BD+C require the approval of all parties involved, and hence, are only indirectly changeable by tenants. Additionally, LEED ID+C is relatively cost effective, compared to LEED BD+C. All of this is assumed to make LEED ID+C in prime
locations more likely. Beyond this, the development of the proportions over time partly varies. Taking into account the points in time when exceeding 100 buildings initially, the interpretation of LEED BD+C, LEED O+M, and LEED ID+C starts in 2003, 2007, and 2006. Whereas both LEED O+M and LEED ID+C decline steadily, LEED BD+C fluctuates. Due to the high number of LEED BD+C, it is formative for the general curve in Exhibit 5 (i.e., increasing until 2006, before decreasing). Due to the later start of LEED ID+C and LEED O+M, an initial pent-up demand in favor of properties in prime locations seems to be realistic for these curves.

**Conclusion**

The findings reveal that commercial green properties are located primarily in prime locations. This applies most notably to high-level certifications, LEED O+M (i.e., the system for existing buildings), and LEED ID+C (the system for tenant fit-outs). Additionally, since 2006, we observe minor hierarchical diffusion pathways from prime to non-prime locations, none more so than low-level certifications and various types of LEED certification.

The contributions of the work to existing research are manifold. In addition to Kaza, Lester, and Rodriguez (2013), this paper contributes by “zooming” into metropolitan areas, in order to detect the status quo of locations of green buildings and their change over time. The study confirms Dermisi’s (2013, 2014) results of a linkage between the greenness of properties and the primeness of locations. Cidell (2009) and Johansson (2011) examined the geography of green buildings at the regional or city level (i.e., the macro level, excluding the micro view within agglomerations). In contrast to Johansson’s (2011) analysis on the macro level, we find hierarchical diffusion trajectories are moderate at the micro level.

Due to the explorative character of our study, we cannot fully explain our results. Nevertheless, we offer explanatory approaches in the literature review and the analysis section. Furthermore, we provide a conclusive qualitative analysis of the relationships between commercial green buildings and their location. Based on the conception of the LEED product, we extensively describe tenant and investor motivations to draw inferences about the location of commercial green properties. As expected, the findings reveal a positive correlation between the green quality of buildings and the “primeness” of location, which qualifies green buildings, particularly those with high-level certifications, as a quasi-market requirement in prime locations. That is, Class A investors (i.e., of properties in prime locations) address long-term green tenant needs by offering high-quality green buildings, partly facilitated by increased market transparency.

Considering the development of the commercial green buildings over time, the observed centrifugal migration from prime to non-prime locations alternates with opposing centripetal effects. In order to explain this non-monotonic hierarchical diffusion, we set up a qualitative five-period model, which includes a rising level of market transparency and increasing experience curve effects. The centrifugal development of commercial green properties since 2006 is assumed to encourage
other commercial players to adopt such investment behavior. In fact, hesitation in this context may reduce competitiveness, which further increases the pressure on the commercial players.

Whereas these contributions address researchers and practitioners, the paper also reveals benefits in favor of the USGBC, as the results are a first step towards balancing target and actual figures about the market penetration of the LEED label. In short, the findings suggest that LEED is not a product exclusively for prime locations. The rising market acceptance of LEED properties in non-prime locations is due partly to product differentiation with respect to the level of certification. The more superior the certification level, the more prime the location of the building. Accordingly, low-level LEED certifications more and more tend to be a product for non-prime locations, which indicates further market potential for LEED on these sites.

At this stage, we focus mainly on exploring the locational pattern of commercial green buildings and provide a sound basis for future research. Due to the character of the paper, the task for further research is clear, namely elaborating the intra-agglomeration rent differentiation approach and isolating LEED activity from general new construction activity. Upon that, the overall objective is to assess the market potential of commercial LEED properties. Additionally, the role of green building policies as a driver in the spatial diffusion of commercial green buildings is still lacking. Even at the micro level, we expect corresponding influences, since policies incentivize the development of green buildings and may render a centrifugal growth within agglomerations more likely. Moreover, the relative advantage of commercial green buildings should be examined in greater detail. In particular, pay-off studies should control for locational information. Overall, the study delivers valuable insights into the diffusion mechanisms of commercial green buildings in the U.S.

**Endnotes**

1. As the nature of the paper is descriptive, the model toolkit for polycentric agglomerations described by Krause and Bitter (2012) seems oversized. The bottleneck is the corresponding data with respect to an intra-agglomeration rent differentiation.

2. The effects are +2.9% for Reichardt, Fuerst, Rottke, and Zietz (2012); +4.8% to +5.2% for Pivo and Fisher (2010); +5.0% for Fuerst and McAllister (2011a, b); +6.0% for Eichholtz, Kok, and Quigley (2013); +9.4% for Eichholtz, Kok, and Quigley (2010); +15.2% to +17.3% for Wiley, Benefield, and Johnson (2010); the effects of retrofitting are +9.1% for Kok, Miller, and Morris (2012). In contrast, Gabe and Rehm (2014) reject tenants’ willingness to pay for energy efficiency.

3. Fuerst and McAllister (2011b) obtain +5.0%, Fuerst and McAllister (2009) obtain +8.0%, and Wiley, Benefield, and Johnson (2010) obtain +16.2% to +17.9%.

4. +25.0% for Fuerst and McAllister (2011a, b) and +11.1% for Eichholtz, Kok, and Quigley (2013); for components like walkability, see Pivo and Fisher (2011).

5. Steven Winter Associates (2004), Lucuik, Trusty, Larsson, and Charett (2005), and Alpha Energy & Environment (2010) identify up to 8.00% higher investment costs for green buildings, while Kats (2003) identifies up to 7.50%. Kats (2003) outlines an
average value of about 1.80%. McAuley (2008) identifies the building shell, the mechanical trade, and ancillary construction costs as cost-pushers.

6 –30% according to Miller, Spivey, and Florance (2008); –5.4% for LEED buildings according to Reichardt (2014).


8 Even if this assumption does not hold for existing buildings, for new construction activities it does.

9 We omitted LEED for Neighborhood Development (LEED ND), as it works on a neighborhood scale. Among LEED BD+C, LEED O+M, and LEED ID+C, we focused on office usage and therefore dropped residential programs, as well as retail, health care, hospitality, data centers, schools, warehouses, and distribution centers in order to cope with the monocentric agglomeration approach at best.

10 In this study, the number of green buildings is applicable, as we regard all investment decisions as equitable in the diffusion of commercial green buildings. We provide information about the gross floor area (GFA) of the labeled properties in Exhibit 1.

References


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