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Foreword

This issue has some seemingly narrow topics, but readers will be pleased to find a wealth of great literature reviews within some of the papers, like the one by Bond on Realtors perceptions. The paper by Robinson and McAllister, our lead paper, addresses some of the nuances in the commercial real estate market with respect to green premiums. In some markets, there is no premium, not necessarily because the market will not pay for better buildings but because the bar for high-quality institutional level buildings in major markets has now been raised substantially. Over time, our building stocks will get better and the premiums will disappear. We also have two papers from Africa, which were selected from a large group of submissions, suggesting increasing interest in sustainability in third world countries. We continue to have papers that address valuation and other policy issues or even training and implementation challenges. We hope a few of these are of interest and help promote a more sustainable world. Below are the papers in this issue, along with brief overviews of their content.

**Heterogeneous Price Premiums in Sustainable Real Estate? An Investigation of the Relation between Value and Price Premiums** by Spenser Robinson and Pat McAllister

Focusing on the voluntary LEED and ENERGY STAR environmental certification schemes in the United States, the authors investigate whether price premiums exist across all building value categories or are localized to specific value segments. They find that the largest value building segment does not demonstrate any price premiums, while the smallest value categories do.

**Incorporating Green Building Features and Initiatives into Commercial Property Valuation** by Saul Nurick, Karen Le Jeune, Emma Dawber, Ryan Flowers, and Jennifer Wilkinson

The rapid acceptance of green buildings internationally has led to awareness of green building features and initiatives (GBFIs) in the South African property industry; however, among South African valuers, it seems the awareness is still in its infancy. Interviews suggest that South Africa’s valuers require a great deal of education but are starting to become aware of green building features.

**The Relevance of Green Building Practice in Emerging Markets: A Perceptual Analysis of Commercial and Industrial Building Users in Ibadan, Nigeria** by A. Olaleye, T.O. Ayodele, and M.O. Komolafe

In this study, the authors examine the operational challenges of existing green building related features/systems to develop hypotheses about factors that will increase the demand for green buildings in less developed countries. They test these hypotheses by examining the potential green building advantages that will influence users’ adoption of green practices and their willingness to pay.

**Factors Influencing U.S. Homebuilders’ Adoption of Green Homebuilding Products** by Andrew R. Sanderford, Matthew J. Keefe, C. Theodore Koebel, and Andrew P. McCoy

While many researchers have analyzed the obstacles to the diffusion of innovation in building construction, little empirical evidence has been gathered about the
factors associated with U.S. homebuilders’ adoption of innovative building products. In this paper, the authors develop a theory-driven diffusion of the innovation conceptual model that drives homebuilders’ adoption of high performance building products.

**Measuring Highway (Noise) Impacts on House Prices Using Spatial Regression** by Marcus T. Allen, Grant W. Austin and Mushfiq Swaleheen

Generally accepted real estate valuation theory, augmented by ample empirical evidence, supports the notion of significant impacts on prices of residential properties near highways. Houses adjacent to highways are exposed to potentially increased traffic noise, although these homeowners may benefit from increased accessibility to highway systems. This study is prompted by a massive new highway construction project (25 miles) that will complete a 110-mile beltway around the Orlando, Florida metropolitan area. The results indicate significant price discounts for houses adjacent to highways, houses near high-traffic highways, and houses farther from highway on-ramps, but no significant impact related to distances from houses to highways or sound barrier walls.

**LEED Certification of Campus Buildings: A Cost-Benefit Approach** by Erin A. Hopkins

This is the first comprehensive cost-benefit analysis of Leadership in Energy and Environmental Design (LEED) buildings certified within the higher education sector. Sixteen institutions of higher education were surveyed with the findings focused on the upfront green premium and down the line energy savings. The net present value and internal rate of return are analyzed.

**Appraising Sustainable Building Features: A Colorado Case Study** by Laura Bently, Scott Glick, and Kelly Strong

The authors investigate the current status of sustainable value integration in Colorado’s real estate markets, an area with limited current/historical value attributed to sustainability. The property appraiser has an opportunistic position to influence stakeholders and potentially increase demand for sustainable building. The appraisal process, necessary inputs, and rules and regulations were studied. Appraisers seem to be catching on to the value impact of sustainable features and design.

**Californian Realtors’ Perceptions towards Energy-Efficient “Green” Housing** by Sandy Bond

Realtors are seen as important enablers of behavior change toward a low-carbon future through the communication of sustainability measures to home buyers and sellers. In 2012/2013, research was conducted to assess Californian Realtors’ knowledge of, and perceptions towards, sustainable housing using an online survey instrument. What consumers and Realtors consider important differ, suggesting the need for more education within the Realtors and to the public at large. With more education, we will certainly see demand for sustainable homes increase, a sector lagging far behind the office sector.

**Assessing the Effectiveness of Mandating Energy Efficiency: Boulder, Colorado’s Implementation of SmartRegs** by Scott Glick, Caroline M. Clevenger, Mark Laverty
On January 3, 2011, the City of Boulder, Colorado implemented the SmartRegs Ordinances updating the city’s housing and rental licensing code by mandating baseline efficiency requirements for rental housing units. The authors examine the SmartRegs inspector training program relative to the prescriptive path checklist for compliance and quality assurance controls from inception through the first quarter of 2014. A key finding suggests that discrepancies in quality control audits may be the result of the training and certification program not adequately preparing inspectors for the field observations needed to competently complete inspections. This may be due to improper planning of implementation policies.
Heterogeneous Price Premiums in Sustainable Real Estate? An Investigation of the Relation between Value and Price Premiums

Authors Spenser Robinson and Pat McAllister

Abstract Focusing on the voluntary LEED and ENERGY STAR environmental certification schemes in the United States, we investigate whether price premiums exist across all building value categories or are localized to specific value segments. We find that the largest value building segment does not demonstrate any price premiums, while the smallest value categories do. The concentrated supply of eco-labeled offices in large, high-quality buildings likely contributes to this phenomenon. Results from hedonic and quantile regressions indicate that price premiums for eco-certified real estate assets may not be uniformly distributed across value segments and that price premiums found in the literature are concentrated in smaller and mid-tier value buildings. This may be due to the comparatively lower market penetration of eco-certification schemes in these segments.

A common, albeit often implicit, objective of eco-labeling schemes is to increase the demand for and supply of sustainable products through the pricing mechanism. In the last decade, in most national real estate markets a range of voluntary and mandatory eco-labeling schemes have been introduced by a blend of governmental, industry, and/or other ad hoc bodies. In turn, researchers have attempted to identify whether eco-labels are having the desired effects on pricing. Largely due to limited data availability, the vast majority of these researchers have estimated average price effects for transaction samples that cover fairly large geographical areas and/or quite lengthy time periods. There is some evidence that the effects of eco-labeling may not be uniform across time and space. For instance, Fuerst and McAllister (2009) found that the positive effects on occupancy rates of the ENERGY STAR label were only significant for the two worst performing deciles. Focusing on the voluntary LEED and ENERGY STAR schemes in the United States, we investigate whether price premiums exist across all building value categories or are localized to specific value segments. For the purposes of this paper, value is defined as the price of a sold property or gross rent of a rental property.

The results indicate that premiums for eco-certified real estate assets may not be prevalent in the largest value buildings. Premiums are still found in the smaller
and mid-tier value segments of sales and rental office buildings. The lack of a premium in the largest segment may be due to the relatively high market penetration of eco-certification schemes in that area. This paper contributes to the literature by demonstrating both price segmentation and the econometric effect of weighting by economic value.

**Background and Context**

Like most areas of business activity, there has been growing interest in the sustainability of the commercial real estate sector among policy makers, regulators, professional bodies, market participants, and climate change activists. This, in turn, has helped to stimulate increased attention from academic researchers. A range of accrediting bodies has emerged around the world around sustainable building certification; in the U.S. the two main certifications are ENERGY STAR (ESTAR) and Leadership in Energy and Environmental Design (LEED).

In the context of U.S. offices, a number of stylized facts emerged from the literature. In terms of transaction numbers, ENERGY STAR tends to be the largest certification group. The majority of LEED-certified Class A offices are also ENERGY STAR rated. Eco-certified buildings tend to be unrepresentative of the wider office stock. Compared to other Class A offices, they tend to be larger and taller. Within the eco-certified Class A office stock, there are notable differences between LEED, ENERGY STAR, and dual certified (LEED and ENERGY STAR) buildings. LEED buildings tend to be fairly new compared to ENERGY STAR, dual certified offices, and the broader stock. Dual certified buildings tend to be extremely large and are typically three times the size of non-certified Class A offices (Exhibit 1).

This research builds upon a body of work that has attempted to measure the financial effects of environmental certification. While there are plausible a priori reasons to expect a range of tangible (higher rents and sale prices, lower operating costs, increased occupancy rates, higher liquidity, increased productivity, lower depreciation etc.) and intangible (image and branding, future proofing) benefits for investors in and occupiers of environmentally certified real estate assets, arguably completely convincing evidence remains elusive for many of these benefits. It is also expected that a tenant’s willingness-to-pay incremental rent for these benefits should vary over time and space, as well as between buildings (Simons, Robinson, and Lee, 2014).

Fuerst, Gabrieli, and McAllister (2012) find that, for the Class A office market segment in the U.S., environmentally certified space has become part of the mainstream and is not a niche product. They estimate that eco-certified office space accounted for almost half of all Class A office space transacted between 2007 and 2012. The data used in this study reinforces the expectation that the supply of eco-labeled offices tends to be concentrated in a segment consisting of large, high-quality buildings.
### Exhibit 1 | Summary Statistics: Sale Sample

<table>
<thead>
<tr>
<th></th>
<th>Price ($psf)</th>
<th>Stories</th>
<th>Size (sq. ft.)</th>
<th>Age (yrs)</th>
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<td><strong>Panel A: Non-certified</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>140.29</td>
<td>3.5</td>
<td>55,806</td>
<td>38.85</td>
</tr>
<tr>
<td>Median</td>
<td>222.77</td>
<td>2</td>
<td>24,600</td>
<td>30</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>131.22</td>
<td>4.49</td>
<td>113,162</td>
<td>28.61</td>
</tr>
<tr>
<td>Obs.</td>
<td>24,770</td>
<td>24,693</td>
<td>24,770</td>
<td>23,819</td>
</tr>
<tr>
<td><strong>Panel B: ENERGY STAR rated</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>222.77*</td>
<td>12.41*</td>
<td>295,062*</td>
<td>29.42*</td>
</tr>
<tr>
<td>Median</td>
<td>191.27</td>
<td>9</td>
<td>203,500</td>
<td>25</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>137.59</td>
<td>11.38</td>
<td>288,209</td>
<td>22.33</td>
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<td>Obs.</td>
<td>933</td>
<td>933</td>
<td>933</td>
<td>933</td>
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<tr>
<td><strong>Panel C: LEED certified</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>246.81*</td>
<td>7.47*</td>
<td>205,873*</td>
<td>28.48*</td>
</tr>
<tr>
<td>Median</td>
<td>194.99</td>
<td>4</td>
<td>115,185</td>
<td>20</td>
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<tr>
<td>Std. dev.</td>
<td>197</td>
<td>9.03</td>
<td>300,399</td>
<td>32.68</td>
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<tr>
<td>Obs.</td>
<td>158</td>
<td>158</td>
<td>158</td>
<td>158</td>
</tr>
<tr>
<td><strong>Panel D: Dual certified</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>256.94*</td>
<td>20.03*</td>
<td>481,173*</td>
<td>27.08*</td>
</tr>
<tr>
<td>Median</td>
<td>231.88</td>
<td>15</td>
<td>381,427</td>
<td>24</td>
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<tr>
<td>Std. dev.</td>
<td>144.95</td>
<td>15.45</td>
<td>384,689</td>
<td>21.46</td>
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<tr>
<td>Obs.</td>
<td>295</td>
<td>295</td>
<td>295</td>
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</table>

*Statistically significant from general population at 1.0% significance level in a difference of means tests.

A common direct aim of environmental certification schemes is to provide credible, low-cost information about the environmental performance of a product to consumers for whom it is often not feasible or too costly to directly measure some desired characteristic such as sustainability. Given the expectation that this bundle of benefits would be transmitted to real estate markets by changing investor and occupier preferences, a great deal of empirical research exists on whether environmental certification effects the prices of real estate assets (Chegut, Eichholtz, and Kok, 2014; Robinson and Reichert, 2015).

Probably the most important finding of the body of research on the link between real estate prices and environmental certification is that nearly all studies find a positive effect. However, the vast majority of studies use hedonic analysis to
attempt to isolate the effect on price of the environmental certificate and the omitted variable problem is pervasive in hedonic analysis. Moreover, given dynamic and heterogeneous markets, up-to-date studies with better (in terms of scale and scope) data are ever needed in a market that continues to change.

A price premium was established in many studies and summarized in Fuerst and McAllister (2011a). Broadly, the results for rental rates tend to be fairly consistent with estimated premiums of 3%–5%. Researchers in the United Kingdom and Australia also find similar positive correlations (Fuerst and McAllister, 2011c; Gabe and Rehm, 2014). Smith (2015) discusses the growing trends for green space in India. However, the results for sale price effects have varied widely with different model specifications and samples. Following the early studies, there have been a number of similar papers continuing the focus on LEED and ENERGY STAR but also examining the price effects of a broader range of voluntary and compulsory energy and/or environmental labeling schemes in other international markets.

While this body of work is too large to review comprehensively, few have attempted to investigate the extent of cross-sectional and temporal variation in the price effects of eco-certification. Probably, the most consistent finding in the body of work examining spatial variations in the market penetration of eco-certified buildings is that there is a positive relation between affluence and the rate of adoption (Choi, 2010; Fuerst, Kontokosta, and McAllister, 2011; Kok, McGraw, and Quigley, 2011). It is notable that there has been no investigation of supply and price effects. Drawing on the CoStar database, Miller, Spivey, and Florance (2008), Eichholtz, Kok, and Quigley (2010), Wiley, Benefield, and Johnson (2010), and Fuerst and McAllister (2011a) produced papers that examined the sale and rental price premiums of LEED and/or ENERGY STAR certified offices in the U.S. Pivo and Fisher (2011) found premiums using appraisal-based data. Reichardt, Fuerst, Rottke, and Zietz (2011) applied a difference-in-differences approach and panel regression to estimate variations in rental premiums over time. For the panel regression fixed effects model, average rental premiums of 2.5% and 2.9% are estimated over the sample period. Reichardt (2014) finds lower operating expenses for LEED buildings. Das and Wiley (2013) interacted variables such as size, class, and age with LEED and ENERGY STAR dummies to assess whether there were any additive effects. They find mixed results with the strongest being an additive effect on the price premium associated with size. Dippold, Mühl, and Zietz (2014) find differences in local demographics may effect green certified stock, while Freybote, Sun, and Yang (2015) find neighborhood certifications may impact property types in that neighborhood. Some effect of green certification has been noted on mortgages in the residential and commercial space (Pivo, 2014; Sanderford, Overstreet, Beling, and Rajaratnam, 2015).

Data

The primary data source for this analysis is sales and rental observations from CoStar. The CoStar database contains over 2.8 million U.S. commercial real estate
assets, including sales and leasing information. Data contain, but are not limited to location, physical building characteristics, tenants, and lease details. The sample is from 2011:Q4 for the rent data, and 2001 to 2011 for the sales data. All available office buildings over 10,000 square feet are selected. Key dependent variables include size, age, building class (A, B, C) and market. Rent and sale price PSF are the independent variables. A detailed list of variables used is in the Appendix. The rent data are cleaned to include only data with size and rent fields existing, and the sales data cleaned to only include data with sale price and size fields in place. The data consists of 48,540 rent observations across top 50 metropolitan statistical areas (MSAs) in the U.S.; the 50 MSAs further refine into 56 defined markets. Sales data covers from 2001 to 2011, and contains 25,422 records.

Several extremely small minimum PSF prices observed in the data are verified as reasonable. There are approximately 20 sales under $1.00 PSF. All but one occurred during the financial crisis period, and several are noted as auction or distress sales, which are controlled for in several of the regression specifications. Even though portfolio sales are explicitly exempted from the sales sample, several sales of over $1 billion dollars are removed, and assumed to be part of a portfolio sale. The sample is summarized in a number of tables that broadly confirm a number of previously identified attributes of eco-labeled properties.

For sold properties, compared to non-labeled buildings, eco-labeled buildings tend to be better quality, larger, taller, and younger; consequently, they tend to rent and/or sell for more. Price per square foot, stories, age, and size are all statistically different from the general population at a 1.0% significance level. For the sample period, we can observe the effects of the cycle on transaction levels. For all categories of offices, transaction levels peaked in 2007–2008. While the absolute number of eco-labeled buildings is small, the fact that eco-labeled offices tend to be much larger means that they tend to account for a higher proportion of space sold. For instance, total non-labeled space accounted for $194 billion of transaction volume, while dual-labeled and ENERGY STAR labeled space accounted for $36 billion and $61 billion respectively. Given that a much higher proportion of non-labeled offices are non-Class A, it is clear that eco-labeled space has accounted for a substantial proportion of all sold office space and a high proportion of all sold Class A office space.

In terms of space transacted, the vast majority of eco-labeled office space is either ENERGY STAR or dual labeled. LEED-only certified offices account for a relatively small proportion of the transaction volume. While eco-labeled buildings accounted for 3.5% of buildings sold, some cities have much higher proportions. A similar pattern can also be seen in the summary statistics for the rent sample (Exhibit 2). One notable difference is that the median age of a LEED-only labeled office in the rent sample is four years. This suggests that LEED-certified offices tend to be more recently constructed.

Focusing on variations by value of transaction, it is clear that eco-labeled stock accounts for a much larger proportion of the large lots. For instance, for sales
### Exhibit 2 | Summary Statistics: Rental Sample

<table>
<thead>
<tr>
<th>Panel</th>
<th>Non-certified</th>
<th>ENERGY STAR rated</th>
<th>LEED certified</th>
<th>Dual certified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rent $psf</td>
<td>18.62</td>
<td>24.57*</td>
<td>28.61*</td>
<td>27.73*</td>
</tr>
<tr>
<td>Stories</td>
<td>3.5</td>
<td>10.1*</td>
<td>9.1*</td>
<td>18.6*</td>
</tr>
<tr>
<td>Size (sq. ft.)</td>
<td>56,124</td>
<td>228,020*</td>
<td>220,637*</td>
<td>422,996*</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>26.66</td>
<td>20.98*</td>
<td>8.06*</td>
<td>18.82*</td>
</tr>
<tr>
<td>% Leased</td>
<td>73.89</td>
<td>83.41*</td>
<td>72.7</td>
<td>85.57*</td>
</tr>
<tr>
<td>Median</td>
<td>17</td>
<td>22.5</td>
<td>25.75</td>
<td>25</td>
</tr>
<tr>
<td>Std. dev.</td>
<td>10.23</td>
<td>11.05</td>
<td>16.86</td>
<td>16.12</td>
</tr>
<tr>
<td>Obs.</td>
<td>45,289</td>
<td>2,454</td>
<td>275</td>
<td>625</td>
</tr>
</tbody>
</table>

**Note:**
*Statistically significant from general population at 1.0% significance level in a difference of means tests.

Over $60 million, nearly 35% of the buildings sold were eco-labeled (Exhibit 3). In contrast, the comparable figure for buildings sold for less than $26 million, 2% of buildings were eco-labeled. The figures are comparable for the sample of rents. It seems clear that while eco-labeled buildings are found in different classes and sizes of buildings, they are much more likely to be large Class A buildings. In this market segment, eco-labeled offices have a substantial market share. In contrast to lower value or smaller buildings, in the large building segment they are not a niche or scarce product and may not be regarded as a superior product by investors and/or occupiers. Below, we model price premiums for eco-certified buildings and focus specifically on the relation between value and premium.
Exhibit 3 | Sales Sample Distribution

<table>
<thead>
<tr>
<th>Whole Population</th>
<th>&lt; $26 MM</th>
<th>&gt; Value</th>
<th>&lt; $60 MM</th>
<th>&lt; Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A: Eco-labeled stock distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building-N</td>
<td>25,515</td>
<td>23,089</td>
<td>1,389</td>
<td>1,037</td>
</tr>
<tr>
<td>ENERGY STAR-N</td>
<td>933</td>
<td>315</td>
<td>304</td>
<td>314</td>
</tr>
<tr>
<td>LEED-N</td>
<td>158</td>
<td>83</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>Dual-N</td>
<td>295</td>
<td>38</td>
<td>61</td>
<td>196</td>
</tr>
<tr>
<td>Panel B: Rent sample distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building-N</td>
<td>48,630</td>
<td>41,177</td>
<td>4,673</td>
<td>2,780</td>
</tr>
<tr>
<td>ENERGY STAR-N</td>
<td>2,473</td>
<td>824</td>
<td>824</td>
<td>825</td>
</tr>
<tr>
<td>LEED-N</td>
<td>278</td>
<td>100</td>
<td>78</td>
<td>100</td>
</tr>
<tr>
<td>Dual-N</td>
<td>628</td>
<td>75</td>
<td>132</td>
<td>421</td>
</tr>
</tbody>
</table>

Research Method

To assess differences across value categories, the data are split into three value categories. Thirds are selected as a natural break in the real estate office markets such as Class A, B, and C. An evenly distributed building population sample was tested, but because eco-labeled buildings are not uniformly distributed by value, it yields insufficient eco-labeled buildings for meaningful comparisons. The total LEED population is more heavily skewed towards higher value buildings and if the total LEED + Dual population of roughly 900 is split into thirds, it too heavily unbalanced compared to the ENERGY STAR portfolio. The most meaningful and sensible method of separation is to divide by thirds relative to the ENERGY STAR population. The minor disadvantage is a population skew to the smallest value portion. However, each of the sections has a statistically meaningful building $N$ of more than 1,000 for each section.

In addition to dividing by value categories, the data are also regressed weighted by value; the intention is to create a dollar-weighted effect on the potential premiums. The sales data uses recorded sale price as the weight, while revenue (Average Building Rent $\times$ SF $\times$ Occupancy) is used as the weight for the rental regressions.

Define:

\[
Value_{total} = \sum_{j}^{N} Value_j
\]
Where $Value_j$ is the value for property $j$, and

$$w_j = \frac{Value_j}{Value_{total}} \quad (2)$$

$W_j$ is the value weight of the building being estimated. The basic regressions are then:

$$\ln(PSF_{jt}) = (\alpha_j + \beta X_i + \varphi_j Z_i + \epsilon_j) \ast w_j. \quad (3)$$

Where:

- $\ln(PSF_{jt}) = \text{Natural log of sales price per square foot (or rent PSF) in a given building } j$;
- $X_i = \text{A vector of the property-specific explanatory variables}$;
- $\beta_i = \text{The regression-derived coefficient for property characteristic } i$;
- $Z_i = \text{A vector of time and non-property variables}$;
- $\varphi_i = \text{The regression-derived coefficient for time and non-property variable } i$;
- $\epsilon_i = \text{Random error term}$;
- $j = \text{Property}$; and
- $t = \text{Time}$.

Weighting can potentially introduce issues of multicollinearity when the weighting variable relates to an independent variable. However, a detailed analysis of the variance inflation factors (VIF) shows that only two control variables are higher than ten. The two variables are the A-Class and B-Class office building type controls. Since they are not the subject of the research, they are left in as controls. Location controls are included in the regressions where not only each market but each submarket is controlled. Propensity scoring was also tested but recent research suggests that propensity scoring does not improve the reliability of a regression result in green building estimations (Robinson and Sanderford, 2015); results were qualitatively similar.

**Results**

Following the modeling approach and data sampling outlined above, we first fit regression models to both the full set of observations and the sub-samples of the different value segments. The results for the sales sample are presented in Exhibit 4.

Models 1 and 2 represent the entire building population showing results first in traditional ordinary least squares regression and then weighted by value (sale price or gross revenue as described above). Models 3–4, 5–6, and 7–8 repeat the
### Exhibit 4 | Results from OLSDV Regressions on lnPSF

<table>
<thead>
<tr>
<th>Weighting</th>
<th>Variable</th>
<th>Whole Data Set</th>
<th>None</th>
<th>Sale Price</th>
<th>&gt; Value &lt; 26,000,000</th>
<th>None</th>
<th>Sale Price</th>
<th>Value &gt; 26,000,000</th>
<th>None</th>
<th>Sale Price</th>
<th>Value &gt; 60,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 1</td>
<td>0.242***</td>
<td>0.060***</td>
<td>0.015</td>
<td>0.023</td>
<td>-0.011</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 2</td>
<td>0.208***</td>
<td>0.114***</td>
<td>0.013</td>
<td>0.078</td>
<td>(-0.335)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 3</td>
<td>0.114***</td>
<td>0.007</td>
<td>0.007</td>
<td>0.009</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 4</td>
<td>0.015</td>
<td>0.007</td>
<td>0.008</td>
<td>0.009</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 5</td>
<td>0.015</td>
<td>0.007</td>
<td>0.008</td>
<td>0.009</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 6</td>
<td>0.015</td>
<td>0.007</td>
<td>0.008</td>
<td>0.009</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 7</td>
<td>0.015</td>
<td>0.007</td>
<td>0.008</td>
<td>0.009</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Model 8</td>
<td>0.015</td>
<td>0.007</td>
<td>0.008</td>
<td>0.009</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lnsize</td>
<td>0.268***</td>
<td>0.111***</td>
<td>-0.005**</td>
<td>0.009**</td>
<td>0.007***</td>
<td>0.009**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stories</td>
<td>0.015***</td>
<td>0.007***</td>
<td>-0.005**</td>
<td>-0.012***</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A Class</td>
<td>0.520***</td>
<td>0.353***</td>
<td>0.456***</td>
<td>0.358***</td>
<td>0.146***</td>
<td>0.164***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B Class</td>
<td>0.193***</td>
<td>0.142***</td>
<td>0.211***</td>
<td>0.178***</td>
<td>0.077**</td>
<td>0.094***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Inland</td>
<td>0.117***</td>
<td>0.044***</td>
<td>0.114***</td>
<td>0.057***</td>
<td>-0.003</td>
<td>-0.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Amenity</td>
<td>0.086***</td>
<td>0.082***</td>
<td>0.083***</td>
<td>0.078***</td>
<td>-0.040**</td>
<td>-0.041**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.91</td>
<td>9.577</td>
<td>9.466</td>
<td>10.722</td>
<td>(-2.026)</td>
<td>(-2.060)</td>
</tr>
</tbody>
</table>
### Exhibit 4 (continued)

Results from OLSDV Regressions on $\ln{\text{PSF}}$

<table>
<thead>
<tr>
<th>Weighting</th>
<th>Whole Data Set</th>
<th>Value &lt; 26,000,000</th>
<th>&gt; Value &lt;</th>
<th>Value &gt; 60,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
<td>Model 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.479</td>
<td>0.693</td>
<td>0.457</td>
<td>0.522</td>
</tr>
<tr>
<td>Model N</td>
<td>25,417</td>
<td>25,417</td>
<td>22,993</td>
<td>22,993</td>
</tr>
<tr>
<td>Sale cond. controls</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Time dummies</td>
<td>X</td>
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<td>X</td>
</tr>
<tr>
<td>Age controls</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Weighted by price</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>ESTAR-N</td>
<td>933</td>
<td>933</td>
<td>315</td>
<td>315</td>
</tr>
<tr>
<td>LEED-N</td>
<td>158</td>
<td>158</td>
<td>83</td>
<td>83</td>
</tr>
<tr>
<td>Dual-N</td>
<td>295</td>
<td>295</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>

Notes: This table presents results from OLSDV regressions on $\ln{\text{PSF}}$ (per square foot sales price) of the building population as a whole, then split into thirds by sales price of the ENERGY STAR buildings. Each set contains ordinary and then weighted regressions by sale price.
ordinary least squares and then weighted by value pattern for the lowest, middle, and highest value categories respectively.

The (log of) price PSF is explained as a function of building attributes (age, size, class, number of stories, land area, presence of amenities) and eco-certification. The fact that the transactions took place in different time periods is controlled for with standard time fixed effects. For the full sample, the overall explanatory power of the model is 48% (adjusted R-squared). The coefficients of the explanatory variables largely have the expected signs. In line with previous studies, there is a positive relation between price and both plot size and height of the building (number of stories). A further expected finding is that, while controlling for both plot size and height, there is a discount for buildings with larger square footage. All else equal, investors pay less per square foot for larger offices.

Turning to the variables of interest, eco-buildings are differentiated by ENERGY STAR, LEED, or dual as described earlier. Previous studies indicate different eco-premiums for each of the three labeling categories and they are thus treated distinctly. For Model 1, we find that ENERGY STAR, LEED, and dual certified offices sold at large premia of approximately 24%, 32%, and 32% respectively compared to non-certified offices. However, when these are weighted by price, these estimated premia decrease dramatically falling to 6%, 13%, and 9% respectively. The value-weighted results for the three segments are, therefore, consistent with the interpretation that premiums for eco-certified offices tend to be associated with smaller, lower value, buildings. This finding motivates further investigation into building price segmentation to determine what strata of building value drives price premia.

Models 3 and 4 are based on properties that sold for less than $26 million, which accounted for the vast majority of the observations from this data set of 10,000 SF office buildings and larger (22,993 out of 25,417 observations). It is only for this smallest value segment that statistically significant premia are identified for eco-certified offices. Models 5–8 show no price premia for any of the eco-buildings. This finding of small building premia is only consistent with the initial value weighting. When each observation is no longer treated equally, but weighted by their respective dollar value, the premia reduces.

Several possible trends may explain the distribution of sales price premia observed. First, the clear trend in large A-Class office buildings has been towards more eco-certified buildings. This pattern indicates that eco-certified buildings in the largest segment are becoming the norm and expectation rather than a premium product. The large premiums in the smallest sections may be attributable to a “best-in-class” phenomenon or more simply may reflect a lower supply of eco-certified buildings in this sector or even a combination of both effects.

The rental results of a regression on rent PSF in Exhibit 5 show similar patterns to the sales, albeit not identical. Again the control variables are as expected in the whole sample regression with size generally increasing revenue, triple net lease
### Exhibit 5 | Results from OLSDV Regressions on lnrent of the Building Population as a Whole

<table>
<thead>
<tr>
<th>Weighting</th>
<th>Variable</th>
<th>Whole Data Set</th>
<th>Rent &lt; 3.06 MM</th>
<th>&lt; Rent &gt;</th>
<th>Rent &gt; 6.12 MM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>None</td>
<td>Revenue</td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>ESTAR</td>
<td>0.015**</td>
<td>0.024***</td>
<td>0.025***</td>
<td>0.020***</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>2.429</td>
<td>5.897</td>
<td>2.573</td>
<td>3.461</td>
<td>0.883</td>
</tr>
<tr>
<td>LEED</td>
<td>0.095***</td>
<td>0.072***</td>
<td>0.123***</td>
<td>0.095***</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td>5.798</td>
<td>7.337</td>
<td>4.599</td>
<td>5.422</td>
<td>2.541</td>
</tr>
<tr>
<td>Dual</td>
<td>0.032***</td>
<td>0.145***</td>
<td>-0.005</td>
<td>0.012</td>
<td>0.031**</td>
</tr>
<tr>
<td></td>
<td>2.76</td>
<td>26.02</td>
<td>(-0.163)</td>
<td>0.650</td>
<td>2.045</td>
</tr>
<tr>
<td>Intercept</td>
<td>2.847***</td>
<td>2.822***</td>
<td>3.021***</td>
<td>3.550***</td>
<td>8.509***</td>
</tr>
<tr>
<td></td>
<td>64.324</td>
<td>71.867</td>
<td>55.398</td>
<td>81.246</td>
<td>72.693</td>
</tr>
<tr>
<td>Insizes</td>
<td>0.024***</td>
<td>0.039***</td>
<td>0</td>
<td>-0.036***</td>
<td>-0.442***</td>
</tr>
<tr>
<td></td>
<td>11.995</td>
<td>18.062</td>
<td>0.182</td>
<td>(-15.951)</td>
<td>(-49.693)</td>
</tr>
<tr>
<td>Renovated</td>
<td>0.038***</td>
<td>0.030***</td>
<td>0.042***</td>
<td>0.028***</td>
<td>0.019**</td>
</tr>
<tr>
<td></td>
<td>8.07</td>
<td>6.913</td>
<td>7.715</td>
<td>6.608</td>
<td>2.36</td>
</tr>
<tr>
<td>Percent leased</td>
<td>0.001***</td>
<td>0.001***</td>
<td>0.001***</td>
<td>0.001***</td>
<td>0.000***</td>
</tr>
<tr>
<td></td>
<td>6.272</td>
<td>(-7.978)</td>
<td>8.844</td>
<td>6.069</td>
<td>2.793</td>
</tr>
<tr>
<td>A Class</td>
<td>0.255***</td>
<td>0.228***</td>
<td>0.243***</td>
<td>0.233***</td>
<td>0.129**</td>
</tr>
<tr>
<td></td>
<td>46.234</td>
<td>33.10</td>
<td>37.249</td>
<td>46.129</td>
<td>8.67</td>
</tr>
<tr>
<td>B Class</td>
<td>0.124***</td>
<td>0.131***</td>
<td>0.123***</td>
<td>0.123***</td>
<td>0.065***</td>
</tr>
<tr>
<td></td>
<td>37.966</td>
<td>22.681</td>
<td>36.308</td>
<td>34.684</td>
<td>4.751</td>
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</table>
## Exhibit 5 | (continued)

Results from OLSDV Regressions on ln(rent) of the Building Population as a Whole

<table>
<thead>
<tr>
<th>Weighting</th>
<th>Whole Data Set</th>
<th>Rent &lt; 3.06 MM</th>
<th>&lt; Rent &gt;</th>
<th>Rent &gt; 6.12 MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Model 1</td>
<td>Model 2</td>
<td>Model 3</td>
<td>Model 4</td>
</tr>
<tr>
<td>NNN</td>
<td>-0.101***</td>
<td>-0.138***</td>
<td>-0.093***</td>
<td>-0.105***</td>
</tr>
<tr>
<td>FSG</td>
<td>0.105***</td>
<td>0.070***</td>
<td>0.107***</td>
<td>0.086***</td>
</tr>
<tr>
<td>Amenity</td>
<td>0.008***</td>
<td>0.005</td>
<td>0.006**</td>
<td>0</td>
</tr>
<tr>
<td>R²</td>
<td>0.569</td>
<td>0.717</td>
<td>0.465</td>
<td>0.521</td>
</tr>
<tr>
<td>Model N</td>
<td>48,541</td>
<td>48,541</td>
<td>41,131</td>
<td>41,131</td>
</tr>
<tr>
<td>ESTAR-N</td>
<td>2,473</td>
<td>2,473</td>
<td>824</td>
<td>824</td>
</tr>
<tr>
<td>LEED-N</td>
<td>33,278</td>
<td>278</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Dual-N</td>
<td>628</td>
<td>628</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Submarket controls</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Age controls</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Weighted by rent</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Note:
* Significant at the 10% level.
** Significant at the 5.0% level.
*** Significant at the 1.0% level.
Exhibit 6 | Summary of Results from Exhibits 4 and 5

<table>
<thead>
<tr>
<th>Whole Sample</th>
<th>Smallest</th>
<th>Mid</th>
<th>Highest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panel A: Sales sample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESTAR</td>
<td>Significant†</td>
<td>Significant†</td>
<td>No premium</td>
</tr>
<tr>
<td>LEED</td>
<td>Significant†</td>
<td>Significant++</td>
<td>No premium</td>
</tr>
<tr>
<td>Dual</td>
<td>Significant†</td>
<td>Significant++</td>
<td>No premium</td>
</tr>
<tr>
<td>Panel B: Rent Sample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESTAR</td>
<td>Significant</td>
<td>Significant†</td>
<td>No premium</td>
</tr>
</tbody>
</table>
| LEED         | Significant† | Significant | No premium | Significant"
| Dual         | Significant++ | No premium | Significant | Significant++ |

Notes: Summary of results from Exhibits 4 and 5 showing sales and rental premiums in the different value categories.
† Economically significant reduction in estimate through value/revenue weighting.
++ Economically significant increase in estimate through value/revenue weighting.

structure subtracting rent, and percentage leased increasing PSF rent as well. The ENERGY STAR buildings show premiums for the whole sample (Models 1 and 2) and in the smallest gross revenue category (Models 3 and 4), but not for the middle and larger value buildings (Models 5–8). This is a consistent pattern as with the sales sample. Curiously, revenue weighting increases the premia in the whole sample regression for ENERGY STAR, but the difference is economically small.

LEED only buildings, as in the sales models, do not show premiums in the largest value category. This finding of no rent premia amongst the highest revenue (value) buildings is further evidence of a de facto requirement for green features in the large, high value asset segment. LEED buildings do show rental premiums in the middle section as well as the smallest. The dual buildings are disproportionately found in the largest value section and do show a rental premium of 6.3%. Interestingly, when revenue weighted in the largest section, the premium increases dramatically. This could be because of a small number of super-A, trophy buildings demonstrating rental premiums. Their large square footage even further impacts on weighting.

With the exception of the dual category, likely driven by some super-A dual buildings as suggested by the weighted regression, the general pattern of smaller revenue buildings showing premiums and larger buildings not showing them holds in the rental data.

The results are summarized in Exhibit 6. The results indicate that price premiums found in the literature may be driven by smaller value buildings.
Exhibit 7 | Sales Quantile Results

The y-axis represents percentage premiums (approximated from natural log parameter estimates) and the x-axis represents where each observation falls on the value spectrum from smallest to largest.

Robustness Check: Quantile Regression

Quantile regression is a method that presents estimates of the dependent variables at various points over their conditional distributions (Koenker and Bassett, 1978). Its use here provides further insights into the behavior of price premiums for eco-certified offices across their value distributions. The vertical axis of the graphs presented below show the estimated premium in log of sale price PSF for the buildings and the x-axis shows quantile distribution by value. In other words, the y-axis shows the percentage premium for the subject green classification relative to the population and the x-axis shows where, in percentage terms, the observations are across the spectrum of building value. For sales price PSF, the impact of ENERGY STAR seems to decrease with value. This is consistent with a negative relation between price premium and total building value/size. Land values are distributed across a greater footprint in larger buildings, usually reducing the PSF price relative to smaller buildings. Obviously, the largest buildings will tend to have the highest nominal price. Thus decreasing green premiums with PSF shows more prevalence in less nominally valuable buildings.
Similarly, the price premium for dual certified offices decreases with PSF sales price, only LEED certified shows the opposite trend. However, sample size is much smaller for this category. The results for ENERGY STAR, LEED, and dual are shown in graphical form in Exhibit 7.

Exhibit 8 shows graphical results from the quantile rental regressions for ENERGY STAR, LEED, and dual. As in the sales data, many of the variables do not have uniform estimates across their conditional distributions. We find the same pattern of a negative relation between building value and estimated rental price premium for eco-certification.

**Conclusion**

Environmental certificates are intended to provide trustworthy information to investors and occupiers about environmental performance. A range of approaches
to estimating the effects on real estate asset prices of features such as location, size, height, proximity to transport nodes, and amenities etc. have been used in numerous research studies on real estate markets. In this case, the variable of interest is the effect of environmental certification on rental and sale price. There are, indeed, a range of reasons to expect investors and occupiers to pay more for an environmentally certified office relative to a similar office that is less energy efficient. The presence of high-quality water heating equipment, lighting, etc. should reduce expenditure on replacement and maintenance. Some investors may obtain a psychic income from “green glow” effects.

The results from the empirical tests demonstrate clear patterns in the distribution of price premiums for eco-certified offices suggested market segmentation in the pricing of green buildings. This paper provides evidence that potential price premiums for environmentally certified offices are value dependent. Broadly, the smaller buildings possess premiums, while the larger buildings provide limited evidence of sustainability premiums. At this point, institutional quality buildings may simply demand a minimum level of sustainable features. This is consistent with greater diffusion of green buildings in the largest segment.

The findings also suggest that large, cross-sectional studies may need additional controls for varying segments. Evidence is also provided that weighting by economic value can provide important information about the distribution of price premiums.

The quantile regression results confirm this pattern; they clearly show variations along the conditional means. Each of the premiums measured by the sustainability categories tail off at the upper end of their distributions. It demonstrates that both value weighting and value segregation alter regression results in real estate hedonic estimations. The pattern observed broadly in thirds from the hedonic regression is supported at more micro levels. Future research could explore the value effect in more detail and examine the specific demand and supply factors that determine how the price effects of eco-labels vary in commercial real estate markets.

### Appendix

### Variable Definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>CoStar Field Rent</th>
<th>CoStar Field Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESTAR</td>
<td>1 if building is ENERGY STAR rated, but not dual</td>
<td>energy_star</td>
<td>energy_star</td>
</tr>
<tr>
<td>LEED</td>
<td>1 if building is LEED certified, but not dual</td>
<td>leed_certified</td>
<td>leed_certified</td>
</tr>
<tr>
<td>Dual</td>
<td>1 if building is both ENERGY STAR and LEED</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Appendix (continued)

Variable Definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>CoStar Field Rent</th>
<th>Costar Field Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>lnrent</td>
<td>Natural log of average weighted building rent</td>
<td>average_weighted_rent</td>
<td></td>
</tr>
<tr>
<td>PSF</td>
<td>Per square foot sales price</td>
<td></td>
<td>Sale_price/bldg_sf</td>
</tr>
<tr>
<td>Insize</td>
<td>Natural log of rent</td>
<td>rentable_build_area_bldg_sf</td>
<td></td>
</tr>
<tr>
<td>NNN</td>
<td>1 if lease type = triple net</td>
<td>services</td>
<td></td>
</tr>
<tr>
<td>FSG</td>
<td>1 if lease type = full service gross</td>
<td>services</td>
<td></td>
</tr>
<tr>
<td>Percent Leased</td>
<td>Percentage of building leased 2011:Q4</td>
<td>percent_leased</td>
<td></td>
</tr>
<tr>
<td>ren_within_10</td>
<td>1 if building was renovated from 2001 forward</td>
<td>year_renovated</td>
<td></td>
</tr>
<tr>
<td>lnland</td>
<td>Natural log of land</td>
<td>land_area_sf</td>
<td></td>
</tr>
<tr>
<td>stories</td>
<td>Number of Stories in Building</td>
<td>number_of_stories_number_of_floors</td>
<td></td>
</tr>
<tr>
<td>A_class</td>
<td>1 if building is “A” class</td>
<td>building_class</td>
<td>building_class</td>
</tr>
<tr>
<td>B_class</td>
<td>1 if building is “B” class</td>
<td>building_class</td>
<td>building_class</td>
</tr>
<tr>
<td>amenity</td>
<td>1 if building contains any amenities like bank, fitness center, etc.</td>
<td>Amenities</td>
<td>Amenities</td>
</tr>
<tr>
<td>Market</td>
<td>Market for physical building</td>
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</tr>
<tr>
<td>Age Controls</td>
<td>Age of building</td>
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</tr>
<tr>
<td>Time Controls</td>
<td>Quarter of sale date</td>
<td></td>
<td>Sale_Date</td>
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References


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Incorporating Green Building Features and Initiatives into Commercial Property Valuation

Authors  Saul Nurick, Karen Le Jeune, Emma Dawber, Ryan Flowers, and Jennifer Wilkinson

Abstract  The rapid acceptance of green buildings internationally has led to awareness of green building features and initiatives (GBFIs) in the South African property industry; however, among South African valuers, it seems the awareness is still in its infancy. Semi-structured interviews were conducted with valuers of varying degrees of experience in Cape Town, online surveys were completed by a sample of South African valuers, and a valuation simulation was conducted to determine the impact of GBFIs. The findings indicate that even though South African valuers have limited knowledge of green buildings, they recognize the importance of incorporating GBFIs in the valuation process.

Green buildings are increasingly being prioritized by owners and developers (Lang, 2008). Commercial property owners are starting to pay more attention to green building, which ties into the realization that buildings and their construction contribute to greenhouse gas emissions, water consumption, and other environmental impacts (Gardiner & Associates, 2010). The United States Energy Information Administration (EIA, 2012) forecasts the world energy consumption to increase by an average 47% from 2010 to 2035, with most of the increased demand coming from emerging economies due to robust economic growth, but with U.S. energy consumption to grow, by comparison, at a modest average annual rate of 0.3% from 2010 through 2035.

Yudelson (2009) suggests that the “green building revolution” is a global movement for energy-efficient, environmentally aware architecture and design. Global warming and the increasing accumulation of greenhouse gases (GHGs) in the atmosphere have proven to be a significant driver for the start of this movement (Lang, 2008). The property and construction industry is acknowledged as one of the largest contributors to global warming and environmental destruction. This industry contributes up to 33% of CO₂ emissions, 30%–40% of the world’s energy consumption, and 40%–50% of raw material usage (Kerr, 2008). Thus, the necessity for green building in the construction sector has become increasingly significant, and therefore has been better acknowledged in the last decade due to the major resource consumption involved (Korkmaz, Erten, Syal, and Potbhare, 2009).

In South Africa, the green building movement has been developing rapidly as the country starts to recognize the global acceptance of green. Frost and Sullivan
(2010) point to the fact that although the South African property market is still in its infancy with regards to green buildings, there are numerous indicators in the economy that suggest the market for green buildings is ready and capable of rapid growth in South Africa, and is responding well to green building features and initiatives (GBFIs).

The Green Building Council of South Africa (GBCSA) was established in 2007, making it one of the youngest green building councils compared to those in Europe, North America, and Australia (Buch, 2009). It could be argued that because the GBCSA is a relatively new entity, South African commercial property valuers have yet to incorporate green building features and initiatives (GBFIs) fully in their valuation models in a clinical and robust way; however, Warren, Bienert, and Warren-Myers (2009) suggest this is a global phenomenon.

The two main valuation techniques used by South African commercial property valuers, as recommended by the International Property Databank (IPD), are the income capitalization and discounted cash flow methods (IPD, 2010). These methods require input variables that are sensitive to changing market conditions, such as capitalization and discount rates (Peto, French, and Bowman, 1996). Valuers are currently unsure on how to account for the implementation of GBFIs in their valuation models (Madew, 2006; Warren, Bienert, and Warren-Myers, 2009), as currently there is limited evidence on the financial performance of green buildings with the economic rationale for developing green buildings being based on almost entirely anecdotal evidence (Eichholtz, Kok, and Quigley, 2009). Globally this has meant that valuers are unable to indicate clearly whether GBFIs affect market value, not necessarily because a link between the two does not exist, but rather because the ability of valuers to assess these features in commercial property, and identify the value of these features, is inherently difficult (Warren, Bienert, and Warren-Myers, 2009).

The aim of this paper is to establish, from the perceptions of South African commercial property valuers, which GBFIs they consider to be the most significant value-adding attributes of commercial green buildings and to establish how South African commercial property valuers could account for GBFIs within the valuation process.

---

**Green Buildings**

The history and trend towards green building has rapidly grown in status in response to the mounting concerns about climate change and environmental degradation. The most notable change has occurred within the corporate environment as companies become more aware of the need for increased environmental concern and green building (CB Richard Ellis, 2009).

In South Africa, the operation of the built environment accounts for 23% of GHGs, while emissions from the manufacturing of key materials required for use in this sector amount to approximately 18 million tons of CO₂ per year, which equates to about 4% of total CO₂ emissions (CIDP, 2009; Milne, 2012). South Africa is
ranked the 12th largest emitter of absolute CO₂ emissions in the world. Due to the developing nature of the economy, it is anticipated that the already elevated levels of GHGs are expected to increase as the economy develops and the country aims to achieve its national development goals (National Treasury, 2010). Despite the infancy of the market, South Africa’s green building movement is gaining momentum (Milne, 2012). Green buildings have become an area of key focus especially within the commercial sector, following the substantial increase in electricity prices, and the launch of the Green Star SA Rating tool (Milne, 2012).

Fuerst and McAllister (2011) identify that, internationally, green certified buildings tend to be newer, single tenanted or owner-occupied buildings and are mostly in the office sector. This trend is prevalent in South Africa where the majority of buildings certified as Green Star rated are still under development and therefore have not yet achieved an “as built” status (GBCSA, 2012).

Gunnell (2009) states that green building design has garnered increased momentum within the U.S., Australia, and Europe for many years. In contrast, green buildings in the South African corporate real estate market are still a relatively new concept (Gunnell, 2009). However, growth and awareness have dramatically increased in recent years due to: electricity shortages and prices; increased local awareness of possible water shortages; increased international awareness of climate change concerns; and increased demand from international bodies operating in South Africa (Milne, 2012).

**Drivers and Barriers to the Adoption of Green Buildings**

Reed and Wilkinson (2005) suggest that the international market for green commercial buildings is gaining momentum in the design and construction sectors; however, there is still minimal development and investment from the private sector. This is supported by Nelson (2008), who argues that although an exponential growth in development of green buildings has occurred, this has been mainly concentrated within wealthier nations.

Within South Africa, the support of green buildings has been strong, and building valuation and certification systems have been seen to be driving the growth of green building market. Furthermore, the establishment of the green building rating tools have allowed for common criterion and standards of measurements for green buildings to be developed. This has further driven and supported the development of GBFIs in South Africa (Frost & Sullivan, 2010). Bond and Perrett (2012) suggest that the training provided by the New Zealand Green Building Council (NZGBC) could clearly demonstrate the business case for green building to the property sector in New Zealand.

Mansfield (2009) argues that major economic benefits resulting from green buildings include improved building performance and durability as a result of a reduction in the maintenance and operational costs required during the buildings lifecycle. Evidence of this is presented in research conducted by RICS (2005)
across a section of building types in Canada and the U.S. (office buildings, industrial, retail, residential, educational), confirming that in the opinion of green building stakeholders, green buildings are leasing at above average rates (on average 3%–5% more), green buildings are able to attract tenants faster (on average 6%–10% better success), and have lower tenant turnover rates compared to that of conventional buildings. This is consistent with the findings of Das, Tidwell, and Ziobrowski (2011), who state that green office buildings yield superior rentals to non-green buildings in San Francisco and Washington DC.

Despite the awareness of these advantages and the growing emphasis placed on green, buildings with GBFIs remain relatively limited (CB Richard Ellis, 2009). The New Zealand property investment industry, when surveyed in the late 2000s, was hesitant to implement GBFIs, which has been especially evident from the private sector (Myers, Reed, and Robinson, 2008). Despite the significant role of the property industry, market players, such as valuers, are the slowest in responding to challenges imposed by green buildings (Lorenz, 2006), possibly due to the lack of convincing, quality, transparent, freely available data on the performance of commercial buildings with GBFIs (Gripne, Martel, and Lewandowski, 2012). Warren-Myers (2012) identified a missing factor to Cadman’s “vicious circle of blame,” whereby Australian investors, occupiers, constructors, and developers all blame each other for the lack of motivation to invest in green buildings, namely the role of valuers as advisors to the different stakeholders.

Mansfield (2009) argues that green buildings provide financial advantages. One of the foremost barriers to the adoption of green buildings is the perception that they are disproportionate with regards to initial capital expenditure (CB Richard Ellis, 2009). However, international cost-value studies from the U.K., France, U.S., Australia, and Japan contesting this view have been undertaken by Bartlett and Howard (2000), Frej (2003), Zhou and Lowe (2003), Pivo and McNamara (2005), Reed and Wilkinson (2005), and Matthiessen and Morris (2007), who have provided substantial research indicating that there is in fact no substantial variance in the average initial construction costs of commercial green buildings when compared with conventional buildings. Nicolay (2007) argues that although there may be 2%–3% additional costs associated with the incorporation of GBFIs within new commercial green building designs, these may recovered through operational savings, reduced maintenance costs, and reduced energy costs, which benefit not only investors but also tenants.

In South Africa, many professionals overvalue the costs of green design and construction by more than 17% (Frost & Sullivan, 2010). Early research by the GBCSA indicates that the South African property industry should expect a cost premium of 1%–10% to build a new commercial green building, based on data supplied by the initial eight Green Star rated buildings (Milne, 2012).

Milne (2012) argues that commercial green buildings in South Africa are still an emerging concept, and valuers are assigned the problematic task of navigating the effects of GBFIs on value. Additionally it is the initial cost of design and construction that is most often given the greatest attention, and little attention is
given to the possible cost and energy savings, which would occur over the entire lifecycle of the building (Frost & Sullivan, 2010). Through integrating green issues into property valuation theory and practice, it is argued that there will be greater success in achieving more green developments (Lorenz, 2006). Until valuers begin to account for GBFI in the values of property, investment within green buildings will not expand (Pearce, 2005). Ellison and Sayce (2007) support this argument by stating that without the development and understanding of GBFI to assess the effect on values and performance, the property sector will continue to struggle to successfully engage with the increase in green building development. Dermisi (2009) speaks of short-term data evidence in the U.S. where the degree of GBFI intervention has a positive effect on a property’s market value, but urges the establishment of long-term trends. This highlights the “chicken and egg” scenario, where valuers cannot value buildings with GBFI without adequate comparable data (Warren-Myers and Reed, 2012), and therefore remain ignorant of the benefits of GBFI. Without new perspectives, valuers will be unable to advise a new pool of investors wishing to invest in commercial green buildings (Nicolay, 2007).

**Green Building Features and Initiatives**

Mansfield (2009) contends that a commonly accepted group of features and initiatives need to be acknowledged in order for valuation professionals to be able to correctly assess the possible impact on market value. Muldavin (2010) and Runde and Thoyre (2010) concur that buildings need to be defined as “green,” and this could be done by incorporating three criteria: (1) a commonly recognized group of features founded on the principle of green; (2) independently verifiable features; and (3) modeled performance that is verifiable by actual results.

GBFI need to be evaluated on the same basis as regular commercial buildings, in order to be considered relevant in valuation (Mansfield, 2009). Assessing how GBFI affect and impact value can only be achieved when the GBFI are identified and isolated, enabling green value to be interpreted and established (Ellison, Sayce, and Smith, 2007).

The selection of the four categories of GBFI, which were chosen because they carried the most weight in the calculation of a Green Star rating by the GBCSA, is supported by Heerwagen (2000), Boyd (2005), Ellison, Sayce, and Smith (2007), and Muldavin (2010). These are: (1) energy efficiency, (2) indoor environmental quality (IEQ), (3) water and waste management, and (4) materials. Runde and Thoyre (2010) concur with the choice of the first three, but include site efficiency as opposed to materials as their fourth category. Boyd (2005) and Ellison, Sayce, and Smith (2007) suggest that the list should not be exhaustive, and should instead be able to change and adapt over time with the evolving green trends.

**The Role of the Valuer**

The valuer is perceived to be the custodian of property information as valuers are involved in every aspect of development, from feasibility and planning until the
property’s disposal or destruction at the end of its useful life (Motta and Endsley, 2003). Peto, French, and Bowman (1996) suggest that the most common objective of the valuer is the assessment of the market value of a property. Isaac (2002) highlights that this assessment is to take place prior to the transaction occurring, using the most appropriate valuation method.

**Commercial Valuation Methods**

We focused on the valuation methods that are applicable to the valuation of commercial property. The two methods that are predominantly used in valuing commercial buildings in the South African property market are the income capitalization and the discounted cash flow (DCF) methods. This is confirmed by the IPD (2010), who established that South African valuers predominantly used the DCF method to value commercial (retail, office, industrial) property (75.6% of valuations representing 62.1% of property by value), while the income capitalization method is used for 22.5% of the properties representing 37.1% of the capital value.

The investment method of valuation relies on the premise that a property’s income-generating value and its capital value are related; this method aims to establish this capital value through the assessment of the property’s annual income (Millington, 1982).

**Incorporating GBFIs into Valuations Methods**

The incorporation of GBFIs into traditional valuation methods, such as the income capitalization and DCF methods has yet to be done explicitly (Boyd, 2005; Jefferies, 2010). Babawale (2011) suggests that the incorporation of GBFIs into valuation methods could be done in the following two ways: (1) valuing properties that are built with GBFIs, while using a traditional valuation method, making adjustments for value using the various indicators of greening (valuation variables); and (2) assess buildings on the basis of their GBFIs with relation to their contribution to the triple bottom line. Robinson (2005) mentions that traditional models are in fact applicable to value green buildings, where Lorenz (2006) is of the opinion that the use of traditional methods will result in conflicting value assessments. However, Babawale (2011) states that quantifying the effects of GBFIs is still not reflected in the models that are in use. The author feels that change is imminent in the valuation profession. This change will embrace new valuation techniques, methods, and indicators of greening (valuation variables), which can be used to better assess the value of such property.

Bienert et al. (2010) state that the following five valuation variables are appropriate for an adjustment with regards to the impact of GBFIs: (1) potential gross income, (2) operating expenses, (3) lease terms and tenant retention, (4) remaining economic life, and (5) yield and capitalization rates. Boyd (2005) notes that it cannot be concluded that a positive effect on market value will frequently occur, as the degree and timing of the impact of GBFIs will differ according to the
Incorporating Green Building Features and Initiatives

Research Method

Green building councils rely on case study analysis to provide data on green buildings (GBCSA, 2008), while researchers concerned with valuation of green buildings such as Boyd (2005), Bowman and Wills (2008), and Van den Tol (2010) used a combination of interviews, surveys, and/or a sensitivity analysis. Boyd

Austin (2012, p. 108) cautions valuers to avoid generalizing the results of sustainability studies “across property types, market areas and market conditions.”

GBFIs are seen to have the largest impact in reducing operating costs, resulting in a higher net operating income (NOI) (Lorenz and Lutzendorf, 2008). The comparative make-up of gross income between a conventional and green building is shown in Exhibit 1.

Exhibit 1 | GBFI Impact on NOI

Source: Adapted from Lutzkendorf and Lorenz (2011).
Nurick, Le Jeune, Dawber, Flowers, and Wilkinson (2005) used a comparative valuation simulation of a single case study in the Brisbane CBD using the DCF method to attempt to determine the possibility of quantifying the effect of GBFIs on investment property.

We used a mixed method research approach in order to consolidate both qualitative and quantitative data. Mixed methods attempt to bring together methods from different paradigms (Spratt, Walker, and Robinson, 2004).

The following three research methods were chosen to extrapolate data for analysis for the purpose of this research: (1) semi-structured interviews with a sample of professional valuers in Cape Town ($n_1 = 9$), (2) online survey of a sample of valuers in South Africa ($n_2 = 27$), and (3) a valuation simulation on a commercial building in Cape Town to determine how GBFIs impact the input variables, and therefore the final value when using both the income capitalization and DCF valuation methods. We define a professional valuer as individual registered with the South African Council for the Property Valuers Profession (SACPVP).

The interviewees ($n_1$) are professional valuers with experience ranging from 5 to 27 years. In order to maintain anonymity, each one is allocated a research code of VAL (number of years of experience). For example, the valuer with five years’ experience is referred to as VAL5. One of the interviewees is a non-practicing valuer who works as a developer and is referred to as VALDEV. Valuers who participated in the survey ($n_2$) are employed in a variety of organizations, from South Africa’s largest property investment companies, property management companies, private valuers, parastatals to local government. OWN1 is used to refer to the owner of the building used for the valuation simulation. Semi-structured interviews and surveys are considered to be the optimum research methods. Both these methods have used extensively in green building research as can be seen by previous research in the field by Barlett and Howard (2000), Madew (2006), Myers, Reed, and Robinson (2008), and Milne (2012), among others. This research design involved underpinning qualitative data with quantitative data in order to display the integrity of the findings. From a methodological perspective, this speaks to the reliability and validity of the research methods/design. According to Yin (2003), validity is the link between the theoretical ideas derived from the literature and the researchers’ observations. The author defines a reliable research method as one that can be repeated by other researchers in order to draw similar conclusions. The research methods/design address both of Yin’s definitions concerning validity and reliability. Denzin and Lincoln (2011) state that the usage of qualitative and quantitative data is a form of mixed methods research where the two data types can be assessed either in parallel or sequentially. Simply put, mixed methods research is seen to be choosing the best tools for answering the research question.

**Findings**

The findings are categorized into various themes that were revealed during both the semi-structured interviews and as a result from responses from the online survey.
Motivating Factors

Motivators for the implementation of GBFIs are a mixture of property investors, building tenants, building owners, and government (Madew, 2006). Both the interviews and the online survey yielded similar results. This is partly due to interviewees and survey respondents having similar exposure to the South African commercial property market, as all respondents are members of the SACPVP. There is a view that all the above-mentioned parties have an equal role to play with regards to the implementation of GBFIs, as all these parties can benefit, predominantly from a financial point of view from the successful implementation of GBFIs. Valuers are considered to be objective property professionals who base their valuations on a combination of historical and current data, which is projected into the future, and therefore do not play a role as motivators for the implementation of GBFIs.

Findings from the interviews indicated that large corporate tenants play a key role in driving the implementation of GBFIs. As Milne (2012) notes, this is due to the fact that there is feasible payback for these type of tenants as there is a higher probability of lease renewal. Corporate social responsibility was cited as a secondary driver by large corporate tenants.

Valuers also identified property owners as drivers for the implementation of GBFIs. Property owners are driven by return, and to remain competitive they need to offer a quality product that results in low vacancies and an acceptable NOI. VALDEV noted that tenant requirements will drive owners to provide green buildings in order to remain competitive in attracting tenants.

Government was not identified as a main driver with regards to the implementation of GBFIs. VAL23 felt very strongly that the government is not a driver of green development in South Africa, and indicated that they would never be. When queried further and presented with the argument of a carbon tax and legislation the government could implement to incentivize green building, the interviewee agreed that the government could definitely then become a driver. However, due to the South African government’s key priorities, which are focused on health care, welfare, and combating crime, green building does not feature as a prominent issue that currently needs to be addressed.

Impact of Rating Tools on Value

Findings from both the interviews and the survey indicated that valuers were aware of green building rating tools. We also found that South African valuers had limited knowledge of the Green Star tool, even though access to Green Star is easily accessible.

Perceptions on the relationship between green rating tools and the market value of commercial property varied. Of the negative responses, issues were that although a rating would impact value, currently, given the South African context, it will not have an impact due to the lack of exposure in the commercial property market. These valuers did, however, recognize the potential of green rating tools valuation on commercial property.
Nearly three-quarters of the surveyed valuers indicated that green rating tools would not have a significant impact on value. The main impact would be how the GBFI would affect the risk profile of the building. The risk profile is linked to the valuation variables, which are used to determine value, as stated by CB Richard Ellis (2009), Eichholtz, Kok, and Quigley (2009), and Fuerst and McAllister (2011).

**Green Certification**

Approximately three-quarters of the valuers that participated in the online survey said that green certified buildings would yield greater values compared to buildings that had not acquired a green rating, citing the improved marketability as the likely reason. Improved marketability may result in higher tenant retention, which may reduce the risk factor of the building and thus have a positive impact on the valuation variables, such as the capitalization and discount rates (Muldavin, 2010).

The type of tenant plays a role with regards to the importance of green certification. Large corporate tenants are ideal as firstly they are more likely to be attracted to a green certified building as GBFIs could potentially add value to the image of the company, and secondly blue chip tenants tend to sign longer leases, and therefore the incorporation of GBFIs would make financial sense from a lifecycle costing perspective (Milne, 2012). Tenants with relatively short leases (less than five years) are less likely to be attracted by green certification, as they will have to incur the costs of GBFIs without gaining many of the future long-term benefits.

VAL5, VAL6, VAL11, VAL21, and VAL23 are all of the opinion that the market acceptance for green building has grown in South Africa since the inception of green rated buildings in 2009. It was further noted by VAL23 that even though the building industry in South Africa has plateaued due to the global economic slowdown, there has been an increase, albeit a slow one, in the number of green certified buildings in South Africa.

**The Impact of GBFIs on Value**

There was a unanimous perception from the valuers that were interviewed that it was important to incorporate GBFIs into commercial property valuation. VAL27 noted that it was important that valuers have an understanding to what degree different GBFIs affect value.

There are varying opinions by valuers with regards to how GBFIs impact value and to what degree GBFIs are incorporated into the final valuation calculation. VAL21 has incorporated GBFIs into valuations by adjusting the capitalization and discount rates; however, VAL21 is aware that the market might not necessarily agree with these types of adjustments. When valuing a green building, VAL23 also adjusted the capitalization rate, as the reduction in operating costs (specifically electricity) reduced the risk of the building for investors. The improvement in capitalization rate can also be attributed to the decrease in vacancy rate due to the improved building grade A to grade A+, as noted by VAL23.
VAL5 and VAL27, who had not yet valued green certified buildings, agreed that non-green certified buildings with GBFI attributes were valued similarly by adjustment to capitalization and discount rates.

VAL5 and VAL25 believe that GBFI would increase the market value. VAL25 stated that GBFIs could have the potential of a 10%–20% sales premium. However, VAL27 felt that this premium would occur gradually, as it will require time for complete market acceptance. Twenty-two of the online survey respondents felt that a green building, which has not necessarily acquired green certification, would garner a higher market value than a conventional building. This is consistent with the findings of Madew (2006), Eichholtz, Kok, and Quigley (2009), and Fuerst and McAllister (2011).

The Impact of GBFI on Valuation Variables

GBFI is deemed to affect a variety of valuation variables. VAL25 insists that the two most important variables are net income and the capitalization rate. In theory, a green building will have a positive impact on both of these variables, as cost savings will increase the net income. Costs savings for the tenant will also result in a lower vacancy rate and therefore a lower risk profile with regard to the building, thus decreasing the capitalization rate. VAL27 predicted that as time passes there will be a greater desire for GBFI, which will lead to an increase in the demand for green space, which will therefore result in continuity in rental and rental growth, which may increase prices. This will eventually result in a reduction in the risk profile of a given building, thus resulting in the application of lower capitalization and discount rates, as illustrated in Exhibit 2.

The valuers that participated in the online survey perceived the following three valuation variables to most likely be affected by the implementation of GBFI in commercial property in South Africa: (1) lower operating costs in comparison to conventional buildings, (2) lower yield because risk premium is lower, and (3) higher rent due to a green premium. Exhibit lists the variables that valuers identified that would affected by the implementation of GBFI.

The Impact of GBFI on Property Owners and Tenants

There is mixed opinion amongst valuers whether tenants would be prepared to pay a green premium. Much of this conjecture is attributed to a lack of knowledge regarding GBFI by both property owners and tenants. The impact of GBFI on operating costs is vitally important to tenants. VAL20 stated that if GBFI manage...
### Exhibit 3 | Valuation Variable Impacts

<table>
<thead>
<tr>
<th>Valuation Variables</th>
<th>Most Likely (1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>Least Likely (7)</th>
<th>No. of Responses</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower yield because risk premium is lower</td>
<td>% 0%</td>
<td>33%</td>
<td>46%</td>
<td>0%</td>
<td>17%</td>
<td>4%</td>
<td>0%</td>
<td>100%</td>
<td>2</td>
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<tr>
<td></td>
<td>n 0</td>
<td>8</td>
<td>11</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>24</td>
<td>2</td>
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<td></td>
<td>μ</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td>Lower operating costs in comparison to</td>
<td>% 58%</td>
<td>13%</td>
<td>8%</td>
<td>8%</td>
<td>4%</td>
<td>4%</td>
<td>4%</td>
<td>100%</td>
<td>1</td>
</tr>
<tr>
<td>conventional buildings</td>
<td>n 14</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>Higher rent due to a green premium</td>
<td>% 25%</td>
<td>21%</td>
<td>8%</td>
<td>13%</td>
<td>8%</td>
<td>17%</td>
<td>8%</td>
<td>100%</td>
<td>3</td>
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<td></td>
<td>n 6</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Lower vacancy rate in comparison to</td>
<td>% 8%</td>
<td>8%</td>
<td>17%</td>
<td>38%</td>
<td>13%</td>
<td>4%</td>
<td>13%</td>
<td>100%</td>
<td>4</td>
</tr>
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<td>conventional buildings</td>
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<td>4</td>
<td>9</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.43</td>
<td></td>
</tr>
<tr>
<td>Lower exit yield due to slower depreciation</td>
<td>% 8%</td>
<td>8%</td>
<td>4%</td>
<td>25%</td>
<td>21%</td>
<td>17%</td>
<td>17%</td>
<td>100%</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.64</td>
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</tr>
<tr>
<td>Lower discount rate applied</td>
<td>% 0%</td>
<td>8%</td>
<td>4%</td>
<td>17%</td>
<td>21%</td>
<td>42%</td>
<td>8%</td>
<td>100%</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>n 0</td>
<td>2</td>
<td>1</td>
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<td>5</td>
<td>10</td>
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<td>24</td>
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<tr>
<td></td>
<td>μ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.82</td>
<td></td>
</tr>
<tr>
<td>Expectation that rents would escalate at a higher rate</td>
<td>% 0%</td>
<td>8%</td>
<td>13%</td>
<td>0%</td>
<td>17%</td>
<td>13%</td>
<td>50%</td>
<td>100%</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>n 0</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>24</td>
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<tr>
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<td></td>
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<td></td>
<td>2.01</td>
<td></td>
</tr>
</tbody>
</table>

to slow down operating cost escalations compared to conventional market escalations then tenants would be prepared to pay a rental premium. VAL11 felt that allowance should be made for the role the economic cycle would play in determining whether owners and tenants would embrace GBFIs. During an economic downturn there would be less enthusiasm by both parties to commit capital expenditure on GBFIs, as their main focus would be to minimize short-term spending. However, during an economic boom, both owners and tenants would be more inclined to engage with the idea of implementing GBFIs by investing upfront capital in order to accrue a long-term financial gain.

**Problems Associated with Green Valuation**

The lack of transactional data and the lack of knowledge (experience) with regard to accurately accounting for GBFIs in valuation models were identified as two major problems associated with green valuation, which is consistent with the Madew (2006), Eichholtz, Kok, and Quigley (2009), and Warren, Bienert, and Warren-Myers (2009). Due to the fact that green buildings are still in their infancy in South Africa, there is minimal if any robust transactional data that valuers can rely on for future valuations. Valuers expressed their concern with how to
accurately incorporate GBFIs in their valuation models. With no current set method of accounting for GBFIs when valuing, VAL 20 noted that valuers are forced to intuitively apply what they think may be the most realistic adjustments. As a result, valuations of green building lack a standardized conceptual approach and well-defined terminology to valuing green building among the South African valuer profession.

Valuation Simulation

The purpose of the valuation simulation was to supplement the interviews and online surveys with an actual example of how GBFIs impact the valuation variables, and determine to what degree a change in the valuation variables will impact the final value. A subject commercial building in the Cape Town CBD was used in the simulation to determine the effects of GBFIs on value. The building was purchased by a prominent listed property fund in 2009 for 20 million ZAR. Eight million ZAR was spent on retro-fitting the building with 25% of this capital expenditure used to implement GBFIs (Exhibit 4). In its refurbished (green) state, the building was valued at 37 million ZAR, as of 2011 (Vunani Properties, 2010).

The owner-driven GBFIs that were implemented primarily focused on water and energy savings and included the use of natural lighting to reduce the demand for electricity, waterless urinals, dual flush toilets, and rain water reticulation. Further savings on energy costs occurred due to the implementation of low energy fittings and central air-conditioning systems. The open-plan layout of offices by the tenant also results in a more efficient energy use with regards to the air-conditioning system.

Using the most common commercial valuation techniques (IPD, 2010), the building was re-valued as if the GBFIs had not been implemented by making
adjustments for the following input variables: (1) net rental, (2) discount rate, (3) capitalization rate, (4) exit capitalization rate, and (5) net rental escalation. Both the Income capitalization and DCF methods were used to obtain the value for the building in its conventional (non-green) state. Exhibit 5 illustrates the percentage difference in value when all of the above input variables revert to conventional market values. An increase of 17.3% in value in the building occurs once GBFIs have been implemented, using both valuation methods. The detailed market-related assumptions for the valuation simulation obtained from IPD (2011) are listed in the Appendix.

A sensitivity analysis revealed that by keeping all the input variables equal except for the net rental amount, which increased by a notional amount of 13.35%, yielded an increase in the value of building in the range of 11.1%–13.34%, depending on the valuation method. Exhibit 6 illustrates how the implementation of GBFIs can influence the net rental, and how sensitive the final building value is to a change in this individual valuation variable.
**Conclusion**

The literature and the findings of both the interviews and surveys indicate that although the market for green buildings in South Africa is still in its early stages, it is growing at an exponential rate as evidenced by the increase in Green Star SA rated buildings since 2009. Although few South African valuers we worked with had valued a green building, the importance of taking GBFIs into account within valuations was recognized. However, despite the acknowledged importance of accounting for GBFIs, incorporating them into valuations at present was perceived to be unwarranted due to the infancy of the green building market, current economic climate, and lack of market evidence.

The findings from the research study validated the imperative need for valuers to take into account GBFIs when conducting valuations. As GBFIs become increasingly more prominent in the commercial property sector, valuers will need to learn how to account effectively for GBFIs in order to demonstrate to their clients the value add compared to conventional buildings.

A further conclusion that has been drawn from the GBFIs identified (i.e., energy efficiency, indoor environmental quality, water and waste management and materials) is that energy efficiency is the most significant value-adding feature in commercial green buildings. This is consistent with Madew (2006), who found that energy reduction was also key in the Australian commercial property market. This has been attributed to increasing energy costs in South Africa (Gunnell, 2009; Milne, 2012) and the significant savings in operating costs that can be achieved with energy efficiency.

It was further established that valuers believe the effect of GBFIs are essential to valuations, even though they themselves are not actively taking action to further their own knowledge on green building and how to incorporate GBFIs into valuations. Therefore, the research illustrated that there is a potential link between the implementation of GBFIs and a change in the value of a commercial property. This link has potentially contributed to valuers becoming more aware GBFIs when conducting valuations of commercial buildings that contain components that have both a direct and indirect impact on the environment and building occupants.

Despite the limited involvement in green building, valuers are appreciative of the impact of GBFIs on valuation, and thus contributing to the momentum of the South African green building movement.

Based on the findings, the following recommendations are made for further research in the field of green building:

1. The impact of the recently formed sustainability index on South African property funds.
2. The impact of GBFIs on decision strategies within the South African commercial property market.
4. An investigation into the business case for green commercial buildings in South Africa by applying the principles of lifecycle costing analysis.

Appendix

Valuation Simulation Assumptions

General Assumptions

1. The information supplied to the authors and summarized in the valuations is substantially complete and correct.
2. The green building valuation was conducted by VAL21, a professional valuer in the industry, and the value attained is assumed to be of true market value. Although market value is not an exact science, it is assumed the quantities are relatively accurate.
3. All factors that were included in the green building valuation are correct and function appropriately.
4. The GBFIs within the report are present in the building and are functioning appropriately.

Specific Assumptions

1. Net rental income was used because the operating cost figures given by IPD (2012) were not consistent with the operating costs of the building. The operating cost assumptions are taken into account as net income figures used. Operating costs are also building-specific, thus it is essential that these be excluded as a market average for these costs may skew results. Therefore, the net rental, rather than a gross rental, will give a better indication of the overall performance of the building.
2. A net rental figure of 112.38 ZAR/m²/month was used for the conventional valuation. This information was based on actual cost data for the subject property, obtained from OWN1, and is assumed to be accurate.
3. The capitalization rate of 10.35% was chosen based on the VAL21’s opinion of the current capitalization rate in the market, and based on the individual’s 21 years of experience, it is assumed that this is a fair reflection of the market. VAL21 then applied a capitalization rate of 10.00% to the green building valuation, representing a decrease of 35 bps.
4. The discount rate of 15.5% applied was found by obtaining the average of the 75th and 95th percentiles from IPD (2012). As a green building would attract less risk, the discount rate applied by VAL21 was lower than that of the industry. In this case there is a 2% differential present.
5. The exit yield of 10.80% for the conventional building was applied by determining the average of the 75th and 95th percentiles from IPD (2012). The exit yield for the green valuation was 10.00%. 
6. Net rental escalations in the market have been 5% for the past 17 years, calculated from the IPD (2011). As such, it is assumed that this trend will continue.

7. It has been assumed that the Department of Water and Sanitation will renew their lease irrespective of the fact that the building is conventional, as this is a government tenant and they and generally sign longer leases.

8. Being an A grade building, the property is assumed to be in good condition.

References


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The Relevance of Green Building Practice in Emerging Markets: A Perceptual Analysis of Commercial and Industrial Building Users in Ibadan, Nigeria

Authors A. Olaleye, T.O. Ayodele, and M.O. Komolafe

Abstract In this study, we examine the operational challenges of existing green building related features/systems to develop hypotheses about factors that will increase the demand for green buildings. We test these hypotheses by examining the potential green building advantages that will influence users’ adoption of green practices and their willingness to pay. The sample included 75 commercial and industrial property users in Ibadan, Nigeria. The findings show that respondents face significant operational challenges with existing building features/systems, especially energy and water. Potential advantages relevant to business processes (reduced resource utilization, quality of work life, and ability to sell to pro-environmental customers) have a greater impact on green building demand relative to other advantages. Most respondents were willing to pay between a 1% and a 10% premium for upgrading to green building. Overall, public enlightenment, awareness, and better enabling green building practice can be improved in Nigeria.

There is an increasing level of awareness over the past decade on the consequences of man’s activities and their straining effects on the Earth’s ability to remain sustainable. In particular, the need to encourage sustainable building practices has increased, due mainly to the contributions the built environment can make to the overall global warming and climate change agenda. For example, the built environment is said to account for a sizeable amount of total energy consumption and of the total greenhouse gas emissions around the world (USGBC, 2009; UCL Energy Institute, 2015). Thus, it appears the built environment and the real estate sector have important roles to play in the climate change agenda and in delivering a sustainable energy economy. As opined by Agnieszka (2014), considerable mitigation can be achieved through these sectors. Green building has consequently emerged as an innovative building concept to lessen the environmental impact of buildings, reduce resource use, and at the same time optimize users’ and occupants’ comfort.
While green buildings are fast gaining ground in most developed countries and much of the barriers to its implementation are gradually being surmounted, the concept and practice of sustainable building is yet to become popular in most developing economies; Nigeria inclusive, due to a wide range of barriers (Eichholtz, Kok, and Quigley, 2011; Ofori, Lin, and Tjandra, 2011; Otegbulu, 2011; Samari et al., 2013). A study by CBRE in partnership with Maastricht University in 2014 (CBRE, 2014), shows that by 2013, 13.2% of the commercial building stock, across the 30 largest markets in the United States, had an ENERGY STAR label, LEED certification or both, compared to 1.5% at the end of 2005. Also according to the report, the amount of certified commercial spaces, measured by size, has grown from 5.6% in 2005 to 39.5% at the end of 2013. In addition, the World Green Building Council has three levels of membership (established, emerging, and prospective), having about 100 Green Building Councils (GBCs) at various membership levels around the world, 27 being fully established. Of these 27, Africa has only one established GBC in South Africa, while ten councils are in the early stage of development; Nigeria inclusive (WGBC Impact Report, 2014). It thus appears that the government, private individuals, and other relevant industry stakeholders in most emerging economies have not given commensurate thought to the enforcement of sustainable building design and practices with a view to promoting environmental sustainability.

The reason for the observed little or lack of interest concerning green building practices in Nigeria and perhaps other developing countries can be linked to the conservative attitude of most Nigerians towards changes. There appears to be low level of awareness and enthusiasm about sustainable building in Nigeria’s built environment. This means that building users, occupiers, and other stakeholders are likely to doubt the certainty of its outcomes and benefits. It is believed, in many quarters, that the costs, financial risks, and lack of demand for sustainable buildings far outweigh the benefits (Samari et al., 2013; Djokoto, Dadzie, and Ohemeng-Ababio, 2014). As noted by Massoud, Fayad, El-Fadel, and Kamleh (2010), uncertainty of outcomes and benefits are common barriers to successful implementation of sustainable practices. In other words, the lack of interest in green building practices must have arisen out of inadequate knowledge of the potential benefits (especially long run) and high level of uncertainty about the actual benefits derivable from green building.

However, this belief has been shown to be erroneous. Kok, Miller, and Morris (2012), Zainordin, Abdullah, and Ahmad (2012), WGBC (2013), and Bendewald, Hutchinson, Muldavin, and Torbert (2014) argue that more energy resources would be conserved when green building features are encouraged. This encouragement will eventually translate into cost effectiveness through reductions in operating costs, among several other non-financial and intangible benefits.

Based on the foregoing, and as argued by Reed, Wilkinson, and Warren-Myers (2011), unless the additional benefits of sustainability are valued by users and occupiers, investors and relevant stakeholders might be hesitant to commit costs to green building, thus undermining the full implementation of sustainable green environment. While investors’ perception of green building may be hinged on financial gains derivable by going green, it is rational to believe that space (end)
users will be willing to embrace green features and pay extra if the perceived benefits from using or occupying green property outweigh those from conventional buildings. Thus, if the interest and perception of the end users are sufficiently evaluated and stimulated, it may serve as a catalyst to drive investors and relevant stakeholders to vigorously pursue a green agenda. It may thus be argued that if the case for sustainable building is being pushed by the demand side of the market, it is expected that investors and other stakeholders might be encouraged to see the need for incorporating green building features.

As a result of the foregoing, in this paper we establish the relevance of green building practices among commercial and industrial property users in Ibadan Metropolis, Nigeria. We examine users’ operational challenges on existing building features, thus presenting a picture of the potential gaps that green building can fill. We also examine the potential benefits of green building that will stimulate users’ interest. Users’ commitment to green building is also tested by examining their willingness to pay for green features. Commercial and industrial property users are studied due to their direct involvement in economic activities.

**Literature Review**

In line with incorporating green building principles based on the triple bottom line issues, studies have focused on the concepts of energy maintenance, efficiency and conservation, and renewable energy resources. Juan, Gao, and Wang (2010) identified parameters to be taken into consideration during the design and construction of sustainable buildings. These include proper orientation of the building, waste water technological approaches, and the building’s energy efficiency. Wang, Yan, and Xiao (2012) focused on six substantial areas: climate, building envelope, building services, user’s attitudes towards energy consumption, and indoor environmental quality. Qaem and Heravi (2012) investigated indicators of energy performance in emerging countries. They identified renewable energy, minimum energy performance, fundamental commissioning of a building’s energy systems, enhanced commissioning, and measurement, verification, and optimized energy performance as important criteria for energy efficiency.

While most of these building and design principles are supported by evidence from emerging economies (Nwokoro and Onukwube, 2011; Otegbulu, 2011), other issues that are common in the literature include use of solar power and low-level environmental pollution during and after construction (Akadiri, Chinyio, and Olomolaiye, 2012; Vatalis et al., 2013; Houghton, 2014). Based on the foregoing, six distinct areas where green features could be incorporated into building design are lighting, water, ventilation and air quality, waste generation and control, design, and energy. We investigate these six areas in our survey.

Several authors have investigated perception and drivers of green building demand. They examined the benefits and willingness-to-pay of end-users, occupiers, and other stakeholders in the property market. While some rationalized the position of the stakeholders, others actually surveyed end-users and occupiers opinions. Some early studies from developed markets include Shiers (2000), Barlow and
Fiala (2007), and Wagner et al. (2007). While these studies focused on commercial property users, the authors identified financial advantages, improved productivity, improved internal environment, reduced energy costs, getting value for money, and control over indoor climate as factors driving users’ and occupiers demand for green building.

More recent studies in advanced economies include Brown, Cole, Robinson, and Dowlatabadi (2010), who explored the relationship between green building and workplace design practice in office buildings in Ontario, Canada. Users’ experience in relation to workplace culture and context was also evaluated. The authors reported that, while there are potentially significant gains to be made from integrating green building with workplace design strategies from the outset, there are many other factors beyond the quality of the space that may play a role in shaping users’ experience. Based on findings from the study, the authors indicated possible links between improved occupant comfort, health, and productivity and organizational culture and contextual factors accompanying the move to a green building. Bond (2010) referring to a 2008 survey commissioned by the Green Building Council of Australia (GBCA) noted that nearly half of the study respondents indicated that occupiers’ demand is driving the involvement in green building, despite the occupiers’ unwillingness to pay extra to lease a green-rated building. Furthermore, Bond and Perrett (2012) pointed out the drivers for sustainable development of commercial property in New Zealand. They include environmental impact, tenant demand, financial benefits, corporate social responsibility, and beliefs held by individuals (in ranked order). Newsham et al. (2013) carried out a post-occupancy evaluation of 12 green and 12 conventional office buildings in Canada and the Northern United States. They discovered a variety of physical features that led to improved occupant outcomes across all buildings, including conditions associated with speech privacy, lower background noise levels, higher background levels, greater access to windows, and conditions associated with thermal comfort. The World Green Building Council’s (WGBC) 2013 report pointed out a number of green building benefits that can drive the demand of commercial property users’ towards green building. These include low operating costs owing to reduced energy costs and better environments, which lead to higher staff retention rate and reduction in workplace illness and absenteeism. McGraw Hill Construction (2014) examined the market drivers of green building. They found that greater self-assessed productivity, lower absenteeism, reduced healthcare costs, improved employee satisfaction, improved employee engagement, and improved ability to attract new talent (in ranked order) were judged by owners and managing directors of companies as factors influencing their willingness to embark on sustainable building demand.

For emerging economies, Aliagha, Hashim, Sanni, and Ali (2013) reviewed potential factors and challenges influencing green building demand in Malaysia. They hypothesized that the model of green building demand for Malaysia will comprise seven interrelated factors including quest for environmental sustainability, increased productivity, improved internal building conditions, cost savings, and lower risks. Bangdome-Dery and Kootin-Sanwu (2013) through a survey of 100 Ghanaian stakeholders identified the critical factors influencing the
adoption of sustainable design strategies in Ghana. The factors they identified include overall cost of alternative energy sources, overall client control on design, client awareness, cost considerations, and implications and availability of motivational schemes. Based on evidence from three commercial buildings in South Africa, Windapo (2014) examined the drivers of green building in the South African construction industry. The author finds that the key drivers of green building demand include rising energy costs, the industry’s Green Star rating system, and competitive advantages. The author concludes that the adoption of green building practices is hinged on operational costs and stakeholder demands.

A few of the studies from the Nigerian market include Nwokoro and Onukwube (2011). The findings revealed that important factors considered for sustainable construction include quality of working conditions, improved construction waste management, and design for flexibility and adaptability. Otegbulu (2011) examined occupiers’ preferences with respect to existing building components and services to ascertain the level of their appreciation of green elements. The results of the survey revealed that incidences of flooding, loss of property, and poor electricity were traced to unsustainable building design. The author advocated for a holistic adoption of green design in Lagos metropolis. Dahiru, Dania, and Adejoh (2014) inquired into the expectations of stakeholders on the potential benefits of green building in Nigeria. They find that reduced capital costs, reduced operating costs, market benefits, health and productivity gains, and reduced liability risk were the perceived benefits from implementing green building practices. From the foregoing, with the apparent benefits derivable from sustainable buildings, it is anticipated that if building users and occupants, especially in developing economies, are adequately informed and sensitized, their demand for green building might be better enhanced.

With respect to users’ willingness to pay for green features, researchers have found that commercial and residential occupants will pay premiums for green properties. Examples include CoreNet Global and Jones Lang LaSalle’s (2011) survey of corporate real estate executives. They found that 74% of the respondents were willing to pay a premium to retrofit space that they own for sustainability, while 37% were willing to pay a 1% to 10% rental premium, and an additional 21% percent were willing to pay a rental premium only if the additional cost is offset by lower operating cost. Eichholtz, Kok, and Quigley (2010) find that commercial property users were willing to pay 3% rental premium per square foot, while the premium price for effective rents was 6% for green labeled building. Also, Fuerst and McAllister (2011) assessed price effects on commercial green building certification. They examined the price differentials between conventional and certified commercial buildings. They found that the rental premium for green buildings was 4%–5%, while the sales price premium was 25%–26%. The Natural Resources Defense Council (2013) found that consumers are willing to spend more on products, visit more frequently, or travel farther to shop in areas with attractive landscaping, good tree cover, or green streets. In areas with a mature tree canopy, customers indicate that they are willing to pay 8%–12% more. Moreover, this could generate over $1 million in increased sales annually for a mid-size retail center. This increased revenue for retail tenants suggests higher
rent premiums for retail building owners providing green infrastructure amenities. Wiencke (2013) investigated firms’ willingness to pay for green building in Switzerland. The author found that public corporations showed the highest willingness to pay. However, on average, the premium price ranged from 1.3% to 7.9%. Contrary to these findings, Oladokun, Gbadegesin, and Ogunba (2010) noted that users in the Nigerian market were not willing to pay any additional cost for green features. This might be due to an inability to trace the inherent benefits owing to the low level of awareness on green features.

Aliagha et al. (2013), Newsham et al. (2013), McGraw Hill Construction (2014), and Windapo (2014) suggest a strong link between green building potential benefits and users/occupants demands for green buildings. However, in developing countries generally, and in Nigeria specifically, there are many different forces at work that define demand and adoption of green practices. A particularly important part of understanding user demand and what needs to be tested is to establish a baseline of the kinds of operational and use challenges that apply to existing building to determine the hypothesis of potential demand for green features/solutions that can help solve such problems. Also, we examine the hypothesis that green features which will fill more operational use gaps will command higher demand by users/occupants. Finally, to provide a financial constraint to potential demand, we address willingness to pay.

### Study Area

We focused our study on Ibadan, in south-western Nigeria. It is comprised of 11 local administrative councils, with five in the inner city and six in the outer area. Since its foundation in the 1800s, the city has experienced rapid growth; it was regarded as one of the pre-colonial urban centers in Nigeria. Ibadan, the capital city of Oyo State, is one of the most urbanized states in Nigeria, and one of the 25 largest urban areas in Africa. It is reputed to be the largest indigenous city in Africa. Located about 110 kilometers northeast of Lagos, it is a major transit point between the coast and the northern part of the country. The city is on the railroad line linking Lagos with Kano and is well connected by roads to other cities in the region. According to the 2006 census, the population is about 3,800,000. The city contains several major research institutes, notably the International Institute of Tropical Agriculture, the Cocoa Research Institute, the Forestry Research Institute, the National Horticultural Research Institute, and the Nigerian Institute of Social and Economic Research. Industries include agricultural processing, brewing, vehicle assembly, and tobacco. Most of Nigeria’s leading publishing companies are also based in the city. Thus, there is relatively large concentration of industrial and commercial activities in the study location.

### Methods

The study covers three distinct areas that are pertinent to answering questions on green building demand in Nigeria. First, we examine the operational challenges
being faced by users in the commercial properties in the study area. This is meant to provide a basis for projecting the potential demand for green features that can solve these problems. Second, we analyze the potential advantages of green building that will motivate users to work in a green environment, thus providing information on the advantages of green building that users value more. Third, we analyze the willingness of users to make an actual monetary commitment to green building based on the potential gaps and expected advantages of green building.

We obtained our data through a self-administered, close-ended questionnaire. The data centered on the three areas indicated above. Questions were asked on the operational use challenges based on the literature on the aspects where green buildings tend to fill gaps in conventional buildings. Also, the drivers of green building demand as identified in literature formed the basis of the questions asked on the potential advantages of green building. The last part of the questionnaire inquired on the premiums willing to be given up on green building by the users.

The respondents are commercial and industrial property users within the city of Ibadan. Commercial and industrial properties were selected, partly due to their high energy consumption and because they can easily quantify their costs and benefits in monetary terms, and will be willing to react to any change that has a direct impact on their net income. In addition, commercial and industrial property users are direct participants in the country’s economic activities, thus they are in a better position to supply information relevant to achieving a sustainable economic growth, which is pivotal to the goal of green building.

A preliminary survey of Ibadan showed that the commercial core areas are Iwo Road, Dugbe, Challenge, Bodija, and Ring Road. Also, industrial core areas include Oluyole Industrial Estate, Toll gate, Brewery, and Okebola. Twelve commercial properties were purposively selected in each of the commercial areas, while all the industrial properties that were sighted in the industrial areas were sampled for the study. However, to cover a larger size, some prominent industrial properties located outside the industrial axes mentioned above were also identified. Selections were done to ensure an even spread in terms of mode of use, intensity of uses, property features, and property sizes. Sixty commercial properties and 45 industrial properties were thus selected, giving a total of 105 questionnaires. The questionnaires were delivered personally to the head of operations/property manager of each of the properties sampled. Seventy-five questionnaires (71.4%) were retrieved and used for analysis. The breakdown indicated that 47 and 28 questionnaires were retrieved from commercial and industrial property users respectively.

In analyzing the operational challenges being faced on existing building features, six themes were identified in-line with literature. A list of questions was created to harness information on these operational challenges based on the identified themes, which suggest areas where green buildings tend to fill gaps. The respondents were asked to rank these operating challenges on a five-point Likert scale of very significant, averagely significant, significant, insignificant, and very insignificant; 5 representing the highest significant challenge and 1 the least significant challenge.
Weight is assigned to each of the scales (very significant, taking the highest weight, and very insignificant, the lowest weight) to arrive at a mean value for the identified operational challenges on property types (commercial and industrial) and overall (aggregate of both property types) basis. The challenges were subsequently ranked based on the mean values.

To calculate the mean, the total weight value for each attribute is obtained through the summation of the product of the number of responses for each rating to an attribute and the respective weight value. The total weight value is then divided by the summation of respondents to the ratings.

This can be expressed mathematically as:

\[
mean = \frac{TWV}{\sum_{i=1}^{5} P_i}
\]

where \( P \) is the number of respondents rating a factor and \( TWV \) is the total weight value.

Furthermore, in examining the potential advantages of green building that will influence users to upgrade their buildings, the users were asked to rate the extent of importance attached to the advantages on a five-point Likert scale. Five represents very much important and one not important at all. Subsequently the mean ratings were computed as above. The mean values were then used to rank the potential advantages for each property type (commercial and industrial) and overall (aggregate of both property types).

Also, in determining users’ willingness to pay, respondents were asked to indicate the premiums they were willing to pay for upgrading existing facilities. The responses ranged from no increase to above a 50% increase. To determine the relative willingness to pay on individual building features, scales 1–7 were attached to the response categories: 1 representing no increase; 2 representing a 1%–10% increase; 3 representing an 11%–20% increase; 4 representing a 21%–30% increase, 5 representing a 31%–40% increase; 6 representing a 41%–50% increase; and 7 representing an above 50% increase. The results were then used to rank willingness to pay for individual features for each property type and aggregated for both property types.

**Analyses and Discussion of Results**

For ease of presentation, the results are analyzed and discussed in line with the three focal areas of the study. The first aspect focused on the operational challenges being faced by building users, the second examined the potential advantages of green buildings, while users’ willingness to pay for green features is the third aspect examined.
Users Operational Challenges on Existing Building Features

Exhibit 1 presents the overall ranking of the operational challenges being faced on existing building features according to property types and on overall basis. Most of the operational challenges have a mean ranking greater than 2.5. This indicates that users are facing severe challenges in these areas and might be willing to accept green features that will mitigate some or all of these challenges. The most pressing challenges being faced by users (with mean values above 3.5) included inefficient power supply system (4.36), high cost of maintaining a well-ventilated environment (3.77), and the high cost of water (3.63). These outcomes might be due to the high dependence of commercial and industrial activities on public utilities, which seems to be erratic in the study area. Given that most industrial and commercial activities are driven by a stable power supply, green changes should be tailored towards efficient power systems with a view towards improving water conservation, ventilation, and air quality.

From the section on lighting, it can be observed that cumbersome maintenance of lighting constituted the most pressing operational challenge (3.31), followed by the short life span of lighting equipment (3.27), while the high cost of supply and maintenance of lighting equipment ranked least with a mean value of 3.11. This implies that green lighting features that will last longer with less maintenance might be readily embraced. The relative impact of lighting features on commercial properties also tend to be generally higher than that of industrial properties, with commercial and industrial properties having mean values of 3.33 and 3.08 respectively. This might be due to the fact that commercial users deal more directly with end users and faults in building design are easily felt by customers.

The high cost of water was the most pressing challenge from the section on water (3.63). The majority of the respondents did not have a stable and affordable water source, probably due to the high energy cost as indicated above. The cumbersome operating process of the water system ranked next, with a mean value of 3.27. The relative impact on commercial properties for water features (3.40) also tends to be higher relative to industrial properties (3.05). This might also be traced to the reason identified under lighting.

As observed from the section on ventilation and air quality, the property users had highest challenges with maintaining a well-ventilated environment (3.77). This implies that a good ventilation system that is free from cumbersome maintenance could be of interest to property users in the study area. Most of the respondents ranked the challenge of overheating/user discomfort high as the second highest operational challenge under ventilation, with a mean value of 3.44. This might be attributable to the hot weather in Nigeria, which necessitates the need for free air movement to cool off a building. This challenge is likely to be more severe during power outage when the air-conditioning system may not be functional. This is also true for users who could not afford air conditioning. Green features that supply adequate natural ventilation should therefore be considered and incorporated into building design/construction. The impact of building feature challenges related to ventilation and air quality tends to be higher for industrial properties, as ventilation/air quality had a mean value of 2.90 and 3.21 for
### Exhibit 1 | Operational Challenges Faced on Existing Building Features

<table>
<thead>
<tr>
<th>Operational Challenges</th>
<th>Commercial</th>
<th>Industrial</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lighting</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cumbersome maintenance of lighting process</td>
<td>3.40 (6)</td>
<td>3.21 (15)</td>
<td>3.31 (6)</td>
</tr>
<tr>
<td>Low life span of lighting equipment</td>
<td>3.33 (10)</td>
<td>3.21 (15)</td>
<td>3.27 (8)</td>
</tr>
<tr>
<td>High energy consumption of lighting equipment</td>
<td>3.19 (13)</td>
<td>3.04 (21)</td>
<td>3.12 (16)</td>
</tr>
<tr>
<td>High cost of supply and maintenance of lighting equipment</td>
<td>3.36 (9)</td>
<td>2.86 (26)</td>
<td>3.11 (17)</td>
</tr>
<tr>
<td>Average</td>
<td>3.33 (3)</td>
<td>3.08 (5)</td>
<td>3.21 (3)</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High cost of water</td>
<td>3.81 (2)</td>
<td>3.44 (7)</td>
<td>3.63 (3)</td>
</tr>
<tr>
<td>Cumbersome operating process of the water system</td>
<td>3.33 (10)</td>
<td>3.21 (15)</td>
<td>3.27 (8)</td>
</tr>
<tr>
<td>High water consumption rate of water appliances</td>
<td>3.00 (17)</td>
<td>3.39 (8)</td>
<td>3.20 (14)</td>
</tr>
<tr>
<td>Waste water control challenges</td>
<td>3.49 (4)</td>
<td>2.50 (29)</td>
<td>3.00 (21)</td>
</tr>
<tr>
<td>Unhygienic water supply</td>
<td>3.38 (7)</td>
<td>2.68 (28)</td>
<td>3.03 (19)</td>
</tr>
<tr>
<td>Average</td>
<td>3.40 (2)</td>
<td>3.05 (6)</td>
<td>3.23 (2)</td>
</tr>
<tr>
<td><strong>Ventilation / Air Quality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High cost of maintaining a well-ventilated atmosphere</td>
<td>3.61 (3)</td>
<td>3.93 (2)</td>
<td>3.77 (2)</td>
</tr>
<tr>
<td>Incidences of overheating and user discomfort</td>
<td>3.13 (14)</td>
<td>3.75 (3)</td>
<td>3.44 (4)</td>
</tr>
<tr>
<td>Indoor air pollution</td>
<td>2.83 (20)</td>
<td>3.39 (8)</td>
<td>3.11 (17)</td>
</tr>
<tr>
<td>Indoor health risk</td>
<td>2.76 (22)</td>
<td>3.21 (15)</td>
<td>2.99 (23)</td>
</tr>
<tr>
<td>Maintenance of exhaust water from AC system</td>
<td>2.64 (23)</td>
<td>3.04 (21)</td>
<td>2.84 (25)</td>
</tr>
<tr>
<td>Incidences of overcooling and use discomfort</td>
<td>2.40 (28)</td>
<td>1.98 (32)</td>
<td>2.19 (32)</td>
</tr>
<tr>
<td>Average</td>
<td>2.90 (4)</td>
<td>3.21 (2)</td>
<td>3.06 (4)</td>
</tr>
<tr>
<td><strong>Waste Generation and Control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toilet and bath facilities maintenance challenges</td>
<td>3.49 (4)</td>
<td>3.39 (8)</td>
<td>3.44 (4)</td>
</tr>
<tr>
<td>Waste storage challenges</td>
<td>2.98 (18)</td>
<td>3.58 (4)</td>
<td>3.28 (7)</td>
</tr>
<tr>
<td>Waste collection challenges</td>
<td>2.48 (25)</td>
<td>3.58 (4)</td>
<td>3.03 (19)</td>
</tr>
<tr>
<td>Waste transportation challenges</td>
<td>2.56 (24)</td>
<td>3.38 (8)</td>
<td>2.97 (24)</td>
</tr>
<tr>
<td>Waste treatment challenges</td>
<td>2.48 (25)</td>
<td>3.04 (21)</td>
<td>2.76 (26)</td>
</tr>
<tr>
<td>Waste water management challenges</td>
<td>2.13 (30)</td>
<td>3.21 (15)</td>
<td>2.67 (27)</td>
</tr>
<tr>
<td>Unhygienic toilet / bath maintenance process</td>
<td>2.79 (21)</td>
<td>2.50 (29)</td>
<td>2.65 (28)</td>
</tr>
<tr>
<td>Excess production of waste water</td>
<td>2.21 (29)</td>
<td>2.86 (26)</td>
<td>2.54 (29)</td>
</tr>
<tr>
<td>Average</td>
<td>2.64 (6)</td>
<td>3.19 (3)</td>
<td>2.92 (5)</td>
</tr>
<tr>
<td><strong>Design</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inadequate indoor / outdoor ventilation</td>
<td>3.10 (15)</td>
<td>3.38 (8)</td>
<td>3.24 (11)</td>
</tr>
<tr>
<td>Inefficient access and mobility consideration in design</td>
<td>3.38 (7)</td>
<td>3.04 (21)</td>
<td>3.21 (13)</td>
</tr>
<tr>
<td>Excess / insufficient daylight penetration</td>
<td>2.98 (18)</td>
<td>3.39 (8)</td>
<td>3.19 (15)</td>
</tr>
<tr>
<td>Inefficient drainage system</td>
<td>2.43 (27)</td>
<td>3.56 (6)</td>
<td>3.00 (21)</td>
</tr>
<tr>
<td>Bad indoor / outdoor air quality</td>
<td>2.03 (32)</td>
<td>3.04 (21)</td>
<td>2.54 (29)</td>
</tr>
<tr>
<td>Indoor / outdoor congestion</td>
<td>2.08 (31)</td>
<td>2.33 (31)</td>
<td>2.21 (31)</td>
</tr>
<tr>
<td>Average</td>
<td>2.66 (5)</td>
<td>3.13 (4)</td>
<td>2.90 (6)</td>
</tr>
<tr>
<td><strong>Energy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inefficient power supply system</td>
<td>4.25 (1)</td>
<td>4.46 (1)</td>
<td>4.36 (1)</td>
</tr>
<tr>
<td>Pollution rate from alternative power supply system</td>
<td>3.28 (12)</td>
<td>3.21 (15)</td>
<td>3.25 (10)</td>
</tr>
<tr>
<td>High power consuming building facilities</td>
<td>3.09 (16)</td>
<td>3.39 (8)</td>
<td>3.24 (11)</td>
</tr>
<tr>
<td>Average</td>
<td>3.54 (1)</td>
<td>3.69 (1)</td>
<td>3.62 (1)</td>
</tr>
</tbody>
</table>

Note: Mean values are followed by the ranks (in parentheses).
commercial and industrial properties respectively. This might be traced to the higher rate of heat emission and occupation of space by heavy industrial equipment being used on industrial properties, thus posing more heat and space management difficulties to industrial property users than to commercial property users.

Under waste generation and control, the most pressing challenge was toilet and bath facilities maintenance, with a mean value of 3.44. Waste storage challenges constituted the second most pressing challenge (3.28). Green features that recycle human waste might be needed by the users as they will reduce the stress on waste collection, storage, transportation, and treatment. Although the respondents did not rank operation challenges in this direction (mean value: 2.92) as high as other factors like energy and water. Due to the high volume of waste produced by industrial properties, waste generation and control was ranked high, with a mean value of 3.19 for industrial property, as against 2.64 for commercial properties.

The most pressing challenge on design was inadequate indoor and outdoor ventilation (3.24), followed by inefficient access and mobility considerations in design (3.21). This challenge was peculiar to commercial properties due to higher demand for commercial property spaces leading to adaptation of existing uses to meet the pressing demand. Green buildings adequately designed for future use should thus be encouraged. Also, inefficient drainage tends to pose more of a challenge for industrial property users (3.56) as there is increasing pressure on waste and water control systems.

Mean values from the section on energy showed that inefficient power was ranked highest (4.36), followed by high pollution from an alternative power supply system (3.25) and high power consuming building facilities (3.24). However, high power consuming building facilities (3.39) was ranked next to power supply challenges for industrial property users (4.46), apparently due to heavy equipment use and constant power needed for production. Power supply challenges become more obvious with the use of alternative power supply systems. This results in higher operating and maintenance costs. The green features that will conserve energy may therefore be an essential component for industrial green building design.

Based on the mean ranking of the operational challenges, energy challenges were ranked highest (3.62), followed by water (3.23), lighting (3.21), ventilation and air quality (3.06), and waste generation and control (2.92), while challenges on design (2.90) were ranked the lowest. The overall ranking is similar to the mean values obtained for commercial building users. However, for industrial users, ventilation and air quality (3.21) was ranked next to energy (3.69), followed by waste generation and control (3.19), design (3.13), and lighting (3.08), while water challenges were ranked lowest for industrial buildings (3.05).

Users Perception of Green Building Potential Advantages

Exhibit 2 shows the ranking of factors that could encourage adoption of green features based on property types and aggregates. Most of the identified advantages will enhance users’ willingness to demand green features as most mean values on
Exhibit 2 | Potential Advantages of Green Features

<table>
<thead>
<tr>
<th>Rank</th>
<th>Potential Advantages</th>
<th>Commercial</th>
<th>Industrial</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reduced resource utilization</td>
<td>3.46 (8)</td>
<td>4.11 (1)</td>
<td>3.79 (1)</td>
</tr>
<tr>
<td>2</td>
<td>Improved quality of work life</td>
<td>3.68 (4)</td>
<td>3.75 (2)</td>
<td>3.72 (2)</td>
</tr>
<tr>
<td>3</td>
<td>Increase ability to sell to pro-environmental customers</td>
<td>3.75 (3)</td>
<td>3.58 (3)</td>
<td>3.67 (3)</td>
</tr>
<tr>
<td>4</td>
<td>Enhance occupant comfort and health</td>
<td>3.86 (1)</td>
<td>3.21 (8)</td>
<td>3.54 (4)</td>
</tr>
<tr>
<td>5</td>
<td>Improved ability to work with community stakeholder</td>
<td>3.78 (2)</td>
<td>3.21 (8)</td>
<td>3.50 (5)</td>
</tr>
<tr>
<td>6</td>
<td>Improved public image</td>
<td>3.59 (5)</td>
<td>3.39 (4)</td>
<td>3.49 (6)</td>
</tr>
<tr>
<td>7</td>
<td>Process innovation</td>
<td>3.56 (7)</td>
<td>3.39 (4)</td>
<td>3.48 (7)</td>
</tr>
<tr>
<td>8</td>
<td>Improved personal productivity</td>
<td>3.35 (9)</td>
<td>3.39 (4)</td>
<td>3.37 (8)</td>
</tr>
<tr>
<td>9</td>
<td>Improved overall productivity</td>
<td>3.21 (11)</td>
<td>3.39 (4)</td>
<td>3.30 (9)</td>
</tr>
<tr>
<td>10</td>
<td>Reduced overall and operating cost</td>
<td>3.59 (5)</td>
<td>2.86 (13)</td>
<td>3.23 (10)</td>
</tr>
<tr>
<td>11</td>
<td>Minimize strain on local infrastructure</td>
<td>3.28 (10)</td>
<td>3.04 (11)</td>
<td>3.16 (11)</td>
</tr>
<tr>
<td>12</td>
<td>Increased resale value of property</td>
<td>2.95 (13)</td>
<td>3.04 (11)</td>
<td>3.00 (12)</td>
</tr>
<tr>
<td>13</td>
<td>Reduced life cycle energy cost</td>
<td>2.76 (14)</td>
<td>3.21 (8)</td>
<td>2.99 (13)</td>
</tr>
<tr>
<td>14</td>
<td>Lower health-related cost</td>
<td>3.06 (12)</td>
<td>2.33 (14)</td>
<td>2.70 (14)</td>
</tr>
</tbody>
</table>

Note: Mean values are followed by the ranks (in parentheses).

potential advantages were above the average of 2.5. The highest ranked advantage was the ability to attain reduced resource utilization (3.79), followed by improved quality of work life (3.72), while increased ability to sell to pro-environmental customers ranked third, with a mean value of 3.67. The least ranked advantages were increased resale value of property, reduced life cycle energy cost, and lower health-related costs, with mean values of 3.00, 2.99, and 2.70, respectively. When assessed on property type, “enhanced occupant comfort and health” was ranked first for commercial properties (3.86), followed by improved ability to work with community stakeholders (3.78) and increased ability to sell to pro-environmental customers (3.75), while increased resale value and reduced life cycle energy cost ranked least, with mean values of 2.95 and 2.76, respectively. For industrial properties, reduced resource utilization and improved quality of work life ranked first and second respectively, with a mean value of 4.11 and 3.75 respectively. Reduced overall operating costs and lower health-related costs ranked the lowest, with a mean value of 2.86 and 2.33 respectively. A reduction in energy cost, although established to be a major benefit of green building, was judged to be of less relevance in respondents’ decisions to adopt green practices. Shiers (2000) and Robinson (2005) suggest a relevant explanation for this result. The authors state that savings in running cost (which may be lower than projected) are often of little interest to most property users and occupiers as they adopt a financial short-term view of their business, rather than focusing on long-term savings or
investment opportunities. The result also reveals that potential advantages that are linked more to business activities were rated higher, relative to those relating more to building activities. This finding also lends credence to the views of Addae-Dapaah, Hiang, and Sharon (2009) that occupiers tend to focus more on activities that are core to the business concerns while building-related issues like cost of service charges are deemed to be negligible in comparison to major business activities. According to these authors, the insignificance of service charges, as a proportion of overall business costs, casts doubt on occupiers’ willingness to pay a premium rent for green buildings. Low relative importance attached to lower health-related costs might be due to the respondents’ view of this potential advantage as being too remote to the business process. The overall result on the perceptions of green building advantages indicate the need for increased sensitization on green building advantages, especially on the need to value the long-term benefits of green building and its role in contributing to more efficient business activities.

**Users Willingness to Pay for Green Features**

Respondents were also asked to indicate the premiums they were willing to pay for upgrading existing building facilities. Exhibit 3 shows the willingness of property users to pay for green features in buildings. It also shows that the modal cost premium willing to be paid on lightening was 1%–10%, with 54.7% of the respondents indicating their willingness to pay this proportion. On water, the modal response was 11%–20% cost premium (52% response); ventilation and air quality, 1%–10% (45.3%); waste generation and control, 11%–20% (44% of responses); design, 21%–30% (33.3% response); and energy, 21%–30% (44% response). Property users were also willing to pay more on green features under the energy subcategory (3.78), followed by design (3.26), waste generation and control (2.91), ventilation and air quality (2.81), water (2.89), and lighting (2.23). These results are contrary to the findings of Banfi, Farsi, Filippini, and Jakob (2008) on users’ willingness to pay for energy-saving measures in Switzerland. The results showed that users were willing to pay more for ventilation systems, enhanced insulation of the façade, and energy-efficient windows. This disparity in results might be traced to differences in the country’s level of development, resulting in higher priorities placed on energy needs in Nigeria due to the relative shortage of power. The mean ratings on industrial properties were generally higher relative to commercial properties. This implies that industrial property users were more willing to pay for green features that mitigate building challenges relative to commercial property users.

Most of the respondents were willing to pay premiums between 1% and 10% on an overall basis, while only a few were willing to pay premiums above 30% for green features that would mitigate existing operational challenges. The respondents’ willingness to pay low premiums might be linked to the uncertainty of the benefits of green building. This result contradicts the findings of Oladokun, Gbadegesin, and Ogunba (2010) that most users were not willing to pay any additional premiums for green building features. However, with increasing use
### Exhibit 3 | Willingness of Property Users to Pay for Green Features

<table>
<thead>
<tr>
<th>Green Feature</th>
<th>Property Type</th>
<th>No</th>
<th>1%–10%</th>
<th>11%–20%</th>
<th>21%–30%</th>
<th>31%–40%</th>
<th>41%–50%</th>
<th>Above 50%</th>
<th>Mean</th>
</tr>
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<tbody>
<tr>
<td>Lighting</td>
<td>Commercial</td>
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<td>25</td>
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<td>4</td>
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<tr>
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<td>0</td>
<td>4</td>
<td>2.23</td>
</tr>
<tr>
<td>Water</td>
<td>Commercial</td>
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<td>20</td>
<td>23</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>2.91</td>
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<tr>
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<td>Industrial</td>
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<td>8</td>
<td>16</td>
<td>4</td>
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<td>0</td>
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<tr>
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<td>0</td>
<td>4</td>
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<td>Ventilation &amp; Air Quality</td>
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<td>Waste Generation &amp; Control</td>
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<td>4</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>
**Exhibit 3** | (continued)

Willingness of Property Users to Pay for Green Features

<table>
<thead>
<tr>
<th>Green Feature</th>
<th>Property Type</th>
<th>No</th>
<th>1%-10%</th>
<th>11%-20%</th>
<th>21%-30%</th>
<th>31%-40%</th>
<th>41%-50%</th>
<th>Above 50%</th>
<th>Mean</th>
</tr>
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<tr>
<td>Design</td>
<td>Commercial</td>
<td>4</td>
<td>19</td>
<td>7</td>
<td>13</td>
<td>0</td>
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<td>2.96</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
<td>8.5%</td>
<td>40.4%</td>
<td>14.9%</td>
<td>27.7%</td>
<td>0.0%</td>
<td>8.5%</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
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<tr>
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</tr>
<tr>
<td></td>
<td>Total</td>
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<td>4</td>
<td>4</td>
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</tr>
<tr>
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<td>Percentage</td>
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<td>30.7%</td>
<td>20.0%</td>
<td>33.3%</td>
<td>5.3%</td>
<td>5.3%</td>
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<td>17</td>
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<td>25.5%</td>
<td>17.0%</td>
<td>36.2%</td>
<td>12.8%</td>
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<tr>
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<td>33</td>
<td>10</td>
<td>0</td>
<td>4</td>
<td>3.78</td>
</tr>
<tr>
<td></td>
<td>Percentage</td>
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<td>16.0%</td>
<td>21.3%</td>
<td>44.0%</td>
<td>13.3%</td>
<td>0.0%</td>
<td>5.3%</td>
<td></td>
</tr>
<tr>
<td>Average</td>
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<td>3.83</td>
<td>28.00</td>
<td>23.83</td>
<td>12.33</td>
<td>3.00</td>
<td>2.00</td>
<td>2.00</td>
<td></td>
</tr>
</tbody>
</table>
and incorporation of green building features in the study area, it is expected that users will become willing to pay higher premiums as they realize reduced operational challenges on building features/systems and resultant enhancement of business practices.

**Conclusion**

Considering the alarming environmental impact of conventional buildings, the need for green building is obvious. However, if building users cannot identify with the need for green features and are not particularly willing to tailor their budget towards energy conserving features, the idea of green building may only remain at the fetal stage in Nigeria. We presented evidence of the need for green buildings in the study area. We found that most of the users are experiencing significant challenges on the use and operation of existing green building related features/systems. Also, the respondents indicated a willingness to pay for green buildings if such retrofits would enhance business operations through reduced resource utilization, improved quality of work life, and increased ability to sell. Since most of the respondents indicated a willingness to commit an initial sum of at least 1% to 10% premium, it is expected that willingness to exercise an effective demand on green features will increase as users are sensitized on and as they realize the inherent benefits of green building in terms of operational challenge mitigation and enhancement of business activities. Widespread supply of green features accompanied with increased sensitization is therefore likely to deepen green building practice in the study area.

The Nigerian government can play a key role in stimulating public and private green building adoption by creating an enabling environment, enacting laws, and promoting green building policies. This should also be accompanied with a good awareness program in order to improve the status quo and enhance better green building practice in Nigeria.

**References**


CoreNet Global and Jones Lang LaSalle. Perspectives on Sustainability: Results of the 2010 CoreNet Global and Jones Lang LaSalle Global Survey on Corporate Real Estate and Sustainability. Jones Lang LaSalle, 2011.


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Factors Influencing U.S. Homebuilders’ Adoption of Green Homebuilding Products

Authors
Andrew R. Sanderford, Matthew J. Keefe, C. Theodore Koebel, and Andrew P. McCoy

Abstract
While many researchers have analyzed the obstacles to the diffusion of innovation in building construction, little empirical evidence has been gathered about the factors associated with U.S. homebuilders’ adoption of innovative building products. In this paper, we develop a theory-driven diffusion of innovation conceptual model of homebuilders’ adoption of high performance building product innovations. We are among the first to operationalize a regression model to demonstrate an application of the model using a large dataset from the National Association of Homebuilders. Model results indicate that builders’ selections of high performance products are influenced by internal or firm attributes, external attributes, as well as the attributes of the high performance innovations. These results suggest that the adoption rates of future innovative building products will likely be influenced by product and climate and have the potential to be amplified by bandwagon effects.

Scholars have studied innovation within industries and disciplines from agriculture (Sunding and Zilberman, 2001) to zoology (Müller and Newman, 2005) and generated considerable insight into a range of complex factors affecting its adoption (Venkatesh, Morris, Davis, and Davis, 2003). Whereas Schumpeter (1939) often referred to “new men and new ideas” and “creative destruction,” the adoption and diffusion of innovation highlights the process by which new products and services are substituted for older versions that capture opportunities for new economic profit and competitive advantage (Tsai, 2001; Chesbrough, Vanhaverbeke, and West, 2008). The residential construction industry is no different (Slaughter, 1993). Like other disciplines where innovation is a focal point for research, in the construction literature, the innovation conversation has been parsed into a number of streams including one focused on innovation adopting organizations (IAOs) and the process by which they adopt products that are new to their relevant market and to the adopting firm (Damanpour and Gopalakrishnan, 2001; Blayse and Manley, 2004; Greenhalgh et al., 2004; Larsen, 2005; Koebel, 2007; Gambatese and Hallowell, 2011).

Within the construction literature focused on the adoption of innovation, researchers have advanced various theoretical models illustrating the factors that influence adoption and diffusion of innovative construction products (Arditi, Kale,
Factors Influencing U.S. Homebuilders' 

Given the shortage of residential specific empirical adoption and diffusion models, this paper draws on recent analyses of innovation within commercial construction (Kale and Arditi, 2009; Rose and Manley, 2014; Koebel et al., 2015), commercial real estate (Kok, McGraw, and Quigley, 2011; Malkani and Starik, 2013), high performance consumer technologies (Johnstone, Hascic, and Popp, 2010; Altwies and Nemet, 2012), and other fields (Wejnert, 2002; Venkatesh, Morris, Davis, and Davis, 2003; Greenhalgh et al., 2004) to develop a theory-driven conceptual model. We then operationalize the conceptual model and demonstrate an application of the model using a large dataset from the National Association of Homebuilders (NAHB) that describes homebuilders’ yearly adoption and use of nearly 1,100 construction products. The purpose of this paper is to analyze the factors associated with U.S. homebuilders’ adoption of thermostat and piping innovations from 2000 to 2010.

We examine several technologies from a group of ten construction product innovations the U.S. Department of Housing and Urban Development (HUD) linked to housing affordability: optimum value engineering (OVE), structural insulated panel systems (SIPs), insulating concrete form systems (ICFSs), spray foam insulation, installing HVAC and duct systems in conditioned space, customizing the HVAC system, and programmable thermostats and polyethylene plastic piping (PEX or PEX al PEX).

Noting that green technology innovation in windows was rapidly adopted by builders from 2000 to 2010 (Koebel et al., 2015), we examine two important technologies from the HUD list—programmable thermostats and high performance water piping. Each product cluster is a factor in a home’s total energy consumption and both categories have experienced significant product innovation over time (e.g., although Google’s Nest thermostat was introduced after our study period, it represents a significant leap forward in thermal comfort management and energy consumption. It is illustrative of the type of innovation we investigate during our study period).

Construction innovation scholarship has revealed that factors internal to the adopting firm tend to be stronger influences on the adoption decision than external factors (Tatum, 1987; Kale and Arditi, 2009), with conclusions generated predominantly from mixed-methods analyses of survey and interview data (Cheng, Wen, and Jiang, 2014; Murphy, 2014). For example, where building information modeling (BIM) software has been available since the mid-1980s, empirical evidence on adoption rates is rare (Cao, Li, and Wang, 2014), although qualitative and case-based evidence indicates it is growing more widely used all the time (Taylor and Bernstein, 2009; Azhar, 2011). Further, this research has confirmed,
much like the construction innovation literature, that there are significant internal and external obstacles to broader BIM adoption (Azhar, Nadeem, Mok, and Leung, 2008; Aranda-Mena et al., 2009; Succar, 2009; Azhar, 2011; Bynum, Issa, and Olbina, 2012).

Although the large data set we employ is useful, the scale limited the collection of internal attribute data as well. Given this limitation, we make observations about the extent to which homebuilders’ high performance innovation adoption decisions can be explained when information describing the internal attributes of the adopter is limited. With the recent publication of our work on the diffusion of high performance windows (Koebel et al., 2015), in this paper we are the first to make comparisons between the findings of the other empirical diffusion model and offer insight into the adoption and diffusion patterns of high performance housing technologies.

**Background and Conceptual Model Development**

Theoretical frameworks and empirical models have been used to examine the adoption and spread of products and processes within markets. Designed to examine S-shaped curves that describe a typical pattern of cumulative adoption of an innovation over time, scholars have developed multiple theoretical and empirical frameworks to contextualize and explain the curve and how it changes over time (Bass, 1969; Burt, 1973; Easingwood, Mahajan, and Muller, 1983; Mahajan, Muller, and Bass, 1990; Moore, 1991; Baumol, 2010; Kok, McGraw, and Quigley, 2011). The residential construction industry is often noted for having low levels of innovation and being constrained by path dependency (Lutzenhiser, 1994; Xue, Zhang, Yang, and Dai, 2014) and other industry-specific attributes (Koebel and McCoy, 2006; McCoy, Koebel, and Sanderford, 2013). Emphasis on the laggard status of the industry has, until recently, been compounded by limited empirical investigation of the diffusion of specific construction innovations (Taylor and Levitt, 2007; Rose and Manley, 2014).

Construction innovation researchers have often noted the importance of diffusion of innovation frameworks and models (e.g., Larsen, 2005; Pries and Dorée, 2005; Koebel, 2007; Sargent, Hyland, and Sawang, 2012), although few have embraced mathematical models to analyze the factors associated with the diffusion of specific construction innovation. Several papers have advanced empirical diffusion of innovation models relative to innovation adopting organizations with foundations in Bass (1969) or Rogers’ (1995) work.1 These researchers have analyzed heavy equipment (Arditi, Kale, and Tangkar, 1997), innovative software (CAD) (Kale and Arditi, 2005), concrete technology (Kale and Arditi, 2006), and road construction product adoption (Rose and Manley, 2012, 2014). Confirming results outside the construction domain, these papers illustrate strong roles for internal and external factors firm adoption. Kale and Arditi observed strong influence from internal adopter attributes while Rose and Manley, like recent non-construction diffusion models (e.g., Kok, McGraw, and Quigley, 2011), focused on external factors.
Until quite recently, analyses of the diffusion of innovation of specific housing technologies into the housing market were based on very small samples, case studies, or remained theoretical. We are the second group to analyze the factors associated with the diffusion of residential building technologies using an empirical model (Koebel et al., 2015). We are the first to examine the diffusion of programmable thermostats and PEX piping as innovations among U.S. homebuilders and to control for their adoption of additional high performance technologies during the same time period.

To define a conceptual model relative to U.S. homebuilders for this work, we first conducted a literature review. At the broadest level, the review indicated that diffusion of information models have several important tasks and components. First, models should recognize that diffusion of innovation is a complex process that must be integrated into existing firm, political, and cultural contexts (Venkatesh, Morris, Davis, and Davis, 2003; Ansari, Fiss, and Zajac, 2010). Second, models should be theory-driven, process-oriented, ecologically-sensitive (setting based), and reflect contributions from multiple disciplines (Greenhalgh et al., 2004; Greenhalgh and Rogers, 2009). Third, models should identify the factors of the innovation, adopter, and environment that replace time as an explanatory factor and are associated with the decision to adopt or not adopt (Wejnert, 2002).

Bass (1969) or Rogers (1995) models of the diffusion of innovation models typically analyze the adoption decision as a function of the factors that could be associated. The literature indicates that dichotomous choice is one of the more common ways of modeling the adoption decision (Feder, Just, and Zilberman, 1985) as it captures the adopt versus not-adopt framework (Mercer, 2004). Both logit and probit models can be applied to a binary choice and Tobit and multinomial logit applied to reflect choice complexity. While the binary nature of the traditional framework reflects a good deal about the adoption choice, research also indicates that multiple stage adoption dependent variables can also be used for analysis (Dimara and Skuras, 2003).

The attributes of the innovation that influence the adoption decision have been well documented in the literature. Rogers’ (1995) omnibus work distilled five central factors: observability, trialability, relative advantage, complexity, and compatibility. Together, these attributes relate to the adopter’s ability to see, touch, try, compare, and understand the innovation in their market context. An array of literature confirms the role each plays in the adoption decision, including a meta-review by one of the modern experts of innovation theory and practice (Greenhalgh et al., 2004).

With respect to the internal factors that influence the adoption of innovation, the literature highlights the presence of technology champions (Koebel, 2007), levels of research and development funding, project manager support for innovation (Damanpour and Schneider, 2006), the firm’s sense of how innovation will create value, whether they adopt early or later, and the extent to which firms see the availability of competing innovations (Hartmann, 2006). Outside of the construction literature, research has shown that the adopter’s characteristics and their perception of the attributes of the innovation are linked and influence the
duration of the adoption process (Ostlund, 1974). Additional traits included: firm size (Kimberly and Evanisko, 1981; Dewar and Dutton, 1986), managerial attitude toward change, technical knowledge resources, administrative intensity, internal/external communications, centralization (Damanpour, 1991), and concerns about reputation (Gann and Salter, 2000).

Research shows that the contextual (Dale and McQuater, 1998) or external factors that influence the adoption of an innovation are time (Rogers, 1995), client orientation, climate (Andrews and Krogmann, 2009; Kok, McGraw, and Quigley, 2011), industry structure or relationships, attributes of the built environment (Ewing and Hamidi, 2013; Ewing, Meakins, Hamidi, and Nelson, 2014), communication networks (Rogers, 1995), and market area control variables are each important (Koebel, 2007), as are the spillover effects between markets (Simcoe and Toffel, 2011). Additionally, where research is often concerned about substitution innovations or the process of supplanting old with new, industrial economics literature supports the concept of complementarity, or the adoption of substantively or functionally related innovations that play a role in the adoption of innovation (Freeman, 2002; Cassiman and Veugelers, 2006; Miravete and Pernias, 2006; Gilli, Mancinelli, and Mazzanti, 2013). While identifiable, scholars have noted that assessing causal relationships from complementarity can be a challenge given the timing of adoption and available data (Fagerberg, Mowery, and Nelson, 2006; Greenhalgh and Rogers, 2009).

Regulation is also a significant and complex factor in the adoption of innovation and warrants more in-depth discussion as it connects to sustainability. Research shows that regulation influences adoption decisions in construction and other built environment disciplines (Choi, 2009; Simons, Choi, and Simons, 2009; Hardie and Newell, 2011; Kontokosta, 2011). For example, recent raising of building code standards and efficiency requirements for markets indicates growing rates of the diffusion of energy efficiency in buildings (Kok, McGraw, and Quigley, 2011). Additionally, researchers have observed accelerated diffusion where the cost of achieving increased performance has dropped (Beerepoot and Beerepoot, 2007; Harvey, 2013; El-Shagi, Michelsen, and Rosenschon, 2014). To wit, the diffusion of energy innovations appears to be reflected and capitalized in the prices of commercial (Eichholtz, Kok, and Quigley, 2010; Eichholtz, Kok, and Yonder, 2012; Harvey, 2013; Nappi-Choulet and Decamps, 2013; Geiger, Cujas, and Fuers, 2014) and residential buildings (Costa and Kahn, 2009; Brounen and Kok, 2010; Aroul and Hansz, 2011; Bloom, Nobe, and Nobe, 2011; Dastrup, Graff, Costa, and Kahn, 2012).

Given the guidance that diffusion of innovation models are theory-driven and contain attributes of the innovation, the adopter, and additional external factors, Exhibit 1 represents a conceptual model of the adoption of building product innovations among U.S. homebuilders.

Operationalizing the Conceptual Model and Data

To mimic the adoption decision, the researchers operationalized dependent variables as binary, single-stage decisions to adopt a higher energy performance
product from a cluster of economic substitutes. In Spring 2012, the U.S. Department of Housing and Urban Development (HUD) proposed 10 energy performance products that could be leveraged toward affordability: framing-optimum value engineering (OVE), structural insulated panel systems (SIPs), insulating concrete form systems (ICFs), spray foam insulation, installing HVAC and duct systems in conditioned space, customizing the HVAC system, programmable thermostats, and polyethylene plastic piping (PEX or PEX-AL-PEX).

Complete records for each energy performance product from 2000 to 2010 were not available within the BPS. Therefore, we specified our first dependent variable as a homebuilder’s use (or non-use) of cross-linked polyethylene water distribution piping known as PEX (or PEX-AL-PEX when it includes an aluminum component) in each year from 2000 to 2010.

We specified the second dependent variable as a homebuilder’s use (or non-use) of a programmable thermostat from among a cluster of lower energy performance economic substitutes in each year from 2000 to 2010. In the context of the cross-sectional non-longitudinal data in the BPS, Exhibit 1 illustrates the cumulative adoption curve or diffusion trajectory of the high performance piping alternatives against their traditional substitutes during the study window. It is clear that the higher energy performance alternative grows to become the market leader over time.

We chose the specification of the dependent variable for several reasons. First, the specification imitates the dichotomous choice homebuilders are faced with when
deciding to install building products. It also reflects the central tendency of the innovation literature to use binary single-stage dependent variables to model adoption decisions. Second, recent literature (Kok, McGraw, and Quigley, 2011; Malkani and Starik, 2013) has noted that green and high performance attributes of buildings represent innovation. Third, these building technologies both play key roles in increasing the environmental performance of a home. Higher performance thermostats increase precision for heating-and-cooling-based energy consumption, the highest consumption of energy in the home. Similarly, high performance piping significantly reduces thermal transmission loss as water travels from the hot water heater to the tap (water heating being another large energy consumer). Fourth, these technologies exhibit important attributes that can affect use; for example, differences in adoption patterns for technology innovations that are placed inside the wall versus outside the wall (observability) or other important product attributes (McCoy, Koebel, and Sanderford, 2013). Finally, with binary dependent variables describing the adoption of a high performance product from among a cluster of economic substitutes, our specification allowed for controlling two Rogers’ (1995) defined attributes of innovations: compatibility and complexity.

The embedded assumption in this simplification is that as the technologies are economic substitutes for one another, the adopter is aware of the complexity and compatibility of the products and adopts the product based on other characteristics. An associated challenge in modeling the adoption process as described is that it is extremely difficult to understanding builders’ tacit knowledge or knowledge acquisition processes about innovative technologies. For example, some may be slow to adopt because the innovations require substantial research and education to understand and use. This tacit knowledge level would be an internal factor and is, in this model, not something for which we can account beyond their signaling about innovation through the use of other products. Based on the technology adoption literature, it would reasonable to expect that how knowledge about the attributes of the innovations is acquired (e.g., how much effort is required to learn about something new or find new vendors and whether or not to trust them) would significantly influence the adoption decision.

To gain some insight into the tacit knowledge associated with the adoption of high performance housing technology innovations and their inclination towards innovation, we introduce an independent variable measuring the builder’s other high performance innovation choices. The variable seeks to account for the respondent’s tendency to adopt higher performance building products and reflects their orientation toward innovation in high performance products. While it does not control for the difficulty of knowledge acquisition, it should help signal the firm’s orientation towards the adoption of high performance innovation.

Data for the dependent variable from the Builders’ Practices Survey (BPS), an annual survey conducted by Home Innovations Research Lab, a subsidiary of the National Association of Homebuilders (NAHB). The BPS documents the self-reported material selections of NAHB member respondents (NAHB, 2014). The survey covers nearly 1,100 products, across more than 40 categories, and has been conducted since the late 1990s. Our research utilizes data from 2000 to 2010 in
Factors Influencing U.S. Homebuilders’

Exhibit 2 | Attributes of Innovation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Construction Wholesale Firms</td>
<td>Total number of construction wholesaling firms in CBSA</td>
<td>County Business Patterns</td>
</tr>
<tr>
<td>Relative Advantage</td>
<td>Average cost per unit of high performance technology/average cost per unit of economic substitutes</td>
<td>RS Means</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>Average cost of construction in CBSA</td>
<td>RS Means</td>
</tr>
</tbody>
</table>

the dependent variable specification representing approximately 30,000 builder respondents. We limited the sample to respondents that reported operating in the contiguous 48 states during the sample period. With each of these restrictions, the total number of observations in each model (described below) was approximately 10,000.

It appears that the BPS is the largest set of cross-sectional data available to analyze research questions focused on builders’ annual use of individual construction technologies. Although it cannot be considered a random sample of the universe of residential builders in the U.S. or a longitudinal data set, as respondents’ product choices cannot be tracked across time, the distribution does appear representative of the U.S. homebuilding industry. Comparing the distribution of the BPS to the distribution of homebuilders in the U.S. Census’ County Business Patterns data in randomly selected years of our analysis period revealed an average coefficient of determination of 0.70, indicating sufficient similarity between the distributions (McCoy, Koebel, and Sanderford, 2013). The BPS data do not contain any information about the characteristics of the firms beyond the city and county of the respondents’ addresses and summary measures of the number, size, building type, and price of the housing units built during the previous year.

Independent variables were classified into three categories: (1) attributes of the innovation (Exhibit 2), (2) attributes of the adopter (Exhibit 3), and (3) contextual or external conditions (Exhibit 4). Given the extensive literature describing factors influencing the adoption of innovations across many industries, there has been consistent focus on the attributes of the innovation—linking directly to Rogers’ (1995) historical classification of attributes that most significantly influence product adoption: observability, trialability, complexity, compatibility, and relative advantage. The total number of construction wholesalers, as measured by the county business patterns, in the respondent’s Core Based Statistical Area (CBSA), accounted for trialability, complexity, and observability of each of the high performance products. Relative advantage, a function of price, was measured, using RS Means data, as a ratio of the price of the dependent variable over the average price of its economic substitutes. Where prior sustainable real estate literature has focused on the price of green buildings relative to the economic value they generate, the ratio specification of the relative advantage attempted to capture the quick calculus a builder might use in selecting a product among its
### Exhibit 3 | Internal Attributes of the Adopter

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complementarity Index</td>
<td>Sum of respondent’s binary choices to adopt high performance window, framing, foundation, insulation, and either piping or thermostat technologies (dependent variable excluded per model)</td>
<td>BPS</td>
</tr>
<tr>
<td>Total # of Homes Built</td>
<td>Total # of homes built by respondent (hundreds)</td>
<td>BPS</td>
</tr>
<tr>
<td>% of Multifamily HU</td>
<td>% of MF units built within respondent’s annual housing unit total</td>
<td>BPS</td>
</tr>
<tr>
<td>Weighted Avg Size</td>
<td>Average of single-family housing unit size weighted by type: starter, move-up, luxury. Type defined by NAHB.</td>
<td>BPS</td>
</tr>
<tr>
<td>Weighted Avg Price</td>
<td>Average of single-family housing unit price weighted by type: starter, move-up, luxury. Type defined by NAHB.</td>
<td>BPS</td>
</tr>
<tr>
<td>Gravity-Network Index</td>
<td>Distance decay calculation: distance and total # of SF building contracting firms in CBSA</td>
<td>Author</td>
</tr>
</tbody>
</table>

### Exhibit 4 | External Attributes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010 Median Housing Value</td>
<td>2010 median value of housing units</td>
<td>Census</td>
</tr>
<tr>
<td>% Owner Occupied HU</td>
<td>2010 percentage of owner occupied housing units in CBSA</td>
<td>Census</td>
</tr>
<tr>
<td>2010 Med. HH Income</td>
<td>Median household income in CBSA</td>
<td>Census</td>
</tr>
<tr>
<td>2010 GDP / Capita</td>
<td>2010 gross domestic product / capita of CBSA</td>
<td>BEA</td>
</tr>
<tr>
<td>2010 Total Population</td>
<td>Total Population in 2010 in CBSA</td>
<td>Census</td>
</tr>
<tr>
<td># of Pluming or Electrical Contractors</td>
<td>Total of plumb &amp; HVAC contracting firms in CBSA</td>
<td>County Business Patterns</td>
</tr>
<tr>
<td>DSIRE: Energy Rebates</td>
<td>Count of local, regional utility energy rebates available to all parties in the state</td>
<td>EPA</td>
</tr>
<tr>
<td>DSIRE: Energy Grants</td>
<td>Count of energy grants available to all parties in the state</td>
<td>EPA</td>
</tr>
<tr>
<td>DSIRE: Other Incentives</td>
<td>Count of other (non-rebate or grant) energy incentives available to all parties in the state</td>
<td>EPA</td>
</tr>
<tr>
<td>5 Year KWH Price</td>
<td>Prior 5-year average of electricity prices by state</td>
<td>EIA</td>
</tr>
<tr>
<td>ARRA Funds / Capita</td>
<td>$ / Capita of federal stimulus funds spent in state</td>
<td>ARRA</td>
</tr>
<tr>
<td>Heating Degree Days</td>
<td>30-year average of heating degree days in state</td>
<td>NOAA</td>
</tr>
<tr>
<td>Cooling Degree Days</td>
<td>30-year average of cooling degree days in state</td>
<td>NOAA</td>
</tr>
<tr>
<td>Sprawl Index</td>
<td>Factor analysis of multiple measures of compact growth</td>
<td>R. Ewing</td>
</tr>
</tbody>
</table>
substitutes. An additional variable describing the cost of construction in a CBSA was included to control for market-to-market cost variation.

Given the size of the data set, creating detailed measures about the attributes of the adopter was impractical. Therefore, the model is agnostic to the firm’s investment in research and development, the executive’s support for innovation, the presence of an innovation champion, its perceptions about the innovation, or other related attributes. However, a model without internal attributes of the adopter would be incomplete. Variables included in the conceptual model of this work are: firm size, total number of homes produced, average home price and average home size, and a complementarity index. The complementarity index sums the number of adoptions of high performance technologies in large building systems by the builder. The index variable is included to reveal information about the inclination of the respondent towards high performance product innovations. Additionally, where the diffusion of innovation is largely a communicative process, the researchers also included a variable (Gravity Network Index) describing the potential linkages or communication networks amongst single-family home builders. Each variable, with the exception of the Gravity Network Index metric, was drawn from BPS data.

External or contextual factors are the third category of independent variables. We included these variables in the conceptual model as economic, climate, regulatory, demographic, industry, and built environment attributes. We collected each variable from public data. We specified data at the level of the CBSA, or in some cases the state that respondent listed as their primary business address.

**Methods of Analysis**

Based on the collected variable set for the conceptual model, specifically the homebuilder’s decision to adopt a product innovation from among a cluster of its economic substitutes, the research team then designed a logistic regression framework to operationalize our conceptual model on the two focus technologies (Agresti, 2002). The model is represented generically through the following equation:

\[
\ln \left( \frac{p}{1 - p} \right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k
\]  

and then functionally reduced, given the data, as:

\[
Use of High Perf Product_n \ln \left( \frac{P_n}{1 - P_n} \right) = \mu + \beta_1 + \beta_2 + \cdots + \beta_n,
\]
where \( n \) equals one of the two high performance products, \( \mu \) is the y-intercept, and \( \beta_x \) for \( x = 1, 2, \ldots, n \) are time, attributes of the innovation, attributes of the adopter, and external or contextual attributes.

Analytically, we created two logistic regression models for each dependent variable: (1) a univariate model where \( \text{Year} \) was the only predictor and (2) a model that included the full list of candidate predictors described above. Comparison of the univariate to the multivariate models provided an opportunity to gauge improvement in the model’s ability to identify factors other than time influencing a builder’s innovative product decisions. As the data set contains a large number of predictors, adding additional factors beyond time is expected to improve model fit; however, there is risk of producing an over-fit model as well.

To reduce risk of over-fit and move towards a parsimonious final model, we implemented a penalized regression technique from the generalized linear modeling toolkit known as the least absolute shrinkage and selection operator (LASSO). LASSO has not been widely deployed in the planning literature and offers a new possibility for analysis that \( p \)-value selection does not. LASSO’s class of analytical tools is well suited to both dichotomous choice analysis and large data sets, where the large number of predictors may not correlate appropriately. The LASSO minimizes the residual sum of squares subject to the constraint that the sum of the absolute values of the independent variable coefficients is less than some constant. Thus, the LASSO variable selection technique tends to result in some coefficients being 0, leading to a parsimonious and interpretable model (Tibshirani, 1996). Specifically, the LASSO has superior abilities over stepwise-based variable selection techniques in identifying a meaningful list of predictors from a constellation of candidates.

Mechanically, LASSO works by setting a constraint assumption that forcibly shrinks the size of independent variable coefficient estimates towards zero, optimizing model selection, decreasing prediction variance, and decreasing prediction error (Friedman, Hastie, and Tibshirani, 2010). Typically, the LASSO constraint is chosen using k-fold cross validation. For our modeling purposes, we used 10-fold cross-validation to choose the constraint parameter \( \lambda \). The formulation of the LASSO technique for variable selection and coefficient estimation is as follows:

\[
\hat{\beta}_{\text{lasso}} = \underset{\beta}{\text{argmin}} \{ \sum_{i=1}^{n} (y_i - \beta_0 - \sum_{j=1}^{p} x_{ij} \beta_j)^2 + \lambda \sum_{j=1}^{p} |\beta_j| \}. \tag{3}
\]

At the lambda threshold selected, the selection technique produced a 16 variable model for piping and a 9 variable model for thermostats. Unlike a stepwise selection technique that only allows variables to be in or out of the model, the LASSO continuously allows variables to enter and exit the model with different effect sizes. Thus, with different values of the constraint come different values of the estimated coefficients. In the general linear model framework, the LASSO
### Exhibit 5 | Model Fit Statistics

<table>
<thead>
<tr>
<th>Model Type</th>
<th>C-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Univariate PEX</td>
<td>0.528</td>
</tr>
<tr>
<td>Univariate Programmable Thermostat</td>
<td>0.575</td>
</tr>
<tr>
<td>Adoption of PEX</td>
<td>0.693</td>
</tr>
<tr>
<td>Adoption of Programmable Thermostat</td>
<td>0.701</td>
</tr>
</tbody>
</table>

produces a path diagram over all values of \( \lambda \), where the paths are found using the coordinate descent algorithm presented by Friedman, Hastie, and Tibshirani (2010). The PEX path diagram illustrates how variables are tested for inclusion in the model, from a univariate model to the reported model then onto a fully over-fit model.

**Findings: Model Fit**

With respect to model fit (Exhibit 5) for both the thermostats and piping models, when moving from the base case univariate model (Year only) to the full model, the c-statistic or area under the receiver-operating curve grows substantially. For example, the standard, univariate piping model is more capable of discriminating users from non-users than a coin flip (c-statistic: 0.5), although not by a great deal. When the full cluster of independent variables is regressed, the LASSO selects a model that can far more accurately discriminate between high performance piping selection and non-selection (Hosmer and Lemeshow, 2000). A similar trend can be observed in the thermostat model. In practical terms, both models grow significantly in their ability to discriminate between high performance technology adopters and non-adopters. This growth confirms the hypothesis embedded in the analytical strategy that time alone is an insufficient predictor of adoption decisions. Rather, the adoption decision is more complex.

**LASSO Selected Models**

The LASSO selected models indicate that the internal, external, and innovation-specific measures are each associated with U.S. homebuilder’s high performance product adoption choices. Relative to internal attributes of the adopting firm, the results show that firm size is associated with the adoption and diffusion of innovative products. Builders that produce a larger number of units and those that produce multi-family housing units in addition to single-family units tend to have higher odds of adopting high performance piping alternatives. Builders building larger sized housing units are less likely to adopt and install high performance pipe systems.

While we would expect that expect smaller homes would be more energy efficient, higher performance piping is not one of the tools builders have tended to use to achieve this. One reason that builders might not use higher performance piping
in smaller houses is the shorter distance between the hot water heater and points of use. Where PEX piping reduces thermal loss over the water transmission distance, perhaps builders do not see significant efficiency gains in smaller houses over shorter piping distances. The finding on unit sizes is consistent with Koebel et al. (2015), where evidence showed builders producing larger homes were more likely to use higher performance windows—the more exterior surface that could be windowed, the higher the odds of using a window with a superior energy rating. However, with respect to greater odds of PEX use with greater production of multi-housing units, this paper differs from those presented by Koebel et al. (2015).

Additionally, the respondent’s inclination towards innovation, as measured by the complementarity indices, was positively associated with adoption decisions. These results confirm previous literature and suggest that despite lacking a significant volume of data describing the internal aspects of the firm, it is plausible to generate new insight into how U.S. homebuilders make decisions about high performance product innovations based on what else they are adopting and installing. This finding is consistent with Rogers (1995).

Relative to the attributes of the innovation, the number of construction wholesale suppliers but not the number of specialized contractors has positive effects on high performance piping and thermostat selection (Exhibit 6). Suppliers appear to play important roles in the adoption of early technologies as hubs for communication, product trial, and discussion. Further, as suppliers are open to the public, they could easily be a place where the end user, the homeowner, can experiment with the innovations.
The variables representing the external attribute category illustrate that climate, energy-specific regulatory incentives, built environment factors, and economic or market factors are each associated with builders’ innovative product adoption decisions. With respect to incentives, despite being available to an array of parties and not just builders, the presence of incentives in the marketplace is associated with builders’ adoption choices. The difference in signs illustrates that type of policy intervention influences builders’ choices differently. Further, confirming the findings from previous research on windows and energy certifications, both heating degree-days and cooling degree-days are significant predictors of PEX adoption (Exhibits 7 and 8) while only heating degree-days are associated with the selection of thermostats (Exhibit 9). Although small in effect, this sensitivity climate is not reflected in sensitivity to energy costs; longer term energy prices were not selected into the thermostat model. Taken together and with the sprawl index findings, the results confirm aspects of the broader narrative in the green real estate literature that built environment and its physical context influence stakeholders’ choices.

Increases in total population, GDP/capita, and the percentage of owner-occupied housing units are market characteristics negatively associated with builders’ choices to adopt high performance piping products. The population and GDP/capita variables indicate that the adoption of high performance piping innovations is occurring in smaller markets with lower economic output per resident. The ownership rate warrants cautious interpretation while the population and economic
### Exhibit 8 | Adoption of PEX

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>0.3680</td>
<td>1.4449</td>
</tr>
<tr>
<td>Complementarity Index—No PEX</td>
<td>0.2788</td>
<td>1.3215</td>
</tr>
<tr>
<td>Total # of Homes Built</td>
<td>0.0396</td>
<td>1.0404</td>
</tr>
<tr>
<td>% of Multifamily HU</td>
<td>0.0726</td>
<td>1.0753</td>
</tr>
<tr>
<td>Weighted Avg Size</td>
<td>−0.0317</td>
<td>0.9688</td>
</tr>
<tr>
<td>2010 Total Population</td>
<td>−0.0183</td>
<td>0.9819</td>
</tr>
<tr>
<td># of Construction Wholesale Firms</td>
<td>0.0024</td>
<td>1.0024</td>
</tr>
<tr>
<td>2010 Med. HH Income</td>
<td>0.0043</td>
<td>1.0043</td>
</tr>
<tr>
<td>2010 GDP/Capita</td>
<td>−8.8553</td>
<td>0.0001</td>
</tr>
<tr>
<td>Heating Degree Days</td>
<td>0.0006</td>
<td>1.0006</td>
</tr>
<tr>
<td>Cooling Degree Days</td>
<td>−0.0036</td>
<td>0.9964</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>−2.3389</td>
<td>0.0964</td>
</tr>
<tr>
<td>DSIRE: Energy Grants</td>
<td>0.0018</td>
<td>1.0018</td>
</tr>
<tr>
<td>DSIRE: Other Incentives</td>
<td>−0.0167</td>
<td>0.9834</td>
</tr>
<tr>
<td>% Owner-Occupied HU</td>
<td>−0.0348</td>
<td>0.9658</td>
</tr>
<tr>
<td>Sprawl Index</td>
<td>−0.0081</td>
<td>0.9920</td>
</tr>
</tbody>
</table>

### Exhibit 9 | Adoption of Programmable Thermostats

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complementarity Index—No Thermostats</td>
<td>0.3009</td>
<td>1.3511</td>
</tr>
<tr>
<td>Weighted Avg Size</td>
<td>0.4227</td>
<td>1.5261</td>
</tr>
<tr>
<td>Weighted Avg Price</td>
<td>0.0001</td>
<td>1.0001</td>
</tr>
<tr>
<td># of Construction Wholesale Firms</td>
<td>0.0001</td>
<td>1.0001</td>
</tr>
<tr>
<td>Heating Degree Days</td>
<td>0.0003</td>
<td>1.0003</td>
</tr>
<tr>
<td>DSIRE: Energy Rebates</td>
<td>0.0028</td>
<td>1.0028</td>
</tr>
<tr>
<td>DSIRE: Energy Incentives: Other</td>
<td>0.0004</td>
<td>1.0004</td>
</tr>
<tr>
<td>Sprawl Index</td>
<td>0.0023</td>
<td>1.0023</td>
</tr>
</tbody>
</table>

Output variables help provide more context to the findings for construction cost and income of the potential housing buyers. The odds ratio for median household income is positive, linking broadly with previous research indicating green home buyers tend to have higher annual incomes. Odds ratios for total building cost indicate that it has a large, negative effect on the selection of PEX. Similar to findings from the green real estate literature around green building certifications...
and home prices, newer products with low market penetration are disadvantaged by both actual and perceived higher building costs.

**Differences in Models**

Builders’ adoption patterns for thermostats vary differently around both internal attributes and external factors. With respect to internal factors, evidence from the application of the model to thermostat choice showed that the greater the home price, the greater the probability of selecting a programmable thermostat. Likely heavily influenced by home size, this may be a reflection both of a “trickle down” effect and the “in front” (observability) of the wall effect that influences adoption of some innovations. Construction literature considers the lack of observability (innovative products exist behind walls here) to be a barrier to adoption and diffusion; they do not get nearly as much attention—an “out of sight, out of mind” logic. Here, where programmable thermostats are something occupants interact with and see regularly as their interface with energy consumption, this finding supports the literature.

With respect to external factors, public policy, climate, and market factors produced different model results. For example, as the number of utility rebates increases, the odds that a builder will select a programmable thermostat grow. Increases in the number of “other incentives” are also positively associated with builder’s thermostat choices. With respect to climate, only heating degree-days (HDDs) play a significant role in the builder’s choice to adopt programmable thermostats, deviating from the piping model and previous work on windows and energy certifications. Further, market area factors were not selected into the full thermostat model. While somewhat surprising, this finding suggests a non-volatile diffusion trajectory of a technology that is already the market share leader within its cluster. In other words, the maturity of the product in the market plays a significant role in the adoption decision and bandwagon effects may play stronger roles.

Finally, time is not selected into this model, indicating that the year-to-year adoption pattern is not associated with builders’ high performance thermostat selection. This exclusion is expected given the high and flat market penetration curve of the mature technology.

Additionally, when comparing the results of the LASSO selected models with the findings about the adoption of high performance windows from Koebel et al. (2015), it is clear that climate and public policy are positively associated with builders’ technology innovation adoption decisions. In both Koebel et al. (2015) and here, HDDs and grants and rebates available to consumers through various state channels were significant predictors of whether or not a builder would select the high performance window, pipe, or thermostat technology over each of their more traditional economic substitutes.

However, across the attributes of the builder and their housing portfolio in a given year, the results are a bit less clear and tell a more technology-specific story about product adoption and diffusion. For example, there was a positive influence on
window and thermostat adoption but not on PEX pipe adoption. Additionally, the overall construction cost in a market was negatively associated with both high performance window and piping selection but not thermostats.

These similarities start to form a preliminary picture of the cluster of factors and attributes that may be common to high performance construction innovations. We are cautious in attempting to explain the model differences without more formal review. However, model specification nuances and dependent variable product nuances likely play a role though we recognize that this is a question that future research should address.

**Conclusion**

Methodologically, this work provides two contributions to the sustainable real estate literature. Primarily, the work is one of the first to adapt a diffusion of innovation model to the analysis of U.S. homebuilders’ high performance building product use. Beyond the novelty of being first adopters, there is also utility in adapting the traditional diffusion model to the specifics of the homebuilding industry. Where previous research had focused on smaller sample analyses heavily weighted towards identifying the internal or firm-specific factors related to the adoption of innovation, this paper shows that when such information is limited, it is possible to generate insight into the builder’s adoption decision. Secondly, the LASSO model selection technique shows that it could provide diffusion of innovation modelers with a tool for creating modeling parsimony. Parsimony benefits future researchers that wish to use mixed-method approaches to dig deeper into the causal relationships between variables, obstacles, and innovations.

Empirically, the LASSO selected models confirm that despite a lack of understanding about the firm’s orientation to innovation, there are significant associations between builders’ high performance product choices and each of the three category types of variables (internal, external, and attributes of the innovation). For example, although the model did not contain much information about the internal attributes of the buyer, using a measure of the builder’s other sustainable product choices helped provide significant context to the adoption decision. In other words, the constellation of high performance products a builder uses influences the way that the builder makes choices about other high performance product selections.

Further, although there is similarity in the findings between models [both between PEX and thermostats as well as with Koebel et al.’s (2015) windows analysis], the factors that influence builders’ innovation decisions vary between technologies. This variation illustrates the lack of a single narrative associated with builders’ high performance innovation choices. In some cases, the inside versus outside wall or mature versus earlier stage distinction helps elucidate the choice patterns. Alternatively, variation in regulatory climate factors shows the importance of context in the adoption of high performance product innovations. Seemingly a self-evident conclusion—builders’ choices in Arizona will differ from those made
in Vermont—it is, nevertheless, useful to confirm that climate and regulation serve
as the backdrop against which adoption decisions are made.

**Endnote**

1 Gambastese and Hallowell (2011) are excluded as exceptions here as they focused on
empirical diffusion of innovation among innovation generating organizations rather than
innovation adopting organizations.

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Measuring Highway Impacts on House Prices Using Spatial Regression

Authors

Marcus T. Allen, Grant W. Austin, and Mushfiq Swaleheen

Abstract

Generally accepted real estate valuation theory, augmented by ample empirical evidence, supports the notion of significant impacts on prices of residential properties near highways. Houses adjacent to highways are exposed to potentially increased traffic noise, although these homeowners may benefit from increased accessibility to highway systems. This study is prompted by a massive new highway construction project (25 miles at a cost of $1.5 billion over a nine-year period) that will complete a 110-mile beltway around the Orlando, Florida metropolitan area. Using observed prices of houses near existing highways, this study provides insights into the potential effects of the new highway on planned and existing houses in this market. The results indicate significant price discounts for houses adjacent to highways, houses near high-traffic highways, and houses farther from highway on-ramps, but no significant impact related to distances from houses to highways or sound barrier walls.

Real estate value theorists and practitioners widely acknowledge the importance of considering external influences when analyzing real estate values. Nearby transportation systems are a classic case of offsite factors that may affect real estate values. While highways, rail, and airports generally provide positive benefits to real estate users at the macro level by increasing accessibility, micro-level effects of planes, trains, and automobiles may be negative due to potential nuisances generated by transportation systems. For residential real estate in particular, a critical issue at the micro-level is the impact of noise from nearby transportation infrastructure on house prices. Numerous studies, some of which are discussed below, use a variety of analysis methods to detect and measure the price effects of transportation-related noise pollution generated by airports, railways, and highways in various housing markets around the world. These studies document consistently significant price discounts for noise pollution related to nearby transportation systems but, not surprisingly, the magnitudes of the reported discounts vary across markets.

Previous studies typically use one of two alternative approaches to consider the impacts of highways on house prices, including noise pollution. The first of these approaches uses noise levels measured in decibels and the second approach uses transportation infrastructure adjacency and proximity measures. As noted by Seo,
Golub, and Kuby (2014, p. 54), noise levels “are quite expensive to measure for individual parcels.” This study relies on the second approach and uses location-based measures to assess highway impacts on house prices. The measures include a highway adjacency indicator, nearby highway traffic volume, straight-line distances from houses to highways, and the presence of sound barrier walls to examine highway impacts on house prices. Adjacency to highways, especially more heavily traveled highways, is expected to reduce house prices, but the negative impact of highway noise on house prices may be offset by sound barrier walls and increased distance from house to highway. This study also controls for potential impacts on house prices related to accessibility to the highway system. Reduced driving distance to nearby highway on-ramps may have a positive impact on house prices.

The impetus for considering highway impacts on house prices in this study is the ongoing construction of a new multi-lane, median divided, limited access, toll road near Orlando, Florida. Portions of the new highway will have sound barrier walls along the right-of-way. Plans for the Wekiva Parkway were approved in 2004 and construction began in 2013, with a projected completion date in 2021 at a cost of $1.5 billion. This 25-mile highway is the final section of a 112-mile beltway highway around the Orlando metropolitan area. The Wekiva Parkway is intended to relieve congestion on U.S. Highway 441 and State Road (SR) 46, the primary surface routes through this portion of Florida. The massive scale of this highway project will undoubtedly improve mobility through the area, but the project may also negatively impact the prices of individual houses in the project’s vicinity. The purpose of this study is to document micro-level house price impacts of other existing highways in this market in an effort to provide a basis for anticipating the impact of the new highway on nearby houses, both planned and existing.

Using transaction data from this market, hedonic price analysis with spatial regression modeling suggests that the average price discount for houses adjacent to highways is approximately 4.0%, holding other value influencing factors constant. The results of this analysis also document significant price discounts related to traffic volume on nearby highways. The results do not indicate that sound barrier walls or increased straight-line distances from houses to the highway impact house prices, but do indicate that houses with shorter driving distances to highway on-ramps sell at price premiums.

The following section provides a brief review of the studies that, like the present study, examine highway impacts on the value of residential real estate using the revealed preferences of market participants with either measured noise levels or location-based measures. In the remaining sections, we discuss the data, the spatial regression models used to analyze the data, and the results of the analysis, respectively. The paper closes with concluding remarks.

Studies Addressing Highway Impacts on Residential Property Values

Bateman, Day, Lake, and Lovett (2001) provide in-depth discussions of some of the key issues, methods, and results from an assortment of studies published prior
to 2001 that analyze highway noise impacts on residential property values using measured noise levels. The authors review 17 studies that consider the effect of highway noise using hedonic price analysis and report an average price discount of 0.4% per decibel in those studies, with a standard deviation of 0.23%. These authors also conduct their own hedonic price study of the impact of highway noise using data from the Glasgow, Scotland area and report a house price discount of 0.2% per decibel for their sample.

Wilhelmsson (2000) provides a notable study that is not included in the literature review provided by Bateman, Day, Lake, and Lovett (2001). Using data from Stockholm, Sweden, his hedonic price estimates indicate an average highway noise discount in house prices of 0.6% per decibel. To put this finding into perspective, Wilhelmsson demonstrates that the difference in value for a house in a noisy and a quiet location in his study sample is approximately 30%.

Numerous other researchers have conducted highway noise pollution impact studies on various property types of residential real estate in markets around the world since the publication of the Bateman, Day, Lake, and Lovett (2001) literature review. Becker and Lavee (2003) report a price discount of 1.2% per decibel for apartments in urban areas in Israel. Rich and Nielson (2004) report price discounts of 0.47% per decibel for apartments and 0.54% per decibel for houses in Copenhagen, Denmark. Theebe (2004) reports an average discount of 5% from traffic noise from planes, trains, and automobiles on houses in the Netherlands. Baranzini and Ramirez (2005) report a discount in apartment rents of 0.63% per decibel in Geneva, Switzerland. Day, Bateman, and Lake (2007) report a price discount of 0.55% per decibel for residential real estate in Birmingham, England. Kim, Park, and Kweon (2007) report a price discount of 1.3% for a 1% increase in traffic noise level in decibels for single-family and row houses in Seoul, Korea. Nelson (2008) discusses prices discounts on property values associated with both aircraft (0.8% per decibel) and road traffic (0.54% per decibel). Andersson, Jonsson, and Ögren (2010) report a discount of approximately 0.7% per decibel for single-family houses in Lerum, Sweden. Blanco and Flindell (2011) report a price discount of 0.45% per decibel for apartments and flats in London, England. Brandt and Maennig (2011) report a discount of 0.23% per decibel level for condominiums in Hamburg, Germany. Li and Saphores (2012) report a negligible discount for general highway traffic (0.006% per decibel), but a more substantial discount for highway truck traffic of 0.65% per decibel for houses in Los Angeles, California.

Several additional studies examine the impact of highways on property values using location-based measures rather than noise level measurements. Hughes and Sirmans (1992, 1993) use average daily traffic counts and an indicator variable for high-traffic streets to identify significant price discounts in the Baton Rouge, Louisiana housing market. They report price discounts of 9.2% for city neighborhoods and 4.6% for suburban neighborhoods for high-traffic streets. Kawamura and Mahajan (2005) discuss the use of hedonic price models with traffic count data. Larsen (2012) reports that houses adjacent to high-traffic streets sell for discounts of 8.1%. Larsen and Blair (2014) report a price discount of 7.8% for single-family houses on high-traffic streets and a price premium of 13.8% for
multi-unit rental residential properties in Kettering, Ohio. Kilpatrick, Throupe, Carruthers, and Krause (1997) show that proximity to transit corridors, not just adjacency to a corridor, is negatively related to property values and that access to the transportation infrastructure is positively related to property values in a sample of houses from Seattle, Washington. Although the intention of sound barrier walls along highways is to reduce the aural and visual nuisances of highways on nearby properties, Julien and Lanoie (2008) show that noise barrier walls between houses and highways result in price discounts of 6% in the short run and 11% in the long run in a sample from Montreal, Canada.

Our analysis follows the lead of Hughes and Sirmans (1992, 1993), Kawamura and Mahajan (2005), Larsen (2012), and Larsen and Blair (2014) in the use of location-based measures to evaluate the impact of highways on house prices. In particular, an indicator variable is used to identify houses adjacent to highways and traffic count data to identify high-volume highways. In addition, we consider the issues of straight-line distance from houses to highways and the driving distance between houses and highway on-ramps following Kilpatrick, Throupe, Carruthers, and Krause (1997) and the issue of sound barrier walls following Julien and Lanoie (2008).

Data Description

The primary source of the data is the publicly available database maintained on the official Orange County Property Appraiser website: http://www.ocpapfl.org. As of October 2014, the website reports 272,124 single-family, detached houses in the county. The database includes information about various attributes of each house (age, size, location, etc.), as well as transaction dates and prices. The initial sample includes 1,306 houses conveyed during the study period (January, 2012–September, 2014) and located in neighborhoods (subdivisions) bordering on one of three key highways in the metropolitan Orlando area: Florida’s Turnpike, Central Florida GreeneWay (SR 417), and Daniel Webster Western Beltway (SR 429). Each of these highways is a limited access, multi-lane, median divided, toll road that is similar to the proposed highway.

Visual inspections of readily available plats, maps, and photographs permit identification of highway adjacency and sound barrier walls for each house in the sample. Straight-line distances between houses and highways (in meters) and driving distances (in miles) between houses and highway on-ramps are GIS-based. After screening the initial data sample to exclude non-arm’s length transactions and records with inconsistent and incomplete data, the study sample consists of 1,025 houses located in 19 suburban neighborhoods. Of the study sample, 91 houses (8.9%) are directly adjacent to a highway while 934 houses (91.1%) are not directly adjacent to a highway. Exhibit 1 provides definitions and summary statistics for the variables considered for each of the 1,025 observations. Exhibit 2 provides mean house prices by neighborhood and reports the differences in mean prices by neighborhood for adjacent and non-adjacent houses for 17 of the neighborhoods. The test statistics are significant for five of the 17 neighborhoods,
### Exhibit 1 | Variable Definitions and Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Expected Sign of Coeff.</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>price</td>
<td>Transaction price in dollars</td>
<td>Negative</td>
<td>$234,942</td>
<td>$85,025</td>
<td>$60,000</td>
<td>$550,000</td>
</tr>
<tr>
<td>adjacent</td>
<td>Highway adjacency indicator = 1 if property is adjacent to highway, 0 otherwise</td>
<td>Negative</td>
<td>0.089</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>sound_barrier</td>
<td>Sound barrier wall = 1 if sound barrier wall is present, 0 otherwise</td>
<td>Positive</td>
<td>0.024</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>straight_distance</td>
<td>Straight-line distance from house to highway, in thousands of meters</td>
<td>Positive</td>
<td>0.344</td>
<td>0.239</td>
<td>0.031</td>
<td>1.493</td>
</tr>
<tr>
<td>traffic_volume</td>
<td>Average annual daily traffic, in thousands</td>
<td>Negative</td>
<td>54.213</td>
<td>22.059</td>
<td>18.3</td>
<td>97</td>
</tr>
<tr>
<td>drive_distance</td>
<td>Driving distance from house to nearest highway on-ramp</td>
<td>Negative</td>
<td>2.871</td>
<td>1.515</td>
<td>0.5</td>
<td>6.4</td>
</tr>
<tr>
<td>age</td>
<td>Age of house in years</td>
<td>Negative</td>
<td>11.484</td>
<td>6.858</td>
<td>0</td>
<td>35</td>
</tr>
<tr>
<td>livarea100</td>
<td>Size of house in hundreds of square feet</td>
<td>Positive</td>
<td>24.477</td>
<td>7.441</td>
<td>10.160</td>
<td>52.020</td>
</tr>
<tr>
<td>lotacre</td>
<td>Size of lot in acres</td>
<td>Positive</td>
<td>0.212</td>
<td>0.093</td>
<td>0.087</td>
<td>0.820</td>
</tr>
<tr>
<td>pool</td>
<td>Swimming pool indicator = 1 if pool is present, 0 otherwise</td>
<td>Positive</td>
<td>0.351</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>trend</td>
<td>Time trend variable taking values of 1 to 33 based on month of sale during study period</td>
<td>Positive</td>
<td>17.393</td>
<td>9.091</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>trend2</td>
<td>Square of time trend variable to control for quadratic changes in price trends over the study period</td>
<td>Negative</td>
<td>385.097</td>
<td>318.761</td>
<td>1</td>
<td>1,089</td>
</tr>
</tbody>
</table>

Note: The number of observations is 1,025.
### Exhibit 2 | Difference in Mean Prices for Adjacent and Non-Adjacent Houses by Neighborhood

<table>
<thead>
<tr>
<th>Neighborhood</th>
<th>Observations</th>
<th>Mean Price of Adjacent Houses ($)</th>
<th># of Adjacent Houses</th>
<th>Mean Price of Non-Adjacent Houses ($)</th>
<th>Mean Price of Adjacent Houses ($)</th>
<th>Difference in Means</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18</td>
<td>125,472</td>
<td>2</td>
<td>124,094</td>
<td>136,500</td>
<td>-0.42</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>218,889</td>
<td>1</td>
<td>222,875</td>
<td>187,000</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>102</td>
<td>261,058</td>
<td>5</td>
<td>258,792</td>
<td>305,020</td>
<td>-2.92</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>208,294</td>
<td>10</td>
<td>212,387</td>
<td>179,640</td>
<td>2.10</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>44</td>
<td>195,352</td>
<td>4</td>
<td>196,688</td>
<td>182,000</td>
<td>0.94</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>39</td>
<td>160,472</td>
<td>5</td>
<td>161,512</td>
<td>153,400</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>61</td>
<td>178,995</td>
<td>4</td>
<td>179,942</td>
<td>165,500</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>45</td>
<td>278,920</td>
<td>3</td>
<td>278,136</td>
<td>289,900</td>
<td>-0.51</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>45</td>
<td>427,122</td>
<td>4</td>
<td>431,476</td>
<td>382,500</td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>38</td>
<td>224,455</td>
<td>3</td>
<td>227,666</td>
<td>187,000</td>
<td>2.35</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>22</td>
<td>333,350</td>
<td>3</td>
<td>347,405</td>
<td>244,333</td>
<td>3.06</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>290,773</td>
<td>2</td>
<td>294,000</td>
<td>276,250</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>38</td>
<td>201,597</td>
<td>22</td>
<td>203,800</td>
<td>199,996</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>47</td>
<td>256,949</td>
<td>4</td>
<td>262,874</td>
<td>193,250</td>
<td>2.64</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>84</td>
<td>301,857</td>
<td>6</td>
<td>305,780</td>
<td>250,867</td>
<td>1.47</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>18</td>
<td>93,617</td>
<td>2</td>
<td>94,819</td>
<td>84,000</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>33</td>
<td>108,209</td>
<td>3</td>
<td>109,130</td>
<td>99,000</td>
<td>1.49</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>92</td>
<td>240,961</td>
<td>0</td>
<td>240,961</td>
<td>n.a.</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>199</td>
<td>221,968</td>
<td>8</td>
<td>222,596</td>
<td>206,988</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>

with the means of non-adjacent house prices greater than the means of adjacent house prices in four of those five neighborhoods.

### Spatial Regression Analysis

Hedonic price theory provides the framework for our empirical analysis. Popularized in the context of house prices by Rosen (1974) and since built upon by many others, hedonic price theory is based on the notion that the value of a house derives from its attributes and that regression analysis can be used to decompose observed house prices into the implicit price of each attribute. Modern hedonic price models recognize potential spatial effects in cross-sectional house price samples in which the relative locations of houses may affect the implicit prices of the houses’ attributes in ways that cannot be adequately modeled with available location variables.
The interdependence of house prices across geographic space is difficult to deny in most markets: nearby houses tend to sell for similar prices. The presence of unmodeled spatial effects violates the assumptions of the ordinary least squares (OLS) regression estimator regarding uncorrelated and homoscedastic errors which, in turn, imply that the OLS estimator is biased and inconsistent. We address potential spatial effects in the data using spatial lag and spatial error regression models as described by Anselin (1999, 2003) and demonstrated in the context of hedonic house pricing by Kim, Phipps, and Anselin (2003) and Osland (2010).

Equation 1 shows the spatial lag regression model:

\[
\ln(PRICE) = \rho W \ln(PRICE) + \beta_j X_j + u, \tag{1}
\]

where \( \rho \) is a spatial autocorrelation parameter, \( W \) is a spatial weight matrix, \( X \) includes \( j \) property characteristics, and \( u \) is a vector of i.i.d. errors. The spatial lag model is useful when house values are affected by their own attribute, as well as the attributes of neighboring houses.

Equation 2 shows the spatial error regression model:

\[
\ln(PRICE) = \beta_0 + \beta_j X_j + \lambda We + u, \tag{2}
\]

where \( \lambda \) is the spatial autoregressive coefficient, and \( W, X, \) and \( u \) are as defined above. The spatial error model assumes that spatial autocorrelation results from a spatial pattern in variables such as location-specific amenities that are omitted from (cannot be controlled for in) the model and, therefore, are subsumed in the composite error term \( \lambda We + u \). In both models, the weight matrix identifies neighboring houses based on inverse distances, with the minimum distance of “neighboring” defined as the first quartile distance of the houses in the sample. Note that when \( \rho \) or \( \lambda \) are zero, both models collapse to the traditional hedonic price function. As demonstrated by Osland (2010), Moran’s I statistic allows testing for spatial dependencies in the data while the Lagrange multiplier statistic and the robust Lagrange multiplier statistic are used to examine whether the spatial lag or spatial error model best addresses spatial dependencies in the data.

In the next section, we present the results of estimating hedonic price functions for this sample of houses and discuss the diagnostic tests for identifying whether OLS, spatial error, or spatial lag modeling is most appropriate for measuring the impacts of highways on house prices in this market based on potential spatial effects in the data.

**Results**

Exhibit 3 presents estimates of the implicit prices of highway impacts and other factors (control variables) on house prices using OLS and a semi-log functional
### Exhibit 3 | OLS Regression Results with Neighborhood Indicators

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>adjacent</td>
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</tr>
<tr>
<td>sound_barrier</td>
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<td>0.035</td>
</tr>
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<td>straight_distance</td>
<td>0.045</td>
<td>0.023</td>
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<tr>
<td>traffic_volume</td>
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<td>0.001</td>
</tr>
<tr>
<td>drive_distance</td>
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<td>0.009</td>
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<tr>
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<td>0.002</td>
</tr>
<tr>
<td>livarea100</td>
<td>0.021</td>
<td>0.001</td>
</tr>
<tr>
<td>lotacre</td>
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<td>0.082</td>
</tr>
<tr>
<td>pool</td>
<td>0.108</td>
<td>0.012</td>
</tr>
<tr>
<td>strnd</td>
<td>0.021</td>
<td>0.002</td>
</tr>
<tr>
<td>strnd2</td>
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<td>0.000</td>
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<tr>
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<td>0.028</td>
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<tr>
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<tr>
<td>neighborhood9</td>
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<td>0.047</td>
</tr>
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<td>0.054</td>
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<td>0.040</td>
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<tr>
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<tr>
<td>neighborhood13</td>
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<td>0.058</td>
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<td>0.045</td>
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<td>neighborhood16</td>
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<td>neighborhood17</td>
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<tr>
<td>neighborhood18</td>
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<tr>
<td>constant</td>
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</table>

Notes: The dependent variable is ln(price). The number of observations is 1,025. For Model 1, the $R^2$ is 86.63% and the $F$-statistic is 222.26. For Model 2, the $R^2$ is 86.57% and the $F$-statistic is 238.05.
form for the regression equation. The semi-log specification allows intuitive interpretation of the coefficient estimates as the percentage change in price for a unit change in the independent variables. Model 1 in Exhibit 3 includes a highway adjacency indicator variable (adjacent), a sound barrier wall indicator variable (sound_barrier), a straight-line distance measure from house to highway (straight_distance), a traffic volume measure (traffic_volume), a driving distance measure from house to nearest highway on-ramp (drive_distance), and various control variables for house characteristics (age, livarea100, lotacre, and pool), market conditions (strend and strend2), and neighborhood characteristics (dummy variables for neighborhood#, where # ranges from 1 to 18). Model 2 in Exhibit 3 includes the same variables as Model 1 with the exceptions of sound_barrier and straight_distance, which are not significant in results for the first model.

The results for Model 2 in Exhibit 3 indicate a significant negative price effect of 4.8% [applying the Kennedy (1981) transformation] for houses adjacent to highways, a significant negative price effect of 1.0% for each unit increase in traffic volume, and a significant negative price effect of 2.6% for houses located an additional driving mile from the nearest highway on-ramp. All of the control variables are significant and have the expected signs. The signs of the control variables for changing market conditions (strend and strend2) indicate that prices rise at a decreasing rate over the study period. All but three of the neighborhood dummy variable coefficients are statistically significant, indicating that most of the neighborhoods have higher or lower average prices than the comparison neighborhood (neighborhood19, which is the most prevalent neighborhood in the sample) holding other variables constant. The adjusted R-squares of the OLS regressions indicate that the results for Models 1 and 2 indicate approximately 87% and 86% of the variation in house prices in this market, respectively, and the F-statistics for both models are highly significant.

Due to justifiable concerns over potential spatial effects in the data that may cause the OLS estimates to be biased and inconsistent in hedonic house price regressions, Exhibit 4 presents the results of the maximum likelihood estimation (MLE) of Equation (1) for the spatial lag model. Model 3 includes all five of the primary variables of interest and Model 4 omits the sound_barrier and straight_distance variables, which are not significant in Model 3. Both models include the same control variables as those used in the OLS models. The spatial lag regression results in Model 4 indicate a significant negative price effect of 4.0% [applying the Kennedy (1981) transformation] for houses adjacent to highways, a significant negative price effect of 0.8% for each unit increase in traffic volume, and a significant negative price effect of 2.5% for houses located an additional driving mile from the nearest highway on-ramp. The coefficients on the property characteristic, market conditions, and neighborhood characteristic variables are consistent in sign and significance with the OLS results.

Exhibit 5 presents the MLE results for Equation (2), the spatial error model. Model 5 includes all five of the highway-related variables of interest and the variables sound_barrier and straight_distance variables, which are omitted from Model 6 as they are not significant in Model 5. Both models include the same control variables as those used in the OLS models. The spatial error regression results in
### Exhibit 4 | Spatial Lag Regression Results

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<tr>
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<th></th>
<th></th>
<th>Model 4</th>
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<th></th>
</tr>
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<tr>
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<td>7.030</td>
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<td>0.039</td>
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**Notes:** The dependent variable is ln(price). The number of observations is 1,025.
### Exhibit 5 | Spatial Error Model Regression Results

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<td>0.448</td>
<td>0.055</td>
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<tr>
<td>neighborhood16</td>
<td>-0.500</td>
<td>0.047</td>
<td>-10.531</td>
<td>-0.514</td>
<td>0.047</td>
<td>-10.883</td>
</tr>
<tr>
<td>neighborhood17</td>
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<td>0.039</td>
<td>-10.438</td>
<td>-0.425</td>
<td>0.038</td>
<td>-11.099</td>
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<tr>
<td>neighborhood18</td>
<td>-0.296</td>
<td>0.056</td>
<td>-5.300</td>
<td>-0.282</td>
<td>0.056</td>
<td>-5.028</td>
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<tr>
<td>constant</td>
<td>12.180</td>
<td>0.107</td>
<td>114.189</td>
<td>12.179</td>
<td>0.108</td>
<td>113.146</td>
</tr>
<tr>
<td>lambda</td>
<td>0.403</td>
<td>0.090</td>
<td>4.490</td>
<td>0.416</td>
<td>0.089</td>
<td>4.690</td>
</tr>
</tbody>
</table>

Notes: The dependent variable is ln(price). The number of observations is 1,025.
Model 6 indicate a significant negative price effect of 4.6% [applying the Kennedy (1981) transformation] for houses adjacent to highways, a significant negative price effect of 0.9% for each unit increase in traffic volume, and a significant negative price effect of 2.6% for houses located an additional driving mile from the nearest highway on-ramp. The coefficients on the property characteristic, market conditions, and neighborhood characteristic variables are consistent with the OLS results.

Exhibit 6 presents the results of diagnostic tests to detect spatial effects in the sample. In the specification used in Models 3 and 5, the Moran’s I statistic of 6.61 is significant at a confidence level greater than 99%, which strongly indicates the presence of spatial autocorrelation in the data. The Lagrange multiplier statistics for spatial error dependence and spatial lag dependence are also highly significant. The larger robust Lagrange multiplier for the spatial lag model points to that model as the appropriate choice for this sample. In the specification used in Models 2 and 4, the Moran’s I statistic of 6.76 is significant at a confidence level greater than 99% and the Lagrange multiplier statistics for spatial error dependence and spatial lag dependence are also highly significant. The larger robust Lagrange multiplier for the spatial lag model again points to that model as the appropriate choice for this sample.
Conclusion

Substantial evidence in the real estate economics literature documents significant price impacts resulting from highway noise and proximity for residential properties. We use spatial regression modeling in this study to analyze the revealed preferences of market participants regarding highway impacts on house prices in the Orlando, Florida metropolitan area. The impetus for this study is a new limited access, multi-lane, median divided, 25-mile toll road under construction in this market at a cost of $1.5 billion. This study documents micro-level house price effects related to highways in this market to better understand the impact of the new highway on planned and existing nearby houses.

Using a sample of 1,025 single-family detached house transactions from 19 suburban neighborhoods located along similar existing highways in this area, the spatial lag regression results reported for Model 4 indicate a significant price discount of 4.0%, for houses adjacent to highways, a price discount of 0.8% for each unit increase in traffic volume, and a price discount of 2.5% for houses located an additional driving mile from the nearest highway on-ramp. The results do not support the contentions that house prices are impacted by the straight-line distance between houses and highways or the presence of sound barrier walls.

The magnitude of the highway adjacency effect is similar to that of Hughes and Sirmans (1992, 1993) in their study of traffic effects on suburban house prices in Baton Rouge, Louisiana, but is approximately half as large as the effects reported Hughes and Sirmans (1992, 1993) for urban houses in Baton Rouge, Louisiana and by Larsen (2012) and Larsen and Blair (2014) for urban houses in Kettering, Ohio. The results do not support Kilpatrick, Throupe, Carruthers, and Krause’s (2007) finding regarding straight-line distance to transit corridors in Seattle, Washington, but do confirm that accessibility to highway systems has a positive impact on house prices. The results contradict the findings of a negative relationship between sound barrier walls and house prices in Montreal, Canada, as reported by Julien and Lanoie (2008). This analysis may prove useful to property owners, transportation system planners/engineers, eminent domain authorities, and appraisers who are concerned with the impacts of highways on house prices in this and other market areas.

Endnotes

1 For more details about the project, see http://www.wekivaparkway.com (accessed 6/1/2015).
2 See Palmquist (1992) for theoretical justification for the use of hedonic price modeling to value localized externalities.
3 The exclusive use of public records as the data source for this study precludes consideration of probability of sale or time-on-market analysis as is common in studies using house price data obtained from multiple listing services (MLSs). Public records have the advantage of including all house transactions in the study area, while MLS
records only include transactions handled by broker-members of the local MLS. The authors do not have access to MLS data in this market.

4 The initial sample consists of all houses with ownership transfers during the study period in 19 neighborhoods that have highway frontage along three major highways in the market area. The final sample does not include sales “disqualified” by the county tax appraiser’s office as non-arm’s length transactions (sales with Florida Department of Revenue sales codes other than 01 and 02), nor does the sample include foreclosure transfers.

5 Differences in means for adjacent and non-adjacent cannot be tested for two of the 19 neighborhoods due to data limitations: neighborhood2 has only one adjacent house and neighborhood18 has no adjacent houses.

6 Sirmans, MacPherson, and Zietz (2005) provide a comprehensive discussion of the variety of house attributes used in hedonic price studies.

7 This study adopts a 95% confidence level to evaluate statistical significance in all instances.

8 Kennedy (1981) demonstrates that the percentage change in the dependent variable is equal to $e^{\beta - 1/2\text{var}(\beta)} - 1$, where $\beta$ is the OLS coefficient on an indicator (binary dummy) variable in a semi-log regression.

9 For a discussion of these test statistics and their interpretations, see Osland (2010).

References


Anselin, L. Spatial Econometrics. School of Social Sciences, University of Texas at Dallas, 1999.


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LEED Certification of Campus Buildings: A Cost-Benefit Approach

Author Erin A. Hopkins

Abstract This is the first comprehensive cost-benefit analysis of Leadership in Energy and Environmental Design (LEED) buildings certified within the higher education sector. Sixteen institutions of higher education (IHEs) were surveyed with the findings focused on the upfront green premium and down the line energy savings. The net present value (NPV), internal rate of return (IRR), and discounted payback period were calculated to determine the financial feasibility of LEED certified buildings within the higher education sector. The findings indicate mixed results when looking at the projects from both an upfront construction cost and full lifecycle perspective.

There are potential benefits and costs for building green on campus. In regards to Leadership in Energy and Environmental Design (LEED) certification for campuses, there are opportunities for universities and colleges to get involved in order to improve their social impact, environmental impact, be a marshal in this new and emerging field, and help create down-the-line value within the community (Ried, 2008). Additionally, institutions of higher education (IHEs) are in a good position to capitalize on the long-term benefits of LEED certification, such as potential cost savings, since they are typically long-term landholders (Ried, 2008). However, a common barrier to adoption of green development policy is the perceived increased upfront costs to build green versus conventional buildings. For example, Richardson and Lynes (2007) discover perceived higher initial capital costs to be a financial barrier in green building at the University of Waterloo in Ontario, Canada.

There is a lack of existing research on actual green building costs to uncover if this perception is warranted. The literature is mixed when determining if there is an upfront green building premium for LEED-certified buildings. To date, there has not been a comprehensive cost-benefit analysis study conducted that looks at the costs and benefits of green building across IHEs. Furthermore, although there have been studies conducted with a sample of LEED-certified buildings, there has been no reported comprehensive cost benefit analysis of a sample of LEED-certified campus buildings nationwide. As shown in Exhibit 1, it is apparent that LEED registrations, which signify intent to seek LEED certification in the higher education sector, are increasing. Therefore, it is important to know if
LEED registration and certification makes economic sense for the higher education sector.

In 2013, there are 2,291 LEED-certified higher education projects and 3,141 LEED-registered higher education sector projects that signify intent to seek LEED certification (J. Van Mourik, personal communication, September 16, 2013). When looking at the number of postsecondary Title IV institutions, which are allowed to participate in Title IV federal student financial aid programs, there are over 7,300 institutions in the United States (National Center for Education Statistics, n.d.). When comparing LEED-certified higher education projects to the number of postsecondary Title IV institutions, it is clear that many IHEs are not participating in LEED, especially when considering that multiple higher education LEED projects may be on one campus. Although the higher education sector within the U.S. Green Building Council (USGBC) is relatively new, the benefit of over 7,300 IHEs participating in a successful LEED certification building policy could be significant since this policy could generate positive environmental and fiscal outcomes. Because of this potential significance, it is important to examine the costs and benefits of existing campus LEED-certified building projects. This examination can uncover the validity of this perceived upfront cost barrier.

The purpose of this study was to discover if the perceived upfront green premium financial barrier is valid by looking at actual initial costs of LEED-certified campus buildings versus conventional campus buildings to discover whether there is an actual upfront green premium. As an upfront green premium was discovered, the time to recover these upfront costs was calculated. Additionally, a cost benefit analysis was performed to examine the initial building costs and operating costs throughout the building lifecycle.
Literature Review

The LEED-certified building literature with regard to financial feasibility can be divided into the upfront green premium and the energy performance during the operational phase of a building.

Upfront Green Premium Literature

Various researchers have found an upfront green building premium. Kats et al. (2003) explore the upfront green premium of 25 office buildings and eight school buildings in California and find the upfront green premium to be $4/sf. Kats (2006) explores the additional cost to build green schools by using a sample of 30 K-12 green schools constructed between 2001 and 2006 within ten states and finds on average a green premium of $3/sf. Kats, Braman, and James (2010) explore the additional cost of building green by using a larger sample of 170 green buildings across multiple sectors in 33 states and eight countries completed between 1998 and 2009 and find a typical cost premium of about $3/sf to $9/sf.

There have also been mixed results when examining the upfront green premium. Matthiessen and Morris (2004) examine the cost of going green with LEED used as the basis for determining the level of sustainable design. They find that many projects are achieving LEED certification within budget and within comparable cost ranges as non-LEED projects and stress that there are high cost and low cost green buildings. Matthiessen and Morris (2007) re-examine the cost of going green with LEED used as the basis for determining the level of sustainable design. They find that there is a continuing problem with the perception that green is an added feature and therefore an added cost. They again find that many projects are achieving LEED certification within budget and within comparable cost ranges as non-LEED projects. Houghton, Vittori, and Guenther (2009) assess 13 LEED-certified and LEED-registered healthcare construction projects and find mixed results, with the upfront green premium ranging from 0% to 5%.

Operational Energy Savings Literature

When reviewing the energy costs of green buildings in operation, there have been studies that show positive results. For example, Kats et al. (2003) find that energy savings of $0.44/sf per year justify the upfront green premium cost. Kats (2006) determines the average annual energy savings of a sample of 30 K-12 green schools to be $0.38/sf. Furthermore, Kats, Braman, and James (2010) find annual energy savings for 60 LEED certified buildings ranging from $0.10/sf to $2/sf.

There has also been mixed results with regard to green building operating costs. Stegall and Dzombak (2004) look at the energy cost implications for New House, the first LEED-certified silver university residence hall in the U.S. at Carnegie Mellon University, based on energy modeling. When compared to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1 baseline, there is a 33% increase in energy efficiency. However, it is important to note that the heat recovery system in New House greatly influences energy
figures. When compared to a similar non-LEED Carnegie Mellon building with a heat recovery system, energy usage is 6%–12% more in New House (Stegall and Dzombak, 2004). Newsham, Mancini, and Birt (2009) examine whether LEED-certified buildings are living up to their expectations by re-analyzing 100 LEED-certified buildings of various types compared to the general U.S. commercial building stock using data supplied from the Turner and Frankel (2008) study. On average, the sample uses less energy when compared to the general U.S. commercial building stock, but 28%–35%, depending on the parameters of the comparison, of the LEED-certified buildings use more energy than conventional buildings.

There have also been negative results when looking at the actual energy performance of LEED-certified buildings. Scofield (2002) examines the first 24 months of energy performance of the Adam Joseph Lewis Center, a 13,600-square foot all-electric two-story classroom building completed in January 2000 and the first green building at Oberlin College in Ohio. An important finding of the study includes no energy benefits for the first 24 months of the building’s operation.

Deficiencies in the Studies

Much of the current literature is outside of the higher education sector, but can be applied to the higher education sector as an IHE has various building types on its campus. However, initial construction costs and operating costs for the full lifecycle need to be examined at IHEs since a campus typically does not move based on occupancy, rental rates, and sales per square foot. Furthermore, the building will most likely be owned by the university its entire life.

Data

The sample was obtained by first identifying the LEED-certified campus buildings in the U.S. This population was identified by utilizing a database called “Higher Ed LEED registered and certified projects,” which can be found on the Center for Green Schools’ website, a division of the USGBC and last updated in July 2013 (http://www.centerforgreenschools.org/main-nav/higher-edu/buildings.aspx). The LEED New Construction (LEED-NC) filter was utilized as LEED-NC is the appropriate version of LEED applicable for the higher education sector for new construction and major renovations of individual buildings. The participants, directors of facilities or someone in a similar role within the IHE, were sent an email with an online survey instrument that was taken from Appendix A of Kats, Braman, and James (2010) and slightly modified. The surveys were anonymous to encourage the sharing of sensitive financial information.

Methodology

There were three quantitative methods employed to answer the two research questions. The first research question, is there a green premium for LEED-certified campus buildings, was answered by gathering the green premium dollar per square
foot figures from the data collection sheets, where available, and calculating the average, median, and mode green premium of the sample. After reviewing the sample for items such as outliers, with the possibility of trimming or removing, the most appropriate measure was used to measure the average green premium of the sample.

The second quantitative method performed was a net cost-benefit analysis on the sample of LEED-certified buildings collected during the data collection phase of the study to determine whether the energy saving benefits outweighed the costs of LEED-certified campus buildings throughout the building lifecycle. The timeframe used in this study was 25 years. Kats, Braman, and James (2010) conservatively used a 20-year time period for their cost-benefit study on all building types within multiple sectors. A critique of using the same time period for all building types and sectors is that it does not account for the different uses, purposes, and goals of the building owners. As the current study focused on one sector, the higher education sector, one timeframe seemed appropriate. Furthermore, the costs and benefits were discounted over a timeframe that is longer than the private sector as IHEs use buildings for a longer time as they tend to be the sole building owner throughout the building lifecycle. According to Castaldi, the general life expectancy of a school building is about 50 years (as cited in Chan and Richardson, 2005, p. 7). Also, Weber and Kalidas (2004), who perform a cost-benefit case study of a LEED-certified silver residence hall at Carnegie Mellon University, mention that they modeled the project life from 20–40 years, with 20 years being liberal and 40 years being a high estimate if the time period does not include major renovation. Therefore, 25 years seemed to still be conservative so that benefits were not overstated.

This green premium dollar per square foot was used as the upfront costs of LEED-certified campus buildings and inputted into year zero of the net cost-benefit analysis. The net energy savings, using ASHRAE 90.1 2007 as a baseline, were inputted throughout the 25-year timeframe. Kats, Braman, and James (2010, p. 4) used a 7% discount rate and justified this rate by noting that “this rate is equal to or higher than the rate at which states, the federal government, and many corporations have historically borrowed money, and thus provides a reasonable basis for calculating the current value of future benefits.” As this study strictly focused on the higher education sector, the discount rate used was lower. A discount rate of 3.5% seemed reasonable as the timeframe was not intragenerational and private investment was not crowded out (Moore et al., 2004).

Calculating project performance criteria was done using the NPV for each survey. NPV was calculated by adding all discounted cash flows together. It is important to note that alternatives, such as using funds on projects other than LEED-certified campus buildings, were not measured, which is a limitation of this study. The internal rate of return (IRR) was also calculated.

The third quantitative method used was the discounted payback period in order to ascertain the payback period for LEED-certified campus buildings. The discounted payback period takes into account the time value of money by discounting the cash inflows of the project by using a 3.5% discount rate. Note
that the discounted payback period was not used in isolation, but merely another calculation tool employed to analyze the data.

**Results**

**Upfront Green Premium**

The average function was employed to answer the first research question pertaining to the upfront green premium for LEED-certified campus buildings. Information was gathered on the green premium $/sf figures from 16 data collection sheets. Responses ranged from $0.00/sf to $235.00/sf. In this case, the median of $5.41/sf was used to better represent the population as there was an extreme outlier and the average function would have been skewed by this outlier. The distribution is positively skewed as the mean exceeds the median. This is because there is a high green premium/sf outlier.

The relationship between LEED level and green premium $/sf was reviewed after removing the outlier of $235.00/sf. As Exhibit 2 illustrates, there is no relationship between LEED level and green premium/sf. The lowest green premium $/sf was a LEED level platinum building and the highest green premium $/sf was a LEED level silver building.

**Annual Energy Savings**

Information was gathered on the energy savings per year per square foot from the same 16 data collection sheets. Responses ranged from $0.25/sf to $42.37/sf. In
this case, since there was an outlier, the median of $0.32/sf was used to better represent the population as there was an outlier and the average function would have been skewed by this outlier. The distribution is positively skewed as the mean exceeds the median. This is because there is a very high annual energy savings per square foot outlier.

The relationship between LEED level and energy savings per square foot per year was reviewed after removing the outlier of $42.37/sf. As Exhibit 3 illustrates, there is no relationship between LEED level and energy savings per square foot per year. The lowest annual energy savings $/sf were LEED level platinum buildings and the highest annual energy savings $/sf was a LEED level gold building.

**Net Cost-Benefit Analysis**

In order to address the second research question of lifecycle energy benefits versus the upfront costs of LEED-certified campus buildings, a net cost-benefit analysis was performed. Calculating project performance criteria was done using NPV, IRR, and the discounted payback period for each survey with a discount rate of 3.5% and a building lifecycle of 25 years. The NPV, IRR, and discounted payback period for each of the 16 surveys are shown in Exhibit 4. NPVs ranged from −$232.20 to $698.32. IRRs ranged from −20.18% to 51.02%. The discounted payback period ranged from 0 years to 10.48 years. There were 10 surveys where the discounted payback period was not calculated as it exceeded the building lifecycle cutoff of 25 years.

**Discussion**

Previous studies have failed to focus on the higher education sector as it relates to LEED-certified buildings. Therefore, there was limited literature and data on the subject. However, when reviewing the literature, the results showed an upfront green premium of $0–$9/sf. For the annual energy savings, results ranged from $0.10 to $2/sf. The results for the green premium ranged from $0.00/sf to $235.00/sf. When the outlier is removed, the green premium ranged from $0.00/sf to $12.00/sf. The annual energy savings ranged from $0.17/sf to $42.37/sf. When the outlier was removed, the annual energy savings ranged from $0.17/sf to $0.75/sf. When comparing the existing results to the current results without the outliers, they seem to be somewhat in line.

There were two extremely high outliers in this study. Firstly, there was a green premium reported of $235/sf. The respondent may have answered in a different measurement versus dollar per square foot. That is why the median was used in this case. Secondly, there was an annual energy savings of $42.37/sf reported. Again, the respondent may have answered in a different measurement versus dollar per square foot and that is why the median was used in this case as well.

It was surprising to see that there was not a relationship between green premiums and LEED certification level. The lowest green premium $/sf was a LEED level
Exhibit 3 | Relationship between LEED Level and Energy Savings $/sf/Year

Exhibit 4 | Net Cost-Benefit Analysis Calculations

<table>
<thead>
<tr>
<th>NPV</th>
<th>IRR</th>
<th>Discounted Payback Period</th>
</tr>
</thead>
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<tr>
<td>(232.20)</td>
<td>-20.18%</td>
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</tr>
<tr>
<td>(5.74)</td>
<td>-1.72%</td>
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<td>(4.09)</td>
<td>-0.36%</td>
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<tr>
<td>(2.39)</td>
<td>-0.36%</td>
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</tr>
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<td>1.10%</td>
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</tr>
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<td>1.26%</td>
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</tr>
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</tr>
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</tr>
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<td>10.89</td>
<td>51.02%</td>
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</table>
platinum building and the highest green premium $/sf was a LEED level silver building. This could be due to different building projects obtaining different LEED points in order to achieve their particular LEED certification level. For example, one building project may have spent more money to obtain 1 LEED point for brownfield development versus development density and community connectivity for 5 LEED points. The municipality and location of the IHE within that municipality may determine if an IHE would even qualify for the development density and community connectivity. For example, it is unlikely a building would qualify, for example, if it is in a rural community with strict zoning density restrictions.

It was also surprising to see that there was not a relationship between annual energy savings and LEED certification level. The lowest annual energy savings $/sf were LEED level platinum buildings and the highest annual energy savings $/sf was a LEED level gold building. Again, this could be due to different building projects obtaining different LEED points in order to achieve their particular LEED certification level. For example, one building project may have decided to obtain 2 LEED points for introducing green power while another project may have opted to obtain 2 LEED points for material reuse. This focus on introducing green power versus material reuse could potentially cause an increase in energy savings for one project versus another.

For the surveys where NPV was greater than 0, LEED-certified campus buildings were profitable. For the surveys where IRR was greater than the discount rate of 3.50%, LEED-certified campus buildings were profitable. For the discounted payback period, results less than the building lifecycle of 25 years made a campus building project profitable. It was interesting that only six surveys had a positive NPV. Additionally, only six surveys had IRRs greater than 3.5% and payback periods less than 25 years. These results show that the majority of campus buildings in this study did not make sense financially. However, there were still multiple building projects that did make sense financially.

**Conclusion**

Incentives/grants can be one way to lower the upfront green premium for the higher education sector. Future research should look at public policy regarding LEED to see what incentives and/or grants help in decreasing the upfront green premium when building to LEED certification standards. Many states, municipalities, and IHEs have enacted policies to require buildings be built to LEED standards. Implementing incentives and grants rather than strictly requirements can help incentivize private IHEs to build to LEED standards that do not have a LEED requirement in place.

As no relationship was seen between the upfront green premium and LEED level, it would be interesting to take a more detailed look at projects to uncover why this may be. This could include collecting and reviewing LEED checklists to see which credits were obtained and whether specific credits cost more than others to obtain. Furthermore, common themes or trends could be revealed.
Although the majority of the projects in this study did not make sense financially by the measures of NPV, IRR, and the discounted payback period, there were multiple projects that demonstrated positive financial results. Therefore, future research is recommended to review financially favorable projects in order to understand why their projects work from a financial perspective.

Another recommendation would be to educate decision makers at IHEs on the value of building lifecycle analysis versus strictly upfront construction costs. This may involve changing the perspective of many presidents and provosts who have decision-making powers as perspectives on building costs have historically been more short-sighted versus long-sighted. This education is essential so decision makers understand the short- and long-term ramifications of building projects. Furthermore, building lifecycle analysis is especially important at IHEs where building lifecycles tend to be longer as the IHE is typically the sole owner of the building.

Many IHEs have enacted policies to require buildings be built to LEED standards. This may be due to the LEED rating system being the leader in green building rating systems. However, there may be campus buildings that are being constructed using other green rating systems. This would be interesting to look into for future research to see the distribution of various green building systems among IHEs, as well as the relative upfront and down the line costs and savings.

Additionally, buildings may be being built to LEED standards or other green building rating system standards, but not being certified due to the cost of certification. This may partially explain why many IHE campus buildings are non-LEED certified. This would be helpful to look into in the future.

LEED certification standards are uniform across the U.S. However, different regions within the country have different climates. It would be interesting to see whether certain LEED points are easier to achieve in different climates and different densities.

Furthermore, as we live in a global context, looking abroad for solutions to green building rating systems would be recommended for future research. Searching internationally for green building rating systems that are succeeding and failing would be useful to review for implementation in the U.S. Perhaps adoption and adaptation of a foreign green building rating system may offer better solutions financially and environmentally going forward.

One limitation of this study is that there may be some flaws in the database used. In the database, some projects labeled as higher ed seem to be private industry, such as geisinger, dunn construction, Bald Head Island Conservancy, Gateway Canyon Resort, Naval Air Station Whidbey Island, Smithsonian Conservation Biology Institute, etc. Therefore, numerous projects in the database may not be accurate. However, this database is the best source of information for campus LEED-certified buildings.

Another limitation of this study is participation was not random as permission was needed from the IHE to obtain the data of interest. There were voluntary
study participants sharing certain types of data, which can create a potential bias in the selection of buildings. For example, IHEs only experiencing positive financial results may choose to participate. Also, the data set was not representative of the national population of LEED-certified campus buildings. Furthermore, I did not compare actual to projected energy and water consumption.

I also did not examine specific credits within the LEED checklist. As IHEs may select different credits based on the type of building and location of their campus, this may affect upfront building costs and operating costs, which were not taken into account in this study. Also, I used the USGBC guidelines for energy baselines although some states and/or localities may require higher baselines for conventional buildings. This can cause overinflated energy savings as buildings not even considering LEED would have had to build to higher standards than these baselines.

The purpose of this study was to examine whether the perceived upfront green premium barrier is valid by looking at actual initial costs of LEED-certified campus buildings versus conventional campus buildings to determine if there is an actual upfront green premium. This study confirms the majority of findings in the literature regarding the existence of an upfront green premium. In this study, an upfront green premium of $5.41/sf was determined for LEED-certified campus buildings. Therefore, the perceived upfront green premium barrier may be valid for LEED-certified campus buildings. However, other considerations such as environmental and community impact should be taken into account, as part of an IHE’s mission is commitment to service versus solely economic feasibility.

Moreover, the energy savings found in this study confirm the majority of findings in the literature as well. In this study, the annual energy savings was found to be $0.32/sf. This should help foster adoption of the LEED green building rating system among campus buildings as there are down the line savings associated with the costs. As the majority of the cost benefit analyses do not show justification from a financial perspective, it could be important to include other down the line savings. It should be noted that it is difficult to quantify some down the line benefits.

This study should prove helpful to policymakers at higher education institutions either considering implementation of a LEED-certified building or institutions that already have one or multiple LEED-certified buildings. Furthermore, this study fills the gap in the literature in multiple ways. First, it provides a comprehensive cost-benefit analysis of a sample of LEED-certified campus buildings nationwide, which can be helpful to state and federal policymakers whom have the ability to provide IHEs incentives, such as grants, for upfront costs to build LEED-certified buildings. Second, this study has produced more recent findings for a sample that focuses strictly on the higher education sector. Additionally, this study provides construction and energy operating costs for a sample of campus LEED-certified buildings within the U.S. that helps to confirm the perceived green premium. However, it was also found that there are operating energy savings that help to address upfront green premium barriers.
In conclusion, the LEED green building rating system continues to grow at IHEs. Cost may not be the whole picture for IHEs as they tend to operate under a different ethos than private industry. IHEs may have a higher tendency to implement policies that encourage environmental responsibility, although it may not make financial sense. However, as seen from this study, although the upfront green premium is reinforced, there are operating energy savings when viewing the project from a building lifecycle perspective.

References


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Appraising Sustainable Building Features: A Colorado Case Study

Authors
Laura Bently, Scott Glick, and Kelly Strong

Abstract
We investigate the current status of sustainable value integration in Colorado’s real estate markets, an area with limited current/historical value attributed to sustainability. The property appraiser has an opportunistic position to influence stakeholders and potentially increase demand for sustainable building. The appraisal process, necessary inputs, and rules and regulations were studied using an exploratory sequential mixed methods approach to conduct a cross-sectional study through archival research, survey distribution, and the collection of quantitative and qualitative data. We confirm that Colorado’s real estate appraisers are increasingly integrating sustainable building features in appraisal assignments, despite existing challenges.

In the United States, buildings account for 41% of primary energy consumed (U.S. Department of Energy, 2011). As a result of energy consumption, buildings contribute 39% of the total carbon dioxide emissions, in addition to other greenhouse gas emissions (Pearce, Hahn Ahn, and HanmiGlobal Co., 2012). It seems only appropriate that since the building sector contributes such a large proportion of these negative environmental impacts, this sector has huge potential to cause change and induce reverse effects through decreasing energy consumption and emissions. This reduction could be achieved through sustainable building and development strategies.

Building sustainably remains largely a voluntary action in the building industry worldwide. Despite advances being made by policymakers and government organizations (Pearce, Hahn Ahn, and HanmiGlobal Co., 2012) and overwhelming evidence pointing to the potential benefits sustainable building could offer to its stakeholders, there remains much resistance to the “green movement” in the construction industry (Warren-Myers, 2011). Researchers have produced a thorough list of barriers to sustainable building (Hakkinen and Belloni, 2011; Pearce, Hahn Ahn, and HanmiGlobal Co., 2012; Warren-Myers, 2011), including financial incentives and affordability as the most important driver and barrier, respectively, for sustainable building (Pitt, Tucker, and Longden, 2009). Therefore, the economic values of sustainable building features must be understood, recognized, and accepted by stakeholders to effectively promote sustainable building practices. Some researchers suggest this may be happening, but not to the extent that may be needed to fully integrate the value of sustainable features.
into the property valuation process. This study focuses on the current status of appraisal practices in Colorado relative to sustainable building in real property markets to begin to understand the relationship between the construction and real estate industries and their impact on achieving sustainable value integration.

This research focus builds on the education and professional practices in real estate and construction realms; therefore, it has the potential to impact all professionals dealing with any aspect of real estate property. A physical building is the end product in these realms and all stakeholders involved in the process of a building’s conception leave some degree of impact on the final product, whether it is a decision made to create the best financial benefit to its investors or a decision on the type of carpet that will be installed. All of these stakeholders also have the opportunity to decide on implementing sustainable building features/practices. This research builds on the importance of understanding barriers and drivers to sustainable building feature integration in order for these industries to be knowledgeable advocates of smarter building practices.

In relation to the real estate realm, an analysis of stakeholder relationships found that the appraiser holds a unique position to inform and influence all stakeholder groups (Lorenz, 2008; Warren-Myers, 2013). Property appraisers use their expertise and knowledge to educate stakeholders, including builders, investors, mortgage lenders, insurance providers, and homebuyers on the cost and value of sustainable building features and technologies. Accurate property appraisals have the opportunity to correct misconceptions many consumers have on the cost and return on investment of sustainable building features.

In addition, this research will also give the construction realm the opportunity to understand how the appraisal process works in relation to sustainable building features, so that construction-related stakeholders can align their practices with those of the appraisal professionals in order to realize the full potential of sustainable building features during a building’s life cycle.

We examine if and where sustainable value integration exists in current real property appraisal practices in Colorado. First, we investigate the nature of sustainable value integration within current appraisal practices in Colorado’s real estate markets. We examine how appraisers obtain information for appraisals and how this translates to collecting information about sustainable building features. Second, we examine the degree of alignment between state mandated criteria for appraiser licensure and their knowledge of sustainable building techniques, materials, and technologies among the current appraiser population. A comparison of state mandated criteria for appraiser licensure and continuing education on sustainability topics reveals areas that are sufficiently or insufficiently meeting the market needs for appraiser competency. Third, we analyze the transparency of the construction industry knowledge of sustainable building techniques, materials, and technologies to the appraisal industry. Fourth, we explore the perceptions of real estate appraisers on the economic implications of sustainable value integration. We also evaluate how appraisers have seen the concept of green building develop. If they see it adding value, and how they see it growing into an everyday practice as real estate markets become more saturated with green building features.
Despite the overwhelming evidence of the benefits of sustainable buildings (Pearce, Han, and HanniGlobal Co., 2012), stakeholders in construction building practices rely on fundamental economics in the business sense, affordability, payback, and financial incentives when deciding to invest in green real estate (Wolff, 2006; Lutzkendorf and Lorenz, 2007; Pitts and Jackson, 2008). Pivo and Fisher (2010) and Kok, McGraw, and Quigley (2011) examine value, income, and returns; they both found that buildings with an ENERGY STAR label, located close to transportation, and sited in redevelopment areas had equal or higher returns than conventional properties, suggesting that responsible real estate investing can be done. However, as pointed out by Prum (2013), lenders may still fail to understand the difference between a loan for a traditional building and one for a building with green features; an issue that could impact the appraisal process. The financial barriers to implementing sustainability in construction were discovered through a review of literature and classified into five categories as follows: property assessment and valuation, initial perceptions of cost, insurance provisions, mortgage lending, and property yield.

First, property valuation creates an interdependent relationship with market value. This relationship revolves around two key concepts: (1) the market value of a property is dependent on the value the public perceives those features are worth and (2) property value is dependent on quantitative and qualitative values reported by the property appraiser.

Second, initial perceptions of cost make it evident that there is a need to inform the public and educate appraisers about the social, environmental and economic benefits of sustainable design and construction (Bartlett and Howard, 2000; Lutzkendorf and Lorenz, 2005; Pitts and Jackson, 2008; Leopoldsberger et al., 2011; Lorenz and Lutzkendorf, 2011). However, previous research has presented conflicting statements on the initial costs of building with green features, so it is no wonder the general public is not confident in making these investments systematically.

Third, circumstances surrounding insurance companies and the insurability of a sustainable project are also affected by property appraisal techniques. Pricing for conventional and green buildings depends on the associated risks. Once building characteristics and performance criteria are implemented in appraisal strategies, insurance companies can begin to develop their risk analyses based on these performance criteria assessments (Mills, 2003; Bakens, Foliente, and Jasuja, 2005; Lutzkendorf and Lorenz, 2005; Lorenz, Truck, and Lutzkendorf, 2006).

Fourth, mortgage lenders and their perception of sustainable buildings are also affected by property appraisal techniques and risk assessment. Interest rates and approval of property loans are determined in direct relation to the associated risks, along with the consideration of the borrower’s ability to make payments and the price stability of the collateralized property. Arguably, since sustainable properties have been shown to increase marketability and provide a stable income stream,
this is a real insight to the credibility and financial benefits of sustainable over conventional buildings (Lutzkendorf and Lorenz, 2005).

Finally, future rental and lease rates are another decisive factor that an investor will examine, in addition to the resale value relative to the local market (National Real Estate Investor, 2013). Pitts and Jackson (2008) believe that green buildings are leasing at above normal market rates with lower tenant turnover. However, research on this topic is still very scarce due to a lack of information in real estate databases and understanding of how to assess the relations between building characteristics and rental or lease rates.

Cadman (2000) contributed a fundamental principle in understanding the dynamic relationships between stakeholders: the “vicious circle of blame” (Exhibit 1). Through an examination of the relationships that exist between occupiers, constructors, developers, and investors, it was determined that the adoption of sustainability in the real estate market will be limited as long as the “blame” of not promoting a sustainable building is passed from one stakeholder to the next in this “vicious circle.”

With the consideration of the five categories of financial barriers previously mentioned, it was determined that insurance providers, mortgage lenders, and appraisers also have a stake in the adoption of sustainability. Lorenz (2008) contributes his contradiction of the “vicious circle of blame” with the inclusion of researchers, educators, policymakers, and owner associations in addition to the aforementioned stakeholder groups. Prior research analyzing relationships among all key stakeholders and their roles in sustainable building has shown that the appraiser holds a unique position to inform and influence all stakeholder groups (Lorenz, 2008; Warren-Myers, 2011).
Increasing investment and demand in sustainable building practices is the common goal within the literature (Pitt, Tucker, and Longden, 2009; Warren-Myers, 2011). However, there is a need for further clarification and exploration in order to overcome barriers and achieve integration of the value associated with sustainable building features in real estate markets. We begin to fulfill the need for empirical data by collecting information from practicing appraisal professionals in Colorado’s real estate markets regarding their current appraisal practices. By discovering where the integration of sustainability value exists in current real estate appraisal in Colorado, a baseline will be created for future research to expand our understanding of the link between property valuation and sustainable design and construction.

**Methodology**

In this mixed methods study, we addressed the status of appraisal practices relative to sustainable value integration in real estate markets in Colorado. This cross-sectional study collected data through archival research that pertained to current appraisal practices and collected survey data from current, licensed appraisers in Colorado. A mixed methods approach was used to collect quantitative and qualitative data. This method offered several advantages to this study. One data set had the potential to explain the other, collecting two sets of data would provide a validity test to the research, and collecting qualitative data offered the opportunity for a much richer examination of the phenomenon being studied (Creswell, 2014). More importantly, the origins of this research approach from Campbell and Fiske (1959) suggest that mixing quantitative and qualitative methods helps ensure any resulting variance within the data sets reflect the relationship being studied instead of constraints inherent in a specific research method (Creswell, 2014). The commonly-used term for the benefits of mixed methods research is “triangulation” (Denzin, 1978).

In the exploratory sequential mixed methods approach there were two phases of data collection (Exhibit 2). In the first phase, we conducted archival research to investigate qualitative information related to mandated laws and regulations for appraisal in Colorado. We identified methodologies and tools suggested by industry organizations and related research available to appraisers for sustainable value integration. By comparing these two initial investigations, an understanding of the sustainable knowledge gap between mandated appraisal practice and opportunities to understand and integrate information related to sustainable
building features and technologies began to appear. We used the data collected in this first phase to develop the content in the survey measurement instrument for the second phase of data collection.

In the second phase of data collection, we distributed the survey to 322 appraisers, using Qualtrics, to collect primarily quantitative information related to awareness of sustainable value integration, types of features they have experience appraising, and if they believe sustainable building features have an economic impact to building appraisal. A list of questions used in the survey is shown in the Appendix. Due to the small number of respondents (45), the conclusions drawn from the data may not be generalizable to the entire appraiser population, but they do represent a beginning to understanding the challenges behind the nature of sustainable value integration practices.

**Data Analysis**

The survey was distributed to 322 licensed and active appraisers in Colorado determined from the National Registry and the Appraisal Institute (AI) Member Registry. Forty-five surveys were returned for a response rate of 14%. The overall goal of this research was to discover the current status of sustainable value integration in appraisal practices in Colorado. Simply stated, are appraisers recognizing and including sustainable building features in their appraisal assignments? Therefore, the survey questions were designed to accommodate the appraisers who fit into the two potential responses to this question: (1) those who were aware of sustainable value integration in property appraisal (Group 1, \(n = 38\)) and (2) those who were not aware of sustainable value integration in property appraisal (Group 2, \(n = 7\)). In addition to questions that were relevant to both responses, specialized questions were also developed to explore the opportunities to collect data and information from both groups.

**Summary of Group 1 Analysis**

The categories of property types most often appraised by the respondents include: commercial, 53%; residential, 34%; industrial, 5%; and other, 8%. The analysis of Group 1 data revealed telling information about the current status of appraisal practices in Colorado relative to sustainable building features and current challenges that appraisers are facing in fully integrating them. First, we found that 84% of respondents are aware of sustainable valuation methods and practices (Exhibit 3).

Major features currently being considered were discovered (Exhibit 4), however, uncertainty as to the extent of appraiser knowledge about sustainable building features and technologies and the degree to which sustainable features are carried through the appraisal process remains.

Second, we found that 82% of respondents had appraised real property in which sustainable features were considered (Exhibit 5). The majority of appraisers began to notice sustainable building features being incorporated into appraisal processes.
**Exhibit 3 | Awareness of Appraisal Methods and Practices**

<table>
<thead>
<tr>
<th>Q3</th>
<th>Are you aware of appraisal methods and practices to valuate sustainable building features that are implemented in real property today?</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>Answer</td>
</tr>
<tr>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

Note: The number of observations is 45.

**Exhibit 4 | Sustainable Features Being Considered in Appraisals**

<table>
<thead>
<tr>
<th>Q8</th>
<th>Based on the building category you most often appraise, which sustainable features are considered in the appraisal process? Please check all answers that apply.</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>Answer</td>
</tr>
<tr>
<td>1</td>
<td>Site Orientation</td>
</tr>
<tr>
<td>2</td>
<td>Building Envelope Quality</td>
</tr>
<tr>
<td>3</td>
<td>HVAC</td>
</tr>
<tr>
<td>4</td>
<td>Building Performance Energy Rating</td>
</tr>
<tr>
<td>5</td>
<td>Insulation</td>
</tr>
<tr>
<td>6</td>
<td>Renewable Energies (Solar Panels, Wind)</td>
</tr>
<tr>
<td>7</td>
<td>Lighting Controls</td>
</tr>
<tr>
<td>8</td>
<td>Appliances / Equipment Selection</td>
</tr>
<tr>
<td>9</td>
<td>Water Efficiency</td>
</tr>
<tr>
<td>10</td>
<td>Proximity to Community &amp; Public Transportation</td>
</tr>
<tr>
<td>11</td>
<td>Indoor Air Quality</td>
</tr>
<tr>
<td>12</td>
<td>Utility Cost (Electric, Water, Wastewater, Stormwater)</td>
</tr>
<tr>
<td>13</td>
<td>Day lighting</td>
</tr>
<tr>
<td>14</td>
<td>Other: Please Specify</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

Note: The number of observations is 38.

within the past seven years (Exhibit 6), which may indicate that sustainable value integration is still relatively new in the industry.

Third, through qualitative and quantitative data analysis, it was discovered that, while many appraisers feel that all building characteristics should be included in
Exhibit 5 | Appraiser Experience with Incorporation

<table>
<thead>
<tr>
<th>Q4</th>
<th>Have you appraised real property in which sustainable/green building features are incorporated into the valuation process?</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>Answer</td>
</tr>
<tr>
<td>1</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

Note: The number of observations is 38.

Exhibit 6 | Sustainable Building Feature Incorporation Timeline

<table>
<thead>
<tr>
<th>Q5</th>
<th>When did you first notice sustainable building features being incorporated into the appraisal process? Please check only one answer.</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td>Answer</td>
</tr>
<tr>
<td>1</td>
<td>0–3 years ago</td>
</tr>
<tr>
<td>2</td>
<td>4–7 years ago</td>
</tr>
<tr>
<td>3</td>
<td>8–12 years ago</td>
</tr>
<tr>
<td>4</td>
<td>Over 13 years ago</td>
</tr>
<tr>
<td>5</td>
<td>I have not noticed.</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

Note: The number of observations is 38.

The appraisals (Exhibit 7), the nature of the appraisal approach may inherently have an impact on sustainable value integration. Considering the different inputs of the sales comparison, income, and cost approaches, some approaches are more likely to include sustainable factors than others. However, appraisers are challenged in obtaining credible information to support input attributes used in the appraisal method chosen. There is risk in uncertainty for appraisers. Therefore, to avoid this risk, appraisers prefer to rely on verifiable, third-party information to base their assumptions and conclusions for final appraisal value. Again, the appraiser needs to validate the content and source of information to be confident that it is factual, even though provided by a third party. These respondents also concluded that there are insufficient tools and information sources available to appraisers relating to sustainable features (Exhibit 8).

The majority of these factors impact the appraiser’s ability to measure and quantify features that influence a property’s appraised value.
Finally, 74% of survey respondents confirmed they require verifiable documentation to support the appraisal of sustainable building features (Exhibits 9 and 10).

**Summary of Group 2 Analysis**

Our analysis of Group 2 data discovered perspectives from those respondents who were not aware of appraisal methods and practices relative to sustainable building...
**Exhibit 9 | Do Appraisers Require Documentation?**

| Q9 Do you require documentation of any of those sustainable features to support the appraised value? |
|---|---|---|
| # | Answer | Responses | % |
| 1 | Yes | 28 | 74% |
| 2 | No | 10 | 26% |
| Total | | | 100% |

Note: The number of observations is 38.

**Exhibit 10 | Sustainable Features that Require Documentation**

| Q10 Which sustainable feature areas do you require documentation for validation of the appraisal? Please check all answers that apply. |
|---|---|---|
| # | Answer | Responses | % |
| 1 | Site Orientation | 3 | 11% |
| 2 | Building Envelope Quality | 4 | 15% |
| 3 | HVAC | 11 | 41% |
| 4 | Building Performance Energy Rating | 15 | 56% |
| 5 | Insulation | 7 | 26% |
| 6 | Renewable Energies (Solar Panels, Wind) | 17 | 63% |
| 7 | Lighting Controls | 1 | 4% |
| 8 | Appliances | 1 | 4% |
| 9 | Water Efficiency | 4 | 15% |
| 10 | Proximity to Community & Public Transportation | 2 | 7% |
| 11 | Indoor Air Quality | 1 | 4% |
| 12 | Utility Cost (Electric, Water, Wastewater, Stormwater) | 16 | 59% |
| 13 | Daylighting | 1 | 4% |
| 14 | Other: Please Specify | 3 | 11% |
| Total | | | 100% |

Note: The number of observations is 27.

features. First, these respondents confirmed there are appraisers currently practicing in the industry that lack knowledge and experience of how to consider sustainable features in an appraisal. However, after being given a list of examples of sustainable building features, it was discovered that some of the appraisers were able to say that several of these features were considered in appraisal
 Exhibit 11 | Group 2 Experience with Sustainable Building Features in Appraisal Assignments

<table>
<thead>
<tr>
<th>Q16</th>
<th>Answer</th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you been assigned to appraise real property in which any of the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sustainable building features listed above could be incorporated into</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the valuation process?</td>
<td>Yes</td>
<td>4</td>
<td>57%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>3</td>
<td>43%</td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Note: The number of observations is 7.

 Exhibit 12 | Appraiser Satisfaction to Recognize Sustainable Building Features

Second, overall respondents were not satisfied in their ability to recognize sustainable features (Exhibit 12). Those features rated with higher satisfaction were features that were similar to elements in traditional buildings. The challenge here lies in how to measure and quantify their impacts. The respondents also rated their ability to value the same features between good and poor (Exhibit 13). Again, without information to quantify their impacts, appraisers cannot apply these measurements and data to appraisal methods.

Finally, availability of accurate information and data was a need expressed by all respondents in this group, specifically data related to economic costs and benefits,
comparable sales, property transactions, and MLS databases (Exhibit 14). In general, respondents are aware of additional opportunities for continuing education and professional development (Exhibit 15); however, these opportunities are not mandatory and not always available to those who face financial and/or location related challenges.

Several dominant themes were discovered in the data analysis process to help explain current appraisal practices and the challenges appraisers face when trying to integrate sustainable features into the process. These overarching themes of information collected from Group 1 and Group 2 present an understanding of the barriers to achieving sustainable value integration facing the real estate and building industries.
**Exhibit 15** | Education and Experience Resources for Sustainable Building

There are opportunities for appraisers to gain additional experience and education on green building related to appraisal practice outside of the mandated curriculum for appraiser licensure. Have you participated in any of the following? Please check all that apply.

<table>
<thead>
<tr>
<th>#</th>
<th>Answer</th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Continuing Education Courses</td>
<td>4</td>
<td>67%</td>
</tr>
<tr>
<td>2</td>
<td>Professional Development Programs</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>3</td>
<td>Appraisal Institute Designation Programs</td>
<td>1</td>
<td>17%</td>
</tr>
<tr>
<td>4</td>
<td>I have not participated in any of these programs</td>
<td>1</td>
<td>17%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

The number of observations is 6.

**Data Analysis and Discussion**

The results suggest that a meeting of the minds could be achieved by discovering what each stakeholder group already knows and what they have yet to discover. Targeting this bigger picture, the results may affect thinking on education, federal and state laws and regulations, methodologies, and industries practices relative to sustainable building features/practices.

We find that the current status of sustainable value integration in Colorado is progressing, with sustainable building features increasingly recognized and considered in appraisal assignments by 82% of survey participants (Exhibit 5). Respondents confirmed that all building attributes, sustainable and otherwise, should be included in the appraisal process; however, some remain unsure and inconclusive of market interaction due to limited information and data, or their lack of experience or knowledge (Exhibit 7). While the majority of the respondents who have experience appraising sustainable features noted seeing sustainable value integration within the last seven years (Exhibit 6), there remain several dominant challenges facing appraisers and stakeholders within the sustainable value integration process. These challenges are summarized below.

First, sustainable feature recognition remains a challenge for a portion of the appraiser population. It was discovered that not all appraisers are able to recognize and therefore, consider sustainable building features for the final appraisal value (Exhibit 3). While the definition of sustainability remains ambiguous and broad, appraisers must decipher the impacts of individual sustainable features as well as those features that create systems within a building to achieve broader sustainability concepts. However, unless appraisers are given specific information about a property’s sustainable features, they are more likely to incorporate those that are visible over those that are not. Despite these challenges, sustainable
building features cannot be ignored. Within the standard property appraisal process established by the Uniform Standards of Professional Appraisal Practice (USPAP), an appraiser must examine the subject property and gather all information on the property’s market area, physical characteristics, and market data on comparable properties. Therefore, it will be important to the future success of sustainable value integration in the industry to include sustainability as a topic in the standard curriculum of appraiser education.

Second, we found that even though respondents are able to recognize sustainable building features, they are continually challenged by the inability to measure and quantify their economic impacts. Property is a heterogeneous product that exists in constantly evolving real estate markets. Because of this, respondents revealed that they were unsure of how to develop a standardized system to measure sustainable building features. We showed that the data inputs relative to the sustainable features being recognized by appraisers now (Exhibit 16) fit into the current appraisal process described for conventional building attributes. Currently, economic cost and benefits such as return on investment, rent premiums, and utility savings are the primary focus of appraisers’ investigation.

Appraisers rely on measureable, verifiable data to create an accurate opinion of market value. Information obtained from energy modeling, performance ratings, and utility bills for those buildings with sustainable features are recommended sources to provide this documented data for appraisers. If this information is not available, the appraiser must find other methods of calculating or obtaining this information, but these processes are not yet standardized. Also, the industry has not yet defined a process to recognize those intangible benefits of sustainable building features, like healthier indoor air quality and higher occupant satisfaction. The standard appraisal process dictates that appraisers collect the property data

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**Exhibit 16 | Format Followed by Appraisers for Appraisal Process**

<table>
<thead>
<tr>
<th>#</th>
<th>Answer</th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Appraisal Institute—Preprinted Form</td>
<td>11</td>
<td>24%</td>
</tr>
<tr>
<td>2</td>
<td>Narrative</td>
<td>39</td>
<td>87%</td>
</tr>
<tr>
<td>3</td>
<td>Client Provided—Bank, Mortgage Broker</td>
<td>9</td>
<td>20%</td>
</tr>
<tr>
<td>4</td>
<td>Government Mandated Criteria</td>
<td>15</td>
<td>33%</td>
</tr>
<tr>
<td>5</td>
<td>Uniform Standards of Professional Appraiser Practice (USPAP)</td>
<td>27</td>
<td>60%</td>
</tr>
<tr>
<td>6</td>
<td>Federal Housing Administration (FHA)</td>
<td>8</td>
<td>18%</td>
</tr>
<tr>
<td>7</td>
<td>Veterans Affairs (VA)</td>
<td>3</td>
<td>7%</td>
</tr>
<tr>
<td>8</td>
<td>Other: Please Specify</td>
<td>6</td>
<td>13%</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>6</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

The number of observations is 6.
and then perform their analysis according to an appraisal approach. Therefore, in order to consider the impact that sustainable building features have on property value, the benefits of the features first need to be measured and quantified. Without this data, appraisers cannot conduct a thorough comparative analysis.

Third, we found that respondents are challenged by a lack of information and data related to sustainable building features. When examining the subject property, respondents noted that they do not get enough information from the builder or owner upfront regarding any sustainable features that have been implemented in the property. What we were not able to determine is when sufficient data fails to be documented, are building features simply excluded from the appraisal? If so, how does this exclusion translate to those stakeholders who are trying to promote sustainable building practices? Product specifications provided to the appraiser by the builder or owner would provide relevant information to conduct research on the products’ performance capabilities and thus to estimate an economic value. We found that 74% of respondents who have appraised property with sustainable features require documentation to validate the appraisal (Exhibit 9). Research confirms that uncertainty creates risk for the appraiser. Therefore, reliable, documented information is preferred to reach an accurate estimation of value. Appraisers expressed a need for updated, searchable databases including MLS listings, comparable sales, property transactions, and market data to determine if these features are recognized by the market. This information is crucial to reaching a conclusive opinion of property value. If a reliable property database is not designed, implemented, and maintained, we may see a perpetual exclusion of sustainable features going forward.

After the data analysis has been conducted on property features, the appraiser must report the results, according to the USPAP standards. Sufficient information and data need to be available for appraisers to use as a comparison to other values in real estate markets. Using this information, the appraiser will determine which property features the market has recognized. Their report will include the property and market data and adjustments made to value, along with justification for those adjustments. These appraisal reports build on existing property and market data and support future property transactions.

To achieve sustainable value integration in all appraisal practices in Colorado, these three major challenges need to be addressed and mitigated. It will be important for appraisal professionals to gain a fluent understanding of sustainable building methods, materials, and technologies through standardized curriculum to recognize and incorporate the value created by sustainable features into their appraisal assignments. The continuing education of appraisers will also play a role as building practices continue to evolve. The development of processes and methods to measure and quantify impacts will be crucial to incorporating value associated with sustainable building features in the appraisal process.

**Research Aims Revisited**

The purpose of this research was to discover the current status of sustainable value integration and form an understanding of the processes and challenges facing
appraisers today in Colorado’s real estate markets. First, we were successful in investigating the nature of sustainable value integration within current appraisal practices in Colorado’s real estate markets. We summarized pertinent terms and provided definitions to create parameters. Next, qualification criteria and the process to obtain appraisal licensure were discussed. Then, research on the governing authority for appraisal standards and practices, laws and regulations, and the typical, step-by-step appraisal process was explained. This information provided much of the demographic information for the study pertaining to the participants. We were able to determine that all active appraisers in the state of Colorado had to have a valid appraisal license. This section also created the baseline for comparison of sustainable value integration practices and regulations against the information collected in objective two.

Second, we identified the degree of alignment between state mandated criteria for appraiser licensure and appraiser knowledge of sustainable building techniques, materials, and technologies. Mandated curriculum for initial licensure and continuing education requirements were summarized for the general property appraiser certification as stipulated by USPAP and the state of Colorado. Educational opportunities targeting sustainability topics were not present in the initial curriculum, but were offered in continuing education opportunities. Then, we investigated primary resources for sustainable building information and data provided by professional organizations. Finally, by comparing the mandated appraisal processes to the education and resources available on sustainable building features, we determined that there is a deficiency in the expectations of the appraisal process and the qualification and education requirements of those who are able to appraise.

Third, we analyzed the transparency of construction industry knowledge in relation to sustainable building techniques, materials, and technologies compared to the appraisal industry. We utilized information discovered in previous objectives to develop a survey targeting two groups of appraisers: (1) those with experience appraising properties with sustainable building features, and (2) those without experience appraising sustainable building features. We assembled contact information for 322 active licensed appraisers in Colorado using the National Appraiser Registry and the AI Member Registry.

Fourth, we explored perceptions of real estate appraisers on the economic implications of sustainable value integration. We were successful in identifying and reporting on the respondents who were aware and unaware of sustainable value integration methods and practices. Those sustainable building features that were being considered and those that appraisers felt should be considered were included in the study. Survey respondent perceptions on those features that add value to a property and the challenges to realizing their potential for impact were also revealed. We conclude that there are three challenges to achieving sustainable value integration in Colorado’s property markets: (1) sustainable feature recognition; (2) ability to measure and quantify economic impacts; and (3) the availability of information and data.
Limitations of the Study

One limitation to the data collected in the study lies in the lack of a uniform definition for the term “sustainable.” Often the term “sustainability,” “green,” and “energy efficient” are used interchangeably in discussions about the same concepts. These phrases may have different meanings dependent on their context and theory of application.

Another limitation to the study lies in the types of sustainable building features that were defined for the survey participants. Due to the ambiguity of “sustainability,” “green,” and “energy efficient,” we developed a list of sustainable features to reference in survey questions and responses. The list included site orientation, building envelope quality, HVAC, building performance energy rating, insulation, renewable energies (solar panels, wind), lighting controls, appliances/equipment selection, water efficiency, proximity to community and public transportation, indoor air quality, utility cost (electric, water, wastewater, stormwater), and daylighting. However, this list presents several issues for the study.

First, it is comprised of both sustainable building features and sustainable building concepts. Many of these terms could still be considered broad and ambiguous to the respondents. For example, when considering water efficiency, this term could be referring to low-flow plumbing fixtures, gray water systems, xeriscaping, etc.

Second, it is difficult to differentiate between a single building feature like insulation and an entire concept like energy efficiency. It is also difficult to define what benefits appraisers need to be aware of and capable of calculating. Is the benefit being seen from the type of insulation, or is the benefit being seen in a better building envelope and therefore lower energy use? Thus, it is difficult to determine which features and/or concepts are good proxies to measure survey inquiries.

A third limitation is created by the heterogeneous nature of property and the types of interest they hold. We examined the typical property appraisal process as mandated by the USPAP and the three primary appraisal approaches. We did not consider the nature of sustainable value integration relative to appraisal practices covering specific types of rights and interests relative to the subject property. Also, we acknowledge that appraisers are often held to include certain criteria for the appraisal by their employers. Rules and regulations pertaining to required criteria and their extents for all property appraisals were beyond the scope of this study.

A fourth limitation lies in the archival research conducted to discover where education related to sustainability and building practices was present in mandated curriculum for initial licensure and continuing education requirements for appraisers. One limitation to the evaluation of the initial curriculum required for licensure is that we did not review every course outline for content related to sustainability. USPAP defines the topics needed to meet their curriculum requirements; however, they do not develop the specific outlines or lesson plans for each class. Therefore, there are many sources to get a real estate appraisal education. We determined that a review of every class offered was unrealistic. It
is possible that issues related to sustainable building features are discussed and applied within other curriculum topics.

Finally, the survey population also limits the study. Those members who are listed on the National Registry are active and licensed appraisers and those listed in the AI Member Registry are also active and licensed, but have a vested interest in being more experienced and knowledgeable of appraisal issues and trends. These AI members have also taken the initiative to earn an additional AI designation, which means they have additional education above and beyond the requirements of USPAP. Therefore, the appraisal population selected for this survey may have been slightly in favor of the study because of their additional experience and education. Overall, there was still a portion of the survey population that was not aware of and did not have experience with sustainable value integration practices in appraisal.

**Conclusion**

The literature review proposed several needs for further investigation into opportunities to mitigate challenges facing stakeholders investing in sustainable building practices/systems. Previous research expressed a need for further research to provide clarification on several fronts in order to achieve sustainable value integration in real estate appraisal.

First, education and continuing education requirements need to adopt sustainability into their curriculum. We found that all appraisers are not able to recognize and value sustainable building features. Mandated education does not have a specific focus on sustainable building concepts and features. Continuing education opportunities related to sustainability are available, but not mandatory. The incorporation of education specifically focused on issues related to understanding, integrating, and reporting on sustainable building features needs to be seriously considered by governing authorities in order to mitigate this deficiency in appraiser knowledge.

Second, the need for a standardized measurement system to assess qualitative and quantitative benefits of sustainable building features and their economic impacts to real estate property has been expressed by other researchers. Our results also confirmed this need. Appraisal approaches are based on quantitative inputs and mathematical formulas. Survey respondents were found to be unsure of how to measure certain tangible and intangible benefits resulting from both visible and not visible building features. These respondents expressed a need for a method to measure and quantify the various economic impacts of sustainable building features and a standardized method to input these figures into an analysis.

Third, researchers have suggested that property transaction databases be created and/or re-furbished to enable comparative studies of properties with sustainable building features. Again, our findings confirmed that this type of information is necessary and crucial to the success of appraisers in being able to collect data and report on market value. Respondent to our survey expressed a need for a new type
of searchable database or updating of existing databases to include sustainable building features. However, it is up the appraisers and other real estate professionals to investigate each property and include this information in these databases.

Fourth, due to the small sample size, several things could be done in future research to confirm and strengthen this study. First, a survey of the non-respondents could be done to help confirm whether the results are representative of a larger population. Second, additional questions could be added to the survey to measure the impact of LEED certification and ENERGY STAR ratings on appraisal practices. It may also be helpful to further distinguish the types of commercial property that are appraised to ascertain if the properties are “high profile” where sustainable features are well known and advertised when leasing or selling.

Finally, our goal was to contribute to the limited empirical data available on what is taking place in the property appraisal industry relative to sustainability, rather than proposing additional suppositions as previous researchers have done. We discovered, from a small population sample of Colorado appraisers, how many appraisers were considering sustainable building features in appraisal assignments. Sustainable building features being recognized by appraisers were found, but their impact on final appraisal value was not. In general, the features being considered are those that are currently quantifiable. From those features, it was revealed they are not being recognized by all markets, and therefore not impacting final appraisal value. We conclude that it will be necessary to mitigate existing challenges and fulfill research and development needs in order for the building and real estate industries to realize the full potential of sustainability and its impact on property value.

**Appendix 1**

**Survey Questions**

These are multiple choice and short answer questions aimed at gathering quantitative and qualitative information to supplement data and information retrieved through the archival research process.

1. I have read and understood the above consent form and desire of my own free will to participate in this study.
2. What format do you follow in the appraisal process? Please check all answers that apply.
3. Are you aware of appraisal methods and practices to valuate sustainable building features that are implemented in real property today?
4. Have you appraised real property in which sustainable/green building features are incorporated into the valuation process?
5. When did you first notice sustainable features being incorporated into the appraisal process? Please check only one answer.

6. In which building category did you first notice sustainable features being incorporated into the appraisal process? Please check only one answer.

7. What building category do you most often appraise? Please check only one answer.

8. Based on the building category you most often appraise, which sustainable features are considered in the appraisal process? Please check all answers that apply.

9. Do you require documentation of any of those sustainable features to support the appraised value?

10. Which sustainable feature areas do you require documentation for validation of the appraisal? Please check all answers that apply.

11. Based on your experience, which sustainable features add the 3 most quality and economic value to a building appraisal? Please check all answers that apply.

12. What would be your preferred method of analysis to appraise the value of sustainable features in residential property?

13. In your opinion, what sustainable building attributes should be included in the appraisal process that are not currently used and why?

14. From your perspective, what information and/or tools used to valuate sustainable building features are needed but not currently available to you?

15. What building category do you most often appraise? Please check only one answer.

16. Have you been assigned to appraise real property in which any of the sustainable features listed above could be incorporated into the valuation process?

17. Which sustainable features were factors considered for appraisal in those assignments? Please check all answers that apply.

18. How satisfied are you in your ability to recognize the following sustainable features and their elements?

19. How would you rate your ability to appropriately valuate the following sustainable features and their elements?

20. There are opportunities for appraisers to gain additional experience and education on green building related to appraisal practice outside the mandated curriculum for appraiser licensure. Have you participated in any of the following?

21. Please describe the barriers that prevent you from participating in these opportunities.

22. From your perspective, what information and/or tools used to valuate sustainable building features are needed but not currently available to you?
References


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Californian Realtors’ Perceptions towards Energy-Efficient ‘‘Green’’ Housing

Author Sandy Bond

Abstract Realtors are seen as important enablers of behavior change toward a low-carbon future through the communication of sustainability measures to home buyers and sellers. In 2012/2013, research was conducted to assess Californian Realtors’ knowledge of, and perceptions towards, sustainable housing using an online survey instrument. The majority of respondents consider good insulation to be the most important feature to contribute to a more sustainable home, yet the green features that buyers most commonly ask about are dual-paned windows and tankless hot water. The biggest barriers to incorporating energy-efficient features into a home continue to focus on cost and poor access to information. Realtors could play a key role to overcoming barriers by providing accurate and relevant information to consumers to improve their understanding of energy efficiency and address misconceptions.

The Kyoto Protocol went into effect on February 16, 2005. It is an international environmental treaty designed to reduce greenhouse gas concentrations in the atmosphere to help address climate change. However, it has not yet been signed by two of the world’s largest emitter’s, the United States and China, which together are responsible for 45% of global greenhouse gas emissions. On November 12, 2014, these two countries announced new targets to reduce carbon pollution: President Barak Obama pledged that the U.S. would cut emissions 26%–28% below 2005 levels by 2025, while China pledged to cap emissions by 2030 and to increase its share of energy that does not come from fossil fuels to 20% by 2030 (The White House, 2014).

Over two-thirds (69.4%) of the electricity in the U.S. is generated by burning coal, petroleum, or natural gas; another 21% is generated by nuclear power stations; and less than 9% comes from renewable sources, with 7% of that from hydro dams. The burning of non-renewable energy sources to supply buildings with electricity makes buildings responsible for the largest share of U.S. carbon dioxide emissions. There are approximately 135 million buildings in the U.S., and 95% of these are homes. Buildings, primarily housing, account for 40% of total U.S. emissions, with 22% of the nations’ energy used on the housing sector (U.S. Department of Energy, 2010). The majority of homes were built prior to 2000 (89%) before the new energy codes that require energy-efficient features and that apply to new construction were introduced.

The U.S. Climate Change Science Program estimates that homes can achieve carbon emission reductions up to 70% with current best practices (McMahon,
McNeil, and Ramos, 2007) and the U.S. Department of Energy (2008a) Building America Program aims to reduce the energy use of new homes by 70% by 2020. Exhibit 1 shows that most of the energy used in a home goes towards heating and cooling. According to the U.S. Department of Energy (2008b), this use is often more affected by the size of the house than the number of occupants. Heating, cooling, and water heating are still the largest single energy end-uses in a home, despite the increased energy efficiency of this equipment. According to the U.S. Environmental Protection Agency (2012), air sealing coupled with insulating a home’s shell is often the most cost effective way to improve energy efficiency and comfort. Further, as windows can allow cold air to infiltrate (and hot air to escape) in winter and hot air to infiltrate (and air-conditioned cooler air to escape) in summer installing energy-efficient windows, doors, and skylights is also a cost-effective method to improve the energy efficiency of a home. If building, using a passive solar design is also cost effective.

In this paper, I report the results of an online survey of Californian Realtors’ perceptions towards energy-efficient “green” housing and how sustainable housing is perceived by buyers and sellers. The next section covers the literature review. The methodology is then outlined, with the results, conclusions, and recommendations following.

**Literature Review**

As mentioned above, it is the house size that affects the use of heating and cooling in a home and these uses consume the most energy. The average size of new houses in many countries has grown significantly over the past twenty years. Until 2008, the U.S. had the largest average size new home. Now Australia leads with the an average new single-family house size of 214.6 m$^2$, according to James (2009), followed by the U.S. at 201.5 m$^2$, New Zealand at 196.2 m$^2$, and Canada at 181 m$^2$.

At the same time, the average household size in the U.S. decreased to 2.54 persons per household (Statistica, 2014). Small households are less efficient as fewer people are sharing space and resources. Fortunately, the U.S. government is taking action to address the energy inefficiency of homes.

**Government Actions**

*Building Codes.* In the U.S., new building energy codes and legislation have been introduced on a state-by-state basis to improve the energy efficiency of homes (Exhibit 2). Thirty states have adopted the 2009 International Energy Conservation Code (IECC) or better. California, Illinois, Washington, and Washington D.C. have adopted the 2012 IECC. Adopting the 2012 IECC, with energy efficiency standards 28% stronger than the 2006 code, can help reduce carbon emissions in homes.

Issues identified by Sewalk and Throupe (2013) are that homes have insufficient insulation, with homes built before the 1970s having little or none. Window
glazing is another weakness, with windows being either single glazed or double glazed but with no argon or xenon gas. At least energy-efficient lighting, the replacement of incandescent with florescent lighting, is mandated by law.

However, requiring homes to be updated to meet building codes can have negative consequences such as making them less affordable to purchasers due to the additional cost required to update them, according to Sewalk and Throupe (2013). They analyzed the cost to bring homes into compliance with the 2012 projected energy code. Data was collected on 130 homes in Denver, Colorado. Homes ranged in value from $124,000 to $883,646, with an average price of $344,333 (standard deviation: $188,608). The average update cost was $22,091, and with an average term of home ownership of seven years would equate to $3,156 per year. However, most homeowners do not update their homes on an annual basis; rather this cost is incurred at the time of sale as it would be required to sell the home. This has the negative consequence of making it less affordable, and thus less appealing, to purchasers, unless the energy savings can compensate for the additional cost.

Mandatory Disclosure Regulations. A small number of U.S. states and cities have adopted building energy rating and disclosure laws to help meet their energy savings and carbon emissions reduction goals (Exhibit 3). The laws are designed to ensure that real estate markets value energy efficiency by requiring information about building energy performance to be disclosed to potential buyers, renters,
### Exhibit 2 | Building Energy Codes and Legislation in the U.S.


### Exhibit 3 | Mandatory Building Energy and Disclosure Laws

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Year Adopted</th>
<th>Policy Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austin TX</td>
<td>2008</td>
<td>Residential and commercial building rating and disclosure under the Energy Conservation Audit and Disclosure (ECAD) ordinance.</td>
</tr>
<tr>
<td>Kansas</td>
<td>2003</td>
<td>Asset rating and disclosure for new homes is required</td>
</tr>
<tr>
<td>Fayetteville, AK</td>
<td>2012</td>
<td>HERS rating required for new homes under the energy code.</td>
</tr>
<tr>
<td>New York State</td>
<td>1981</td>
<td>Truth in Heating Law requires residential building owners to disclose energy bills to prospective buyers and renters if requested.</td>
</tr>
</tbody>
</table>

**Note:** This table has been adapted from Hill and Dunsky (2013).
and the public. These mandatory disclosure laws can help transform markets by motivating voluntary energy efficiency upgrades.

Current building energy rating and disclosure policies and laws in place across the U.S. require property owners to evaluate their buildings using rating tools that measure either the building’s physical characteristics and mechanical equipment, referred to as an “asset rating,” or evaluate the actual energy performance of the building, called an “operational rating.” According to Hill and Dunsky (2013), these laws have so far focused solely on asset ratings, mainly due to the significant impact on energy consumption from occupant behavior that makes comparisons between homes difficult. However, voluntary operational ratings are available in many states. For example, the Department of Energy is supporting pilot programs in Massachusetts, Virginia, Alabama, and Washington that provide voluntary energy evaluations, including Energy Performance Score (EPS) ratings (based on energy use), as part of an efficiency upgrade and financing initiative.

The asset ratings assess the theoretical performance of the physical envelope and major systems of the home or building, using energy modeling software and diagnostic tests. A range of residential property asset rating tools and auditor certifications exist, including the Home Energy Score (HEScore), the Energy Performance Score (EPS), and the Home Energy Rating Score (HERS).

The HEScore was developed by the Lawrence Berkeley National Laboratory and launched in 2012. The Home Energy Score compares a building to a clearly defined baseline. It requires qualified professionals to conduct the assessment, and provides a label displaying how efficient a home is on a 10-point scale: a “1” applying to homes likely to use a lot of energy and a “10” corresponding to the most efficient homes. The calculation methodology takes into account local climate and applies standard assumptions regarding occupant behavior, providing a consistent, national, standardized approach. As of August 24, 2014, 12,984 homes have been scored (U.S. Department of Energy, 2014).

The Energy Performance Score (EPS) is an energy performance asset rating tool developed by the Earth Advantage Institute and the Energy Trust of Oregon. The EPS is a metric that reflects the energy and carbon impact for a home and allows for home-to-home comparison. It requires qualified professionals to conduct the assessment. It has three components: the audit, the scorecard, and the recommendation report to guide improvements in a cost effective manner (Energy Trust of Oregon, 2014). The scorecard shows the score from zero (most energy efficient) to 200 (least energy efficient). The score indicates the energy use per home (rather than by square foot) and the total energy use is converted to a kWh number.

The Home Energy Rating Score (HERS) is an energy performance asset rating tool developed by the Residential Energy Services Network (RESNET), an independent, non-profit organization to help homeowners reduce the cost of their utility bills by making their homes more energy efficient. The HERS Index Score compares a home’s energy rating against a “reference home,” a designed model home of the same size and shape as the actual home. The score requires a certified
RESNET HERS Rater to complete the energy rating (RESNET, 2014). Rated homes are provided with a score from zero (most energy efficient) to 150 (least energy efficient) with 100 being the reference home built to 2004 IECC code (Adams, 2012).

**Green Rating Labels for Homes**

The home rating labels (as opposed to scores) do not measure actual performance but verify that homes are designed and built to be energy and resource efficient. Like many of the above scoring types, they do not take occupant behavior into account and are generally only available for new builds. One of the first home rating systems in the U.S. was the ENERGY STAR for homes introduced in 1995. The ENERGY STAR program is jointly sponsored by the U.S. Environmental Protection Agency and the U.S. Department of Energy. There have been various versions of ENERGY STAR for homes with Version 3 introduced in 2012 taking into account new technology and new building codes and standards. The Energy Star Certified New Homes Market Indices for States compares the number of site built, single family ENERGY STAR certified new homes to the number of new privately owned one-unit homes permitted in each state. California has an ENERGY STAR Certified New Homes Market Index (share) between 10% and 19% with 153,338 ENERGY STAR certified homes built to date; 7,090 ENERGY STAR certified homes were built in 2012 (EPA, 2012).

An industry-led initiative by the U.S. Green Building Council (USGBC) is the LEED for Homes Rating System, introduced in 2008. By comparison to ENERGY STAR, as of June 2012, the USGBC only has 20,000 LEED certified homes (USGBC, 2012). California has 938 projects or 6,835 homes as at May 2013 (USGBC, 2013). In California, Build It Green is a membership-supported non-profit organization established in 2005 that developed the GreenPoint rating program for both new and existing homes. As of April 22, 2013, Build It Green has certified over 15,000 homes (Build It Green, 2013).

**Towards Sustainability in Homes**

The National Association of REALTORS® (NAR, 2014) emailed a survey of buyers’ home feature preferences. Using a random sample weighted to be representative of sales on a geographic basis, surveys were mailed to 72,206 home buyers in the U.S. who had purchased a home between July of 2013 and June of 2014. Consumer names and addresses were obtained from Experian, a firm that maintains an extensive database of recent home buyers derived from county records. A total of 6,572 responses were received, yielding a usable response rate of 9.4%. Heating and cooling costs were at least “somewhat” important to 86% of home buyers (down slightly from 88% in 2010). Energy-efficient appliances and energy-efficient lighting were “very” or “somewhat” important to two-thirds of home buyers. Landscaping for energy conservation and environmentally friendly community features had some importance to the decision of just under half of buyers. By region, environmentally friendly features varied in importance. Heating and cooling costs are more important to buyers in the Northeast and the
South than other regions. Energy-efficient lighting and landscaping for energy conservation are more important to buyers in the West than other regions. These results are comparable to the NAR (2010) results (111,004 U.S. consumers were mailed a survey, and 8,449 usable responses were received for 7.9% response rate). A new question in the 2014 survey asked about the importance to buyers of solar panels installed on the home with 89% responding that these are not important in their purchasing decisions.

Previous research and literature [e.g., a report by Noble and Martinelli (2009) in Australia, Bond (2010a) reporting on results of a postal survey of 1,250 randomly selected residents in Australia to identify their attitudes towards climate change and the drivers and barriers towards energy efficiency in the home, and Bond (2013) reporting on the results of a similar postal survey of 4,000 New Zealand to identify and explain user behavior in residential buildings in relation to the energy consumed] shows that factors affecting the willingness of householders to undertake sustainability improvements include the amount of time involved, effort required, level of comfort provided, and the cost and long pay-back periods. Shipworth (2000) outlines a range of strategies to motivate home energy action. She outlines when and what type of information motivates, as well as a range of financial incentives that can be used.

**The Cost of Going Green**

While a perceived barrier to investing in green buildings is that they cost more compared to conventional buildings, most studies to date are of commercial buildings and show the true cost to be negligible (Matthiessan and Morris, 2004, 2007; Ciochetti and Gowan, 2010). However, some tabulate the cost to be as high as 7% (Kats, 2003; Miller, Spivey, and Florance, 2008). These variances may be caused as much by how the researchers measure the cost premium (Morris, 2007), with some comparing the cost of a green project with the original project budget, or the cost of the building with individual added green features compared to the cost of the building without those features, while others compare the cost of a population of buildings without green features with a population containing green features. The latter approach was used in Australia by Davis Langdon (2007) to determine the cost of achieving specific levels of green (under the Australian Building Council Green Star rating system). They found that the initial impact on construction costs (above comparable non-green projects) is likely to be on the order of 3% to 5% for a 5-star solution, with an impact of a further 5% plus for a 6-star non-iconic design solution.

As found in Bond (2010b) and discussed in Morris (2007), sustainable features can be incorporated into most building types at little or no additional cost, especially if an integrated approach is taken early in the design process so that all building elements work together. In addition, it is helpful if all involved in the building process are on-board with the design, construction, and use of the building from the design team to the end user, including the construction team and building manager. Finally, many design teams make trade-offs—they can offset the costs of green features by reducing the extent of other expensive finishing materials.
Evidence of the Value of Green Rating for Homes

In 2007, the Australia Government (Department of the Environment, Water, Heritage and the Arts, 2008) conducted one of the first studies to determine if home buyers are willing to pay a price premium for sustainable homes. The Australian Capital Territory (ACT) was the first jurisdiction in Australia to introduce mandatory energy disclosure for all houses on the market in 1999. The Energy Efficiency Rating (EER) indicates the thermal performance of the building shell only and excludes the hot water and lighting system and other fixed or movable appliances. The output shows a star rating of between 1 and 10, with 10 being the most energy-efficient home. The study looked at whether a relationship exists between the EER of a house and the sale price. The sample consisted of over 5,000 homes that sold in 2005 and 2006 built before 1995 when new building regulation minimum energy performance standards were introduced that required new houses reach a 4-star energy standard (this stringency was increased to 5 stars through the Building Code of Australia in 2006). All houses built after 1995 were excluded from the dataset to avoid any impact of the new minimum performance standards. The average house size in the study sample was around 141 m$^2$ on a lot of 836 m$^2$ located in a suburban setting with an average energy performance just below 1.7 stars. The relationship of EER to price on average for 2005 was 2.5% for each 1 EER star and 3.8% in 2006, holding all other variables constant. However, when the study takes account of the energy label and energy efficiency characteristics of the house separately, the size of the label effect falls, but it remains positive and significant in almost all cases.

Khan and Kok (2012) examined at the market implications of a green rating on house price in California. The green ratings included the EPA’s ENERGY STAR Version 2 rating, LEED for Homes, and GreenPoint. The sample consisted of owner-occupied single-family homes that sold in California in 2007–2012: 4,231 green homes and 1,600,558 control homes. Seventy percent of the homes with a green label that were sold during this time period were new construction. Homes with a green rating sold for a premium of 12% on average, all other variables held constant. However, LEED for Homes and GreenPoint were insignificant in the models. For homes constructed in the last five years, the green-rated price premium was only 8.7%.

Brounen and Kok (2011) investigated the effect of energy performance certificates in the Netherlands. First, they looked at the factors that influence whether or not a home has an energy rating, and if a home does have an energy rating, they investigate the effect that has on the transaction price of the home. Their results indicate that larger buildings are less likely to have an energy label and that label adoption tends to be associated with difficult selling conditions. Homes with an A, B or C energy label (“green” labels) receive a price premium of 3.7% ceteris paribus. Homes with an A rating tend to sell at 10.2% higher than similar homes with a D rating. They also find that homes with a G rating sell at 5% less than similar D rated homes, all else being equal.

A review of the literature by Hyland, Lyons, and Lyons (2012) found that green buildings trade at a discount of 5.5% in Japan, energy performance certificates of
homes have limited effect on purchasing decisions in Germany, but in the Netherlands and Australia, buildings certified as energy efficient sell at a premium. This premium ranged from 2.5% for each star increase to 10.2% for an A rated home compared to a D rated home or on average, 3.7% for a green label: A, B or C. The authors conducted their own study in Ireland and found that energy efficiency has a positive effect on both the sales and rental prices of properties. The effect of the energy rating was found to be stronger where market conditions are worse, similar to the finding by Brounen and Kok (2011). The dataset comprised 397,258 properties listed for sale and 888,211 properties listed for rent from 2008 to 2012. Of these listings, the Building Energy Rating (BER) certificate was known for 5% of properties for sale and 2.3% of properties to let. Homes that had been assessed were given a rating from A1 to G (where A1 is the most efficient) on the basis of the efficiency of the space and water heating, ventilation, insulation, and lighting fixtures in the building and reported the carbon dioxide emissions associated with the building (expressed as kgCO$_2$/m$^2$/year). The results of the study show that, relative to obtaining a D energy rating, an A-rated property receives a price premium of 11%, while a B rating increases the price by 5.8%. At the other end of the scale, receiving an F or G rating reduces the price by 5.6%, ceteris paribus. These results are consistent with those of Brounen and Kok (2011).

**Summary**

This literature review has outlined the drivers to address the energy efficiency of homes such as stricter building codes, mandatory disclosure regulations, and the introduction of green rating labels. Further, it outlines studies undertaken of consumer attitudes towards sustainability. Generally, existing homes are still performing poorly in terms of energy and water efficiency, despite improvements to the building codes, the introduction of rating tools to measure energy efficiency, and the availability of subsidies and grants for energy efficient home improvements.

According to Knowles (2008), the climate challenge is fundamentally a built environment and behavior change challenge. Energy efficiency interventions and programs are failing to live up to their potential primarily due to the failure to facilitate building occupant and building industry behavioral change.

As outlined in Adams (2012), the information available on the home’s energy performance depends on the stakeholder involved. Exhibit 4 shows the many players within the residential real estate market that provide data on a home.

Adams (2012) reports that the Local Energy Alliance Program (LEAP) in Virginia, one of the partners to pilot the HEScore outlined previously, has successfully increased energy performance rating and reporting by working directly with real estate agents. LEAP is assisting real estate agents become proponents of energy performance reporting by helping them recognize that they can provide their clients with valuable energy efficiency expertise. Ultimately LEAP aims to encourage the local real estate association to include mandatory energy efficiency fields in Multiple Listing Service (MLS) property listings.
As realtors are the professionals that people communicate with when choosing to buy, sell or rent a house, the aim of the research was to determine their awareness and understanding of sustainability and the attitudes of buyers and sellers towards energy-efficient homes.

**Research**

The broad aim of this research was to identify (1) realtors’ awareness and understanding of sustainability features in homes, (2) realtors’ perceptions of their clients’ attitudes towards energy efficient or green labelled homes, and (3) how these perceptions impact the price homebuyers are willing to pay for energy-efficient homes. Knowledge of these factors can help identify ways to build capacity within the real estate profession to communicate sustainability measures to buyers, sellers, landlords, and renters that encourage behavioral change to a more environmentally conserving one and drive demand for energy-efficient homes.

**Methodology**

An email survey was the quickest and most cost-effective way of surveying a large sample of Californian realtors. A 30-question online survey was developed with
a cover letter introducing the research team and outlining the research’s purpose, how long the survey would take to complete, that individual responses would be kept confidential, how the results would be disseminated, and a statement confirming that the survey had Human Ethics Committee approval. Data entry and analysis of the results was carried out using SPSS and included descriptive statistics (frequency analysis of all categorical variables).

**Survey Sample**

Initially, Florida realtor were surveyed. A link to Qualtrics online survey was sent out by the NAR Green REsource Council to Green Designees on December 31, 2012 and to general (green or non-green) members of the Northeast Florida Association of REALTORS® (NEFAR). NEFAR placed the link along with a request for realtor participation on the “Members Only” portion of their website and included the same link and call for participation in a NEFAR Member Weekly Update e-blast that was sent on January 4, 2013. The requested return date was January 21, 2013. Reminders were sent out in the NAR Green REsource Council newsletter on January 28, 2013 and in the NEFAR Member Weekly Update e-blast on January 25 with the deadline extended to February 6, 2013. Unfortunately, the response rate was very low (nine). According to NEFAR Communications Director Melanie Green “it is very difficult to get Realtors to participate in surveys. We issue calls to action frequently, on a variety of topics, and the response rate is usually quite low, even when only a yes or no. The time commitment is always a challenge.” Similarly, Amanda Stinton, media contact for NAR’s Green REsource Council commented “We do have about four to five thousand people who receive the newsletter each month, of which only a couple of hundred would open and click through on something.”

To try to attract more respondents and to see if West Coast realtors have a different attitude to sustainability, we contacted the California REALTORS® Association, who agreed to send out the online link to a Californian-tailored survey to a random sample of their 155,000 members. They agreed to provide 5,000 members’ email addresses. The survey link was emailed to members on the February 28, 2013 with the due date March 11, 2013. To encourage participation, respondents were offered the chance to win one of two $100 Barnes and Noble gift vouchers. By providing their name and email, they had the choice to go into the draw, or not. Only nine responses were received a few days before the close date, so a reminder was sent on the March 9, 2013, which increased the response rate to 110 (84 completed surveys).

**Survey Instrument**

For comparative purposes, the questionnaire was modelled on one used in research conducted in Australia in 2010 and in New Zealand in 2012. However, each country’s survey differed slightly in the questions asked, as they were tailored to the circumstances specific to each country. The Californian questionnaire commenced by asking respondents about their level of real estate sales experience and how aware they think buyers are of factors relating to energy-efficient homes.
Next questions asked about their own level of motivation to act environmentally and about the home they live in: size, number of bedrooms and bathrooms, household composition and whether they consider the energy efficiency and water rating of appliances before purchasing them. Respondents were asked questions to assess their knowledge and understanding of climate change, sustainability issues, and energy-efficient features. Questions were included to determine their perceptions of what buyers look for when buying a home and whether energy efficient or sustainable features are important to them, what the benefits are of including these features in a home, and what acceptable level of additional cost they would be willing to incur to have these in their homes. Next they were asked what they consider the main barriers to incorporating sustainable features in a home, what could be done to overcome these, and what impact mandatory reporting of energy performance might have on the market. Demographic questions were included at the end of the survey. An electronic copy of the survey is available on request from the author.

The response format comprised mostly closed questions but with the options “Other, please specify” or “Not sure” so as not to confine respondents to the predefined responses. Some open questions were included to allow respondents to provide more detailed information about the data requested or to provide further explanation for their response selections. At the end of the survey, they were invited to make any further comments. In the closed questions, a variety of categorical, ranking, and scoring (Likert scale) response options were provided and included classification, knowledge, and perception type questions.

Summary of the Results

Response Rate and Demographics

From 5,000 realtors emailed with a follow up reminder, 110 responses were received (2.2% response rate) and 84 (1.7%) answered all questions. Demographic questions revealed that 75% of respondents were female. Nearly three quarters of the respondents (74%) were 50 years of age or older (41% aged 50–59; 33% aged 60 years or older); 14% were between 40–49 years of age and 10% between 30–39 years old. Nearly three quarters (74%) were California licensed sales agents and 25% were brokers, while 2% classified themselves as “other.”

Designation and Level of Experience

Respondents were asked what professional designations they have and from what groups. Responses were mixed. Of the 100 responses, 66% were NAR, of those, 35% said they were also CAR (23% of the total respondents). In addition to NAR and CAR, others had local designations such as Lodi, Oakland; San Diego; Orange County; Pasadena-Foothills; Silicon Valley; Central Valley; Placer County; Contra Costa; and Lakeland Associations of Realtors. Thirteen percent had the Certified Short Sale and Foreclosure Resource (SFR) designation, 5% were Certified Distressed Property Experts, and 3% were both of these. Twelve percent had the...
Graduate REALTOR® Institute (GRI) designation, which reflects real estate professionals who have secured a strong educational foundation. Less than 10% had the following designations: Certified Residential Specialists (CRS); the NAR E-Pro certification, e-PRO®; Senior Real Estate Specialists (SRES); Certified Negotiation Experts (CNE), and Certified HAFA (Home Affordable Foreclosure Alternatives Program) Specialists. Eleven percent said they had no designations.

Other designations listed by a few respondents included: Accredited Buyer’s Representative (ABR®); Resort and Second-Home Property Specialist (RSPS); Transnational Referral Certification (TRC Relocations); Equator Platinum Certificate; Counselors of Real Estate (CRE); Certified Design and Development Construction Professional (CDP) by the International Council of Shopping Centers; Certified Neighborhood Specialist, Accredited Land Consultant (ALC); LEED Accredited Professional, Residential Management Professional (RMP), and Certified Residential Brokerage Manager, and Certified Property Manager (CPM).

To determine respondents’ level of experience, we asked how many years they had been involved in selling real estate. Of the 110 that responded to this question, nearly half (48%) had over 10 years, 26% had 6–10 years, 12% had 1–5 years; 6% had less than one year, and 7% had “other.” Next we wanted to determine the price level they have experience in selling with this being fairly evenly spread. Of the 89 responses, on average 36% had were involved with selling property below $300,000, 33.5% between $300,000 and $500,000, and 30.4% were involved in selling homes worth over $500,000.

The number of homes respondents sold per month was 1.72, on average, with the range from 0 to 16; annually the average number of homes sold was 12.4, with the range from 0 to 50 homes. In terms of green-rated homes sold, only 12.5% (10) of respondents indicated that they had sold these homes, with the average number sold per annum been 4.4 (range: 1–20), indicating limited experience in selling green-rated homes.

**Size and Age of Home and Type of Home Buyer**

As the size of a home affects its energy efficiency, we asked respondents how big the homes are that they sell, on average. Nearly two-thirds (62.5%) of homes sold were less than 2,000 sq. ft., 26.8% were between 2,001 and 3,000 sq. ft., and 10.7% were over 3,000 sq. ft.

Newer homes tend to be more energy efficient than older ones as they need to meet more stringent building codes so we asked the age of homes sold. Over half (56%) of homes sold were older building stock (more than 20 years old), 37% were 2–19 years old, and only 7% were less than 2 years old (i.e., newer homes). We also wanted to know the types of home buyer that respondents were mainly dealing with: 40.6% on average were homes sold to families, 38% to singles and couples, 15.9% were to investors, and 5.5% to retirees.

**Buyer Awareness of Energy Efficiency**

To get an idea of how aware respondents think buyers are of the factors related to energy-efficient homes, we asked them to indicate using a Likert Scale of 1,
Exhibit 5 | Buyers’ Awareness of Energy Efficiency in Homes

<table>
<thead>
<tr>
<th>Rank</th>
<th>Response</th>
<th>Mean Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The benefits of having a sustainable energy and water efficient home</td>
<td>3.18</td>
</tr>
<tr>
<td>2</td>
<td>Utility company incentives for energy efficiency</td>
<td>3.25</td>
</tr>
<tr>
<td>3</td>
<td>Federal and state incentives or grants available to help fund energy</td>
<td>3.68</td>
</tr>
<tr>
<td></td>
<td>or water efficiency improvements to a home</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>The California Residential Code</td>
<td>3.73</td>
</tr>
<tr>
<td>5</td>
<td>Green rating home schemes, e.g., HERS index score, LEED for Homes</td>
<td>3.75</td>
</tr>
<tr>
<td>6</td>
<td>California energy efficiency legislation</td>
<td>3.85</td>
</tr>
<tr>
<td>7</td>
<td>The California Green Building Standards Code (CALGreen)</td>
<td>4.08</td>
</tr>
</tbody>
</table>

very aware to 5, very unaware various factors. A low mean score indicates more aware. Exhibit 5 indicates that buyers are most aware of the benefits of having a sustainable energy- and water-efficient home and least aware of the CALGreen code.

Respondents’ Level of Motivation to Act Environmentally

Next, the focus turned to respondent’s personal attitudes to sustainability, by asking how motivated they are to reduce their personal climate change emissions. Of the 85 responding, 69% of the participants were either highly (31%) or moderately (38%) motivated to reduce their impact on the environment, 12% were slightly motivated to, while 11% did not care either way. Surprisingly, given the media attention for the need to combat climate change, 7% were moderately unmotivated and 2% were highly unmotivated to reduce their personal climate change emissions.

In line with the above question, given that larger homes are more energy intensive to heat and cool, we wanted to know how big the homes are that respondents live in. As respondents may not know the size of their home in square feet, they were asked how many bedrooms their homes had, as a proxy for size. Of the 84 that responded, 48% had a 3-bedroom home, 25% had 4-bedrooms, and 10% had a large 5-bedroom home. Only 11% had a smaller 2-bedroom home, and 4% had 1 bedroom. Similarly, respondents were asked how many bathrooms their homes have, with 45% of them having two bathrooms, 25% had 3 bathrooms, 8% had 4 bathrooms, 4% had 5 bathrooms. Only 10% of homes had one bathroom, while 6% had 2.5 bathrooms. As research has shown that household size is decreasing, we asked how many people live in the home: 43% of respondents have 2 people, and 25% have 3 people, in line with the national average of 2.54.

Next we asked if respondent’s consider the energy efficiency or water rating of appliances before purchasing with nearly three-quarters (73%) saying they do, 17% say they do sometimes, and 11% do not consider this at all. Respondents
Exhibit 6 | List of Statements

<table>
<thead>
<tr>
<th>Rank</th>
<th>Statement</th>
<th>Mean Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Occupant behavior within the home has a strong impact on the use of energy.</td>
<td>4.16</td>
</tr>
<tr>
<td>2</td>
<td>The size of a home has a big impact on its energy efficiency.</td>
<td>3.51</td>
</tr>
<tr>
<td>3</td>
<td>Climate change can be addressed through improvements to energy efficiency in our homes.</td>
<td>3.46</td>
</tr>
<tr>
<td>4</td>
<td>It is important that buyers and tenants are informed of the likely energy performance of the home.</td>
<td>3.31</td>
</tr>
<tr>
<td>5</td>
<td>It is the role of realtor and property managers to inform buyers, sellers, landlords or tenants about sustainable features that are, or could be, implemented in a home.</td>
<td>3.01</td>
</tr>
<tr>
<td>6</td>
<td>I have experienced demand from buyers/renters looking for a home with sustainability features/improvements.</td>
<td>2.23</td>
</tr>
<tr>
<td>7</td>
<td>The materials a home is built with has little impact on its energy efficiency.</td>
<td>2.06</td>
</tr>
</tbody>
</table>

Respondents were invited to include any further comments in relation to energy-efficient homes. A number commented that while they consider the energy efficiency or water rating of appliances, that it is not the main consideration: reliability, quality, brand, style, and price are. Some respondents were quite negative, with one respondent commenting that they did not like the performance of an energy-efficient dishwasher so replaced it with an older but better performing one.

Perceptions about the Role of a Realtor: Sustainability and Environmental Issues

Respondents were directed to agree or disagree with various statements, using a five-point Likert scale. The aim of asking for agreement/disagreement on these statements was to ascertain the current level of understanding by participants on sustainability features within a building and whether they perceived these options to positively contribute to a more sustainable home. They most strongly agreed that occupant behavior within a home has a strong impact on the use of energy. The next most agreed with statement was that the size of a home has a big impact on its energy efficiency. Given the latter response, it is surprising that many respondents choose to live in large homes with 35% having a home with 4 or more bedrooms and 37% with 3 or more bathrooms in their homes. Exhibit 6 lists these statements.

Features that Contribute to a Sustainable Home

The aim of this question was to ascertain the level of respondent understanding of features within a home and how these features contribute to the sustainability
of the home. These questions covered thermal performance aspects of design, energy- and water-efficient products, solar passive design principles or other lifestyle features known to impact a home’s environmental sustainability (U.S. EPA, 2012). Respondents were asked to rank these features from 1, most important to 10 least important. Exhibit 7 lists these features. Some of the features were added that do not necessarily contribute to sustainability to test what respondents really know and understand.

Respondents were asked how often homebuyers ask them about green features, such as those described above. Responses were mixed with 70% indicating never (32%) or seldom (38%). Just over a quarter (28%) responded that they are occasionally asked and 3% said “frequently.”

Next, respondents were asked, that if homebuyers ask realtors about green features, which three green features do they ask about most commonly. The features listed most frequently were windows (including dual paned, 22). In decreasing order of frequency of listed features were: air conditioning/heating (17), appliances (11), insulation (10), and solar. Other green features listed included water heater, orientation of the home, recycled materials, natural/sustainable wood, light bulbs, native plant landscaping, pool equipment, age and size of the home, and transportation. Some of the features were not strictly green features and others were clearly not related, such as school district, price, granite counter tops, and taxes.

**Buyers Interest in Green Homes**

To find out if buyers interest in green features has changed over time and given the increasing global attention to climate change, we asked respondents if they get asked more now about green features than five years ago. A third of the
respondents get asked more frequently, and 62% are asked about the same amount as five years ago.

**Financing Options Available for Green Homes**

Given that research shows that cost is a reason many homeowners do not buy green homes or more energy-efficient products, respondents were asked if there were more financing options available for green homes that might motivate buyers to invest in these compared to five years ago. Over two-thirds of the respondents were not sure about the availability of financing options for green homes, 17% said there were not more, and 14% said that there were.

Those that responded that there are more financing options available now than five years ago were invited to specify what these are. Responses included tax rebates, manufacturers discount, “Energy Upgrade California,” and the FHA 203K Loan. However, there may be some misunderstanding about the FHA 302K loan as it is not specifically for green homes but for remodeling and updating homes that may or may not make them more energy efficient. What FHA does offer is the Energy Efficient Mortgage Loan program, which is available to anyone who meets the income requirements for FHA’s Section 203(b) fixed-rate mortgage loan. Similarly, Energy Upgrade California is also not a financing option for green homes but instead directs consumers to a resource that has information about available financing, rebates, and incentive programs.

**Information on Green Homes**

We wanted to know if respondents had sourced information on sustainability for homes, including energy and water efficiency measures, rebates or incentives in the last 12 months and if so what source they used for this from a range of listed options. Nearly a third (32%) of respondents said they had sourced this information. The main sources used included the websites of utility companies, local counties, and the federal government. These are indicated in Exhibit 8.

**Housing Characteristics Most Important to Buyers**

To determine how important energy efficiency is as a housing characteristic, respondents were asked to rank from a list of typical housing characteristics what they consider to be the most important factors to buyers (or renters) in their purchasing (renting) decisions. As outlined in Exhibit 9, not surprisingly, price/rent was ranked as most important, with location next. However, low energy efficiency was ranked surprisingly low given how this can significantly increase the comfort of a home by being warmer, dryer, and easier to heat and cool, while also saving on utility costs.

Under “other,” respondents included attached locked garage, good weather for retirement, and crime rate. In terms of number of bedrooms, respondents listed between two to four were most preferred, and more than one bathroom (ranging from 1.5 to 2.5). In terms of floor areas, where respondents specified this, over
1,500 sq. ft. was the most common response with the range of the desired house size being between 1,500 and 2,500 sq. ft.

**Benefits Incorporating Sustainable Features into a Home**

Respondents were asked what they consider, from a home-buyers perspective, are the most important benefits of sustainable features. Exhibit 10 indicates that reduced home running costs was considered the most important benefit, followed by increased property value, and reduced maintenance costs was ranked third. Further comments from respondents included that these items are very important to over 55 year olds and indoor air quality particularly relevant for people with allergies or those who with asthma or respiratory issues.

**Accepted Additional Cost for Incorporating Energy/Water Saving Features**

Respondents were asked for their perceptions of what homebuyers would consider to be an acceptable level of additional cost for incorporating energy/water savings features into a home. Just over a quarter (26%) felt that consumers would be willing to pay 6%–10% more, and 25% felt they would be willing to pay 1%–5% more. A quarter of respondents felt that consumers would not pay any more for these features, and 18% were not sure.

**Energy- and Water-Efficient Features Demanded by Homebuyers and Renters**

Respondents were asked what energy- and water-efficient products or sustainable building design features are buyers and renters asking for in the marketplace. The most commonly listed feature by respondents was dual-paned windows, followed by tankless hot water. Insulation and solar hot water heating were listed next most
Exhibit 9  | Housing Characteristics Most Preferred

<table>
<thead>
<tr>
<th>Rank</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Price / rent</td>
</tr>
<tr>
<td>2</td>
<td>Location (good neighborhood, school zone)</td>
</tr>
<tr>
<td>3</td>
<td>Number of bedrooms</td>
</tr>
<tr>
<td>4</td>
<td>Floor area (sq. ft.)</td>
</tr>
<tr>
<td>5</td>
<td>Number of bathrooms</td>
</tr>
<tr>
<td>6</td>
<td>Proximity to amenities &amp; public transport</td>
</tr>
<tr>
<td>7</td>
<td>Energy efficiency (e.g., full insulation)</td>
</tr>
<tr>
<td>8</td>
<td>Other, please specify</td>
</tr>
</tbody>
</table>

frequently by an equal number of respondents. Energy-efficient appliances and air-conditioning were listed less frequently and only two respondents listed the following: energy efficient lighting, attic fans, low flush toilets, and ceiling fans. Some respondents claimed that no green features are being asked about, with a couple mentioning that buyers are most worried about cost. Another respondent said that demand for green features depends on price, with buyers of homes over $550,000 wanting these features and buyers of low-cost homes not been concerned, but are just hopeful the home already has insulation. Another respondent said that most of their sales are of investment properties and that these owners just want to do the minimum (fresh paint, clean carpets, etc.) and are not concerned about sustainable features. These responses indicate that the type of home, price range, and type of buyer are all relevant as to how important green features are to buyers.

Information about Green Ratings Realtors Communicate to Clients

We asked respondents if they are informing buyers about the green rating of a home, if it has one, with just over half (51%) saying they do, and 39% saying they may in the future, with the remaining 10% saying that they do not. It would be interesting to know the reasons why more respondents do not share this information, but may be due to their lack of experience with such homes given the low number of green-rated homes, particularly for existing stock. ENERGY STAR rated homes, which has the majority of green-rated homes in California, compared to LEED for Homes and GreenPoint rates homes, still has only 10%–19% of the market share (EPA, 2012).

Barriers to Incorporating Sustainable Features and Suggestions to Improve Uptake

Respondents were directed to rank a list of potential barriers to the incorporation of sustainable features into homes, from 1 most important to 9, least important. A summary of the results are outlined in Exhibit 11.
### Exhibit 10 | Benefits of Incorporating Sustainable Features

<table>
<thead>
<tr>
<th>Rank</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reduced home running costs</td>
</tr>
<tr>
<td>2</td>
<td>Increased property value</td>
</tr>
<tr>
<td>3</td>
<td>Reduced maintenance costs</td>
</tr>
<tr>
<td>4</td>
<td>Comfortable home temperature</td>
</tr>
<tr>
<td>5</td>
<td>Healthy indoor air quality</td>
</tr>
<tr>
<td>6</td>
<td>Decreased obsolescence</td>
</tr>
<tr>
<td>7</td>
<td>Reducing environmental impact</td>
</tr>
<tr>
<td>8</td>
<td>Other, please specify</td>
</tr>
</tbody>
</table>

### Exhibit 11 | Barriers to Incorporating Sustainable Features

<table>
<thead>
<tr>
<th>Rank</th>
<th>Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High cost/low benefit of features</td>
</tr>
<tr>
<td>2</td>
<td>Unwillingness to pay additional cost</td>
</tr>
<tr>
<td>3</td>
<td>Poor access to information</td>
</tr>
<tr>
<td>4</td>
<td>Unreliable or unproven technology</td>
</tr>
<tr>
<td>5</td>
<td>Lack of owner/occupier awareness</td>
</tr>
<tr>
<td>6</td>
<td>Limited availability to new technology</td>
</tr>
<tr>
<td>7</td>
<td>Difficulty getting local permits</td>
</tr>
<tr>
<td>8</td>
<td>Lack of developer awareness</td>
</tr>
<tr>
<td>9</td>
<td>Other</td>
</tr>
</tbody>
</table>

Respondents felt that the high cost/low benefit of features was the main barrier, followed by unwillingness to pay additional costs. It appears from the results to the last two questions that respondents and their clients are cost-focused but that this may be more perception than reality given that the literature indicates negligible cost premiums for incorporating sustainable features in buildings. Other comments respondents made include high cost, long payback period, not enough qualified people to install the technology or they do not install it correctly, and poor access to financing. Developers are more interested in providing homes that are affordable and sell.

### Improving Uptake of Energy/Water Saving Features in Designs of Homes

Respondents were asked to rank items that they think would improve the uptake and incorporation of energy or water saving features into the design of new and
Exhibit 12 | Improving Uptake of Sustainable Features

<table>
<thead>
<tr>
<th>Rank</th>
<th>Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>More rebates/subsidies</td>
</tr>
<tr>
<td>2</td>
<td>Building code changes</td>
</tr>
<tr>
<td>3</td>
<td>Better advertising of housing sustainability</td>
</tr>
<tr>
<td>4</td>
<td>Availability of products</td>
</tr>
<tr>
<td>5</td>
<td>Changes to legislation</td>
</tr>
<tr>
<td>6</td>
<td>Building certification</td>
</tr>
<tr>
<td>7</td>
<td>Mandatory disclosure</td>
</tr>
<tr>
<td>8</td>
<td>Other</td>
</tr>
</tbody>
</table>

retrofitted homes. The three most important features that respondents felt would help, in decreasing order of importance, were more rebates and subsidies, building code changes, and better advertising of housing sustainability. The preference shown for more rebates and subsidies is consistent with the feedback from the previous question, which indicated that high cost/low benefit of features and unwillingness to pay additional cost were the primary barriers for incorporating sustainable features. Exhibit 12 outlines these results.

**Perceived Impacts of Mandatory Disclosure**

Interestingly, the mandatory disclosure of energy performance of the building was not ranked highly in the above question. Focusing on mandatory reporting, the next question asked respondents to indicate whether they thought that, if mandatory reporting of the energy performance of homes via energy audits or ratings is introduced would their clients be willing to pay more for a home with a higher HERS, LEED, GreenPoint Rated, or ENERGY STAR rating that indicates a property has a superior energy performance. Only a quarter said yes to this question, over half (52%) were unsure, and the remaining 23% said that did not think their clients would pay more.

The next question asked respondents that if the reporting of the energy performance of homes becomes mandatory, what they think the impact would be on existing home values in their market, with 44% responding that it would reduce their value. Given that existing homes may be older, less efficient stock, the response is not surprising. Over a quarter (27%) of the respondents were not sure what impact it would have, 17% said it would make no difference, and 11% said it would likely increase their value.

**Further Comments**

Respondents were invited to make additional comments. These highlighted some of the issues that dissuades buyers from considering a home with sustainable
features or that are more energy efficient, with many relating to the perception of high additional cost and long payback periods. Some respondents felt that people should have free choice, and that any energy saving devices or greening of homes should be voluntary and not mandatory. Typical comments included: “This would be an expensive proposition people cannot afford”; “The concern is that the state will mandate that homes be retrofitted with all kinds of energy-efficient items. If this happens, a large percentage of properties will lose value and will be difficult to sell.” Conversely, a respondent stated that all counties and cities must adopt a standard green code for permitting for new and renovated homes. “The market will begin to adopt a new baseline and the idea we call green or sustainable will become normal.” Optimistically, one respondent feels that the younger generation will demand more sustainable, energy-efficient homes to ensure the continuation of a healthy environment.

Research Limitations

Due to the very low response rate in Florida for the initial survey, a second attempt was made to survey realtors in California. Although the response rate was higher, it was still relatively low given the sample size of 5,000 CAR members. Therefore, the respondents surveyed may not be representative of the Californian realtor population.

Conclusion

This paper outlines the results of an online survey of California realtors’ perceptions towards energy-efficient “green” housing and how sustainable housing is perceived by buyers. As realtors play a major role in informing and educating buyers and sellers when purchasing a home, they are considered to be an important stakeholder group within the residential housing market that can enable behavioral change.

Despite the low response rate, the results are informative. The majority of respondents have either the NAR or the CAR designation and nearly half have over ten years’ experience selling real estate. Over two-thirds of them were either highly or moderately motivated to reduce their own impact on the environment. While nearly three-quarters of respondents consider the energy efficiency or water rating of appliances before purchasing any item, a number said this is not their main consideration: reliability, quality, brand, style, and price are.

Few realtors had experienced demand from buyers/renters looking for a home with sustainability features/improvements. The majority of respondents consider good insulation to be the most important feature contributing to a more sustainable home, yet the green features buyers most commonly ask them about are dual-paned windows and tankless hot water, followed by insulation and solar hot water heating. The most important benefits of sustainable features from the home buyer’s perspective is reduced home running costs and increased property value.

Respondents ranked the main barriers to the incorporation of sustainable features into homes to be the high costs/low benefits of features, followed by unwillingness
to pay the additional cost, and poor access to information. Indeed, it seems the perception of high cost may relate more to poor information, as in reality, as shown in the literature, the cost of including sustainable features can be minimal.

The most important things that might improve the uptake and incorporation of energy or water saving features into the design of new homes and retrofitting of existing homes identified by respondents were more subsidies and rebates, changes to building codes, and better advertising of housing sustainability. The latter could be aided by including relevant data and fields on the Multiple Listing Service (MLS).

As outlined in a report by the United Nations Environment Programme Sustainable Construction and Building Initiative (2007), the right mix of appropriate government regulation, greater use of energy saving technologies, and behavioral change can substantially reduce CO\textsubscript{2} emissions from the building sector. To aid this, realtors could play a key role in providing information to consumers to improve their understanding of energy efficiency, address misconceptions (particularly those relating to cost of incorporating sustainable features into a home), and reframe perceptions of energy efficiency to something measurable, affordable, and financially and environmentally beneficial. However, to do this, they too need education about sustainability measures and products to ensure they provide meaningful, accurate, and relevant information to their clients to help them prepare for changes towards a low-carbon future. Further, ongoing training of realtors to keep them up-to-date on the latest research relating to the costs, benefits, and payback periods of green features would aid this.

**Endnotes**


3. The words REALTORS and realtor/s will be used interchangeably, but mean those real estate professionals who are members of the NAR.

4. The Green REsource Council was founded to make the knowledge of green real estate practices available by providing sustainable education to real estate agents. They award students who successfully complete the program requirements with NAR’s Green Designation.

**References**


C a l i f o r n i a n  R e a l t o r s ’  P e r c e p t i o n s


This research was supported by a Lincoln University Graduate Assistant Package. In kind support was provided by the California REALTORS® Association, who agreed to send out the online survey link to a random sample of 5,000 of their members. With thanks to the capable help of Nadiah Annur, research associate, Lincoln University, who aided in the collection and collation of the data.

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

Authors Thomas Braun and Sven Bienert

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 (Eichholtz, 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>113.39</td>
<td>141.28</td>
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<td><strong>Panel B: 95% outer ZIP Code ring</strong></td>
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<td>947</td>
<td>1,409</td>
<td>1,445</td>
<td>927</td>
<td>1,009</td>
<td>1,165</td>
<td>801</td>
<td>854</td>
<td>9,125</td>
</tr>
<tr>
<td>Max</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>11</td>
<td>22</td>
<td>81</td>
<td>105</td>
<td>150</td>
<td>85</td>
<td>126</td>
<td>155</td>
<td>91</td>
<td>91</td>
<td>879</td>
</tr>
<tr>
<td>Mean</td>
<td>0.05</td>
<td>0.28</td>
<td>0.23</td>
<td>0.49</td>
<td>0.71</td>
<td>1.44</td>
<td>2.32</td>
<td>9.19</td>
<td>13.68</td>
<td>14.03</td>
<td>9.13</td>
<td>9.80</td>
<td>11.31</td>
<td>7.78</td>
<td>8.29</td>
<td>88.39</td>
</tr>
<tr>
<td>Var</td>
<td>0.07</td>
<td>0.44</td>
<td>0.32</td>
<td>0.76</td>
<td>2.25</td>
<td>5.60</td>
<td>11.71</td>
<td>176.92</td>
<td>596.87</td>
<td>230.71</td>
<td>327.97</td>
<td>440.14</td>
<td>254.33</td>
<td>231.93</td>
<td>21,107.58</td>
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</tr>
<tr>
<td>Mean GFA</td>
<td>270,800</td>
<td>128,498</td>
<td>122,829</td>
<td>108,142</td>
<td>122,842</td>
<td>132,906</td>
<td>166,915</td>
<td>167,685</td>
<td>158,965</td>
<td>102,330</td>
<td>129,012</td>
<td>152,136</td>
<td>163,215</td>
<td>142,924</td>
<td>149,793</td>
<td></td>
</tr>
<tr>
<td><strong>Panel C: Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>7</td>
<td>35</td>
<td>33</td>
<td>71</td>
<td>115</td>
<td>242</td>
<td>411</td>
<td>1,368</td>
<td>1,994</td>
<td>1,990</td>
<td>1,316</td>
<td>1,479</td>
<td>1,668</td>
<td>1,283</td>
<td>1,315</td>
<td>13,322</td>
</tr>
<tr>
<td>Max</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>10</td>
<td>19</td>
<td>38</td>
<td>120</td>
<td>163</td>
<td>203</td>
<td>121</td>
<td>197</td>
<td>222</td>
<td>152</td>
<td>147</td>
<td>1,328</td>
</tr>
<tr>
<td>Mean</td>
<td>0.07</td>
<td>0.34</td>
<td>0.32</td>
<td>0.69</td>
<td>1.12</td>
<td>2.35</td>
<td>3.99</td>
<td>13.23</td>
<td>19.36</td>
<td>19.32</td>
<td>12.78</td>
<td>14.36</td>
<td>14.19</td>
<td>12.46</td>
<td>12.77</td>
<td>129.34</td>
</tr>
<tr>
<td>Var</td>
<td>0.08</td>
<td>0.70</td>
<td>0.53</td>
<td>1.51</td>
<td>4.61</td>
<td>16.46</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>988.28</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>206,008</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

Legend:
- 5% Inner ZIP Code Ring
- 95% Outer ZIP Code Ring
- LEED Registered Buildings
**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>Category</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>Mean</td>
<td>16.07%</td>
<td>31.54%</td>
<td>39.18%</td>
</tr>
<tr>
<td>Certified LEED buildings until 2014</td>
<td>15.00%</td>
<td>31.50%</td>
<td>39.50%</td>
</tr>
<tr>
<td>Certified LEED platinum &amp; gold buildings until 2014</td>
<td>20.91%</td>
<td>39.92%</td>
<td>47.52%</td>
</tr>
<tr>
<td>Certified LEED silver &amp; certified buildings until 2014</td>
<td>12.44%</td>
<td>25.25%</td>
<td>32.93%</td>
</tr>
<tr>
<td>Certified LEED BD+C until 2014</td>
<td>8.88%</td>
<td>23.37%</td>
<td>32.71%</td>
</tr>
<tr>
<td>Registered LEED O+M until 2014</td>
<td>18.59%</td>
<td>34.31%</td>
<td>40.38%</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); and +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 Charette (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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Assessing the Implementation of Mandating Energy Efficiency: Boulder, Colorado’s Implementation of SmartRegs

Authors Scott Glick, Caroline M. Clevenger, and Mark Laverty

Abstract On January 3, 2011, the City of Boulder, Colorado implemented the SmartRegs ordinances updating the city’s housing and rental licensing code by mandating baseline efficiency requirements for rental housing units. We examine the SmartRegs inspector training program relative to the prescriptive path checklist for compliance and quality assurance controls from inception through the first quarter of 2014. We find that discrepancies in quality control audits may be the result of the training and certification program not adequately preparing inspectors for the field observations needed to competently complete inspections. This may be due to improper planning of implementation policies.

The impact of building performance on the environment is an international concern. How to best address the topic remains problematic. Typically two strategies are employed to achieve an improvement in building performance: performance-based measures or prescriptive mandates. In both cases the measurement of outcomes continues to be difficult. In an effort to impact building performance in all European Union (EU) member states, the Energy Performance of Buildings Directive (EPDB) system was adopted in 2002 and updated in 2010 (Burr, 2012). A 2012 review by Burr of the EU EPDB identified several challenges that continue to impede the adoption of the EPDB in several member states including lack of standardization, rating program being hard to understand, and the poor quality of the assessors reviewing the building performance.

In the United States, the construction industry is a main contributor to the depletion of natural resources, air and water pollution, solid waste, deforestation, toxic wastes, health hazards, and other negative consequences (Augenbroe, Pearce, and Kibert, 1998). As awareness of sustainability has increased, the construction industry has been challenged by the public and government to reduce the environmental impacts of both new and existing buildings.

Building codes originally emanated as life safety protections but have evolved to be tools that effect subjects related to health, welfare, and energy efficiency. Over the past decade, many codes have turned into legislation. For example, the Waxman-Markey climate bill of 2009 required that by 2014 all states enact residential building codes 30% more stringent than the 2006 International Energy...
Conservation Code Standard. By 2017, the target is 50% higher with an additional 5% efficiency increase every three years thereafter until 2029.

Drafting building codes is a complex process and their implementation requires resources, planning, and commitment. Jacobsen and Kotchen (2013) state that changes in energy codes may not affect building infrastructure if the codes are not effectively enforced or are not sufficiently stringent to be binding. When successfully implemented, building codes that address energy efficiency are valuable tools in helping to reduce energy use. Research suggests that while codes differ from region to region, and offer varying energy saving potential, adoption typically results in energy savings (Nelson, 2012).

The U.S., like other countries, has a wide range of climate zones, and building technologies vary from region to region. Specifically, climate variations present different sets of regional sustainability issues. As a result, building codes vary from state to state and typically reference model codes that are then adopted by local entities (Laustsen, 2008). Subsequently, each city has the power to adopt its own building code in addition to federal and state mandates. In Colorado, Section 6 of Article XX of the Colorado Constitution, “home rule,” grants to each city or town of two thousand or more inhabitants the power to make, amend, add to, or replace a charter that serves as its organic law, extending to all its local and municipal matters.

The attributes of buildings and construction processes have changed over time with the advent of new materials and construction methods potentially impeding energy efficiency focused regulations. Such factors contribute to the difficulties of establishing effective policy measures to achieve greater energy efficiency (Ryghaug and Sorensen, 2009). In addition there are also building owners who will not occupy the building and therefore may not be concerned with future energy costs or the quality of the indoor environment. Lovell (2005) points out that a common perception of owners is that any additional investment in energy efficiency will benefit others and lower their return on investment since rents are typically determined by location, design, accessibility, and size, not energy efficiency. In sharp contrast to this point of view, Stein, Braun, Salvador Vilia, and Binding (2015) argue that buildings built to be energy efficient generally outperform those that are not when factors like occupancy, value, and rental level are taken into account.

**SmartRegs**

In 2002, the City of Boulder, Colorado passed resolution 906 commonly referred to as the climate action plan (CAP). This plan established the goal of reducing greenhouse gas (GHG) emissions by 7%, compared to 1990 levels, by 2012 bringing the city into accordance with the 1997 Kyoto Protocol. The bulk of these reductions were to come from the commercial, transportation, and residential sectors, which comprised 90% of Boulder’s 2007 total emissions (Rocky Mountain Institute, 2012). In 2006, Boulder voters became the first in the country to pass a
CAP tax in support of these goals. The CAP tax was extended in 2012 and currently provides $1,800,000 annually for six programs aimed at reducing GHG emissions. The City did an assessment of potential GHG sources and identified the residential rental housing market as an area where significant GHG reductions were possible.

The City of Boulder had concerns that rental property owners were merely passing on inefficient building operating costs to tenants instead of making efficiency related repairs or improvements to properties. In response, the City of Boulder developed the SmartRegs Ordinance (SmartRegs), which was adopted on September 21, 2010, and went into effect on January 3, 2011. The SmartRegs key policy outcome mandated that all rental properties meet minimum energy efficiency standards by 2019.

SmartRegs provides both a performance and prescriptive path to achieve compliance. The performance path requires a comprehensive energy audit: measurements of all building dimensions and individual components, air leakage and duct leakage testing, and energy modeling to produce a HERS Index. If the rental unit receives a HERS Index of 120 or less, it is compliant with the ordinance. The prescriptive path assigns point values to specific building components. A score of 100 is considered equivalent to a HERS score of 120. The prescriptive path requires that a SmartRegs inspector perform the audit and award points across 18 sections: walls, windows/fenestration, ceilings, infiltration, slab/foundation, duct leakage, distribution system, heating, cooling, whole house fans, lighting, water heating, refrigeration, solar thermal, photovoltaics, occupant behavior, other, and mandatory water conservation.

**Inspector Qualifications and Training**

In order to qualify as a SmartRegs inspector, an individual must hold a City of Boulder General Contractor Class “G” license, pass the SmartRegs inspector examination, and hold one or more of the following: (1) City of Boulder (COB) License D-9 or General A, B, or C Contractor License; (2) All A, B, and C Licenses must be International Code Council (ICC) Certified; (3) Qualified License Design Professional (architect or engineer); (4) ICC Certified Combination Inspector; (5) American Society of Home Inspectors (ASHI) or National Association of Home Inspectors (NAHI) Certified Home Inspector; (6) ICC Certified Residential or Commercial Energy Inspector; or (7) RESNET Certification.

The City sponsored SmartRegs Inspector training program is four hours long. It is offered four times per calendar year, and at the time of this writing, all training was conducted by a single employee of Populus, LLC. Populus was hired in 2010 by the City to create the prescriptive checklist, write the SmartRegs Guidebook for the SmartRegs training program, and deliver the in-person trainings. At the end of the training, all participants complete the training exam consisting of 23 multiple choice questions worth 40 points (point values range from 1–6 points per question). The passing score is 75%.
**Implementation**

Boulder’s housing stock currently includes approximately 20,000 rental units (City of Boulder, n.d.). Properties that need to meet the SmartRegs requirements and choose the prescriptive path are inspected by a licensed SmartRegs inspector.

In April 2012, the Consortium for Advanced Residential Buildings (CARB), in cooperation with the Department of Energy (DOE) and National Renewable Energy Laboratory (NREL), published a report evaluating the SmartRegs Ordinance. As part of the evaluation, the team verified, using 12 actual building audits, that a perspective path score of 100 was approximately the equivalent of a performance path 120 HERS rating score. However, an additional part of the findings was that any major deficiencies between the performance and prescriptive path scores were primarily due to inspector error. Specifically, inspectors were making incorrect assumptions regarding the efficiency of building components and systems resulting in inflated prescriptive scores (Arena and Vijayakumar, 2012).

We build on this report and perform an in-depth assessment of the SmartRegs training program by examining the training program’s exam results and comparing them to the CARB’s team audits of actual SmartRegs prescriptive path inspections. Exhibit 1 is a diagram of the relationship between the SmartRegs Program and the CAP tax in general, as well as the focus of this research.

**Methodology**

The goal of this research is to ascertain the level to which the prescriptive path implemented to date has achieved the goals of SmartRegs. We performed an exploratory study using a descriptive case study methodology. A case study is a methodology used to describe an intervention within the real-life context in which it occurred (Yin, 2003). The criteria for its use are: (1) the focus of the study is to answer “how” and “why” questions, (2) researchers cannot manipulate the behavior of those involved in the study, (3) researchers explore contextual conditions because they believe they are relevant to the phenomenon under study, or (4) the boundaries are not clear between the phenomenon and context (Yin, 2003). The descriptive case study format can provide both qualitative and quantitative information to help answer research questions. The specific questions for this research were: (1) How is knowledge transfer lost between the SmartRegs training program and field inspector application? (2) How does knowledge loss impact the accuracy and quality of the inspections measured by discrepancies between initial and follow-up inspections using the prescriptive path checklist in the field?

To effectively answer these questions, we identified and analyzed: (1) variables in the training and exam portion of the SmartRegs inspectors; and (2) inconsistencies in initial inspection data and subsequent follow-up quality assurance inspections (audit) where applicable. We collected 94 SmartRegs Inspector Certification Exam results for tests administered from January 2012 through February 2014. In addition, we collected background information on people who had taken the exam
over that same time period through the use of surveys and SmartRegs inspector applications provided to the City of Boulder.

The SmartRegs training exam consists of 23 questions, with point values of 1–6 points, for a total of 40 possible points. Two versions of the exam are administered; Versions A and B. Many of the individuals during the period of study attempted the exam on more than one occasion. The exams, given from 2012 to 2014, represent 69 individuals and 94 total test scores. Of the 69
individuals who took an exam during this time, 29 provided additional data regarding the specific qualifications that each possessed making them eligible for a “G” license. The breakdown is as follows:

1. D-9 with no additional specific certification information: 6 individuals
2. D-9 possessing a Mechanical Class “C” License: 6 individuals
3. D-9 possessing either General Contractor Class “B” or “C” License: 3 individuals
4. ICC Certified Inspector: 2 individuals
5. RESNET Certification: 1 individual
6. ASHI/NAHI Certification: 2 individuals
7. Populus Employees (most RESNET certified): 9 individuals

D-9 contractors must provide one of the following: ICC or ICBO certification, ASHI registration, A, B or C city contractor license, and an architect or engineer registration. In addition, 13 of these 29 individuals had at least one and as many as eight quality assurance follow-up inspections, chosen randomly from a small N, for a total of 37 follow-up inspections conducted by Populus in 2013.

Finally, we had access to an internal report generated for the City of Boulder that contained the results of randomly chosen quality assurance inspection audits performed by Populus. However, each quality assurance inspection was dependent on voluntary owner participation and access to the rental unit. All quality assurance inspections followed the same prescriptive path checklist as the original inspections performed by City of Boulder licensed SmartRegs inspectors.

In the following section, we analyze 69 SmartRegs training exam results of would-be inspectors, as well as the audit results of 37 actual field inspections performed by qualified SmartRegs inspectors (those who passed the SmartRegs training program).

### Analysis and Results

The average non-weighted pass/fail score per question for both Versions A and B of the SmartRegs exams during the period of study, as well as the area of focus for each question tested is shown in Exhibit 2. The non-weighted average score is shown as a percentage out of 40 total points per exam and shows the same trend as a weighted point value would since all exam versions and pass/fail scores used the same denominator of 40 points. The focus of the exam questions are identical for both versions, however there are small differences in the examples used. Specifically, several questions were identical for focus and content, but typically have one variable that is different between the two versions. For example, for questions that tested knowledge of “Walls,” Version A referenced walls constructed using 2 by 4 framing members, while Version B referenced walls constructed using 2 by 6 framing members.

It is interesting to note that 9 of the 23 questions for Versions A and B in the passing category have a variance of more than 10 non-weighted percentage points.
### Exhibit 2 | Per Question Average Non-weighted Score for Versions A and B of the SmartRegs Exam

<table>
<thead>
<tr>
<th>Question</th>
<th>Points</th>
<th>Exam A</th>
<th>Exam B</th>
<th>Focus of Exam Question</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pass</td>
<td>Fail</td>
<td>Pass</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>76%</td>
<td>50%</td>
<td>83%</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>64%</td>
<td>45%</td>
<td>47%</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>52%</td>
<td>47%</td>
<td>57%</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>100%</td>
<td>57%</td>
<td>90%</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>81%</td>
<td>70%</td>
<td>93%</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>67%</td>
<td>60%</td>
<td>53%</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>76%</td>
<td>67%</td>
<td>93%</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>64%</td>
<td>30%</td>
<td>65%</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>90%</td>
<td>50%</td>
<td>80%</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>89%</td>
<td>57%</td>
<td>87%</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>95%</td>
<td>63%</td>
<td>93%</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>62%</td>
<td>67%</td>
<td>87%</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>90%</td>
<td>83%</td>
<td>93%</td>
</tr>
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<td>14</td>
<td>1</td>
<td>81%</td>
<td>60%</td>
<td>93%</td>
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<td>15</td>
<td>1</td>
<td>81%</td>
<td>40%</td>
<td>87%</td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td>81%</td>
<td>52%</td>
<td>87%</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>81%</td>
<td>63%</td>
<td>93%</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>90%</td>
<td>53%</td>
<td>87%</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td>86%</td>
<td>50%</td>
<td>93%</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>86%</td>
<td>63%</td>
<td>100%</td>
</tr>
<tr>
<td>21</td>
<td>1</td>
<td>100%</td>
<td>33%</td>
<td>87%</td>
</tr>
<tr>
<td>22</td>
<td>1</td>
<td>95%</td>
<td>63%</td>
<td>93%</td>
</tr>
<tr>
<td>23</td>
<td>6</td>
<td>83%</td>
<td>43%</td>
<td>82%</td>
</tr>
</tbody>
</table>

For Versions A and B failing scores regarding question numbers 5, 17, 19, 20, and 22, all Version B test takers scored above a non-weighted 75%, while Version A test takers scored below a non-weighted 75%.

### Relationship of Qualifications to Test Results

The individual respondent’s qualifications or certifications were reviewed to see if there were any observable correlations to the exam score. The score variance is illustrated in Exhibit 3 and shows the overall score percentages for the five groups identified previously for passing scores on both exam versions. Each individual possessing a RESNET and ASHI/NAHI certification passed exam Version B, but failed in a previous attempt at Version A.
Exhibit 3 | Average Passing Score for 29 Individuals by Specific Qualification

Average Passing Score by Candidate Qualifications vs. Group Average

Note that the scores total to 27 as two candidates did not fill in information about specific qualifications in the additional data collection phase.

For Version A, all passing scores are within three percentage points from the group average. For Version B, all passing scores are within 6 percentage points, with the exception of the D-9 group, which scored 10 percentage points higher than the overall group average. In reviewing all passing scores by individual qualification versus the overall candidate group, there were no noticeable variances that would suggest that a certain qualification makes one individual perform better than another on the exam.

The scores for those that failed indicate that the Version A respondents had average scores that were lower than those taking Version B of the exam (Exhibit 4). For all groups, the score variance was within 5 percentage points with the exception of the D9 group, who scored almost 20 percentage points lower on Version A.

Inspector Scores and Quality Assurance

In January of 2014, Populus was asked by the City of Boulder to put together a quality assurance report for inspections that had been performed by SmartRegs inspectors in 2013. In total, 37 inspections were performed and 13 separate inspectors were audited and the discrepancies were noted in the report.

Of the 37 quality inspections completed by Populus in 2013, 36 are summarized (Exhibit 5) to show the corresponding averages for questions on exam Versions A and B, what the question content area was, and the percentage that question content was the cause of a point discrepancy in an audit. We excluded one inspector from the analysis results shown in Exhibit 5 as no record of a passing exam score was provided.
Note that the scores total to 27 as two candidates did not fill in information about specific qualifications in the additional data collection phase.

The items with over a 20% issue rate include walls, windows/fenestration, refrigeration, and water conservation (Exhibit 5). The first item, walls, has attributes that are not easily determinable once the structure is finished. The windows are quite observable, as are refrigeration and water conservation. The items with 10%–19% incidences include walls, ceilings, infiltration, distribution systems, heating, and floors/foundations. These items by their nature are more complex than three of the four in the over 20% category; walls is in both categories. The topic of walls is covered in two exam questions. Respondents on both exam versions passed question one on walls and the audit score was 11%. Question 2 on both exams had a failing average score and had a 22% incidence on the audits.

Exam question 3 measured the respondent’s knowledge of windows/fenestration, and it is the only remaining content category that has a failing average score on both exams, and has the second highest rate of discrepancy on audits. The topic of refrigeration, question 17, has the highest audit score variance at 39% yet the exam average scores are 81% and 93% depending on the exam version. Water conservation, question 21, is the next highest area for audit point issues at 19%. However the exam scores suggest that content knowledge was quite high; 100% and 87% depending on the version.

The remaining content areas are ceilings, question 5, infiltration, question 7, distribution system, heating, floors/foundations, and question 10, all at 11%. In the eight areas with over 10% point discrepancies, the average scores for exam Version A were higher in only two content areas, water conservation and walls (question 2). The rest of the average scores were higher in exam Version B with the exception of question 10, distribution systems, heating, floors/foundations, where the average scores were very similar; 89% and 87%.
### Exhibit 5 | Summary of Quality Assurance Audits

<table>
<thead>
<tr>
<th>Question</th>
<th>Exam A</th>
<th>Exam B</th>
<th>Audit Results</th>
<th>Content Focus of Exam Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>76</td>
<td>83</td>
<td>11</td>
<td>Walls</td>
</tr>
<tr>
<td>2</td>
<td>64</td>
<td>47</td>
<td>22</td>
<td>Walls</td>
</tr>
<tr>
<td>3</td>
<td>52</td>
<td>57</td>
<td>33</td>
<td>Windows / Fenestration</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>90</td>
<td>3</td>
<td>Windows / Fenestration</td>
</tr>
<tr>
<td>5</td>
<td>81</td>
<td>93</td>
<td>11</td>
<td>Ceilings</td>
</tr>
<tr>
<td>6</td>
<td>67</td>
<td>53</td>
<td>6</td>
<td>Ceilings</td>
</tr>
<tr>
<td>7</td>
<td>76</td>
<td>93</td>
<td>11</td>
<td>Infiltration</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
<td>65</td>
<td>6</td>
<td>Floors / Foundations, Walls</td>
</tr>
<tr>
<td>9</td>
<td>90</td>
<td>80</td>
<td>0</td>
<td>Duct Leakage</td>
</tr>
<tr>
<td>10</td>
<td>89</td>
<td>87</td>
<td>11</td>
<td>Distribution System, Heating, Floors / Foundations</td>
</tr>
<tr>
<td>11</td>
<td>95</td>
<td>93</td>
<td>6</td>
<td>Distribution System, Floor / Foundations</td>
</tr>
<tr>
<td>12</td>
<td>62</td>
<td>87</td>
<td>6</td>
<td>Heating</td>
</tr>
<tr>
<td>13</td>
<td>90</td>
<td>93</td>
<td>3</td>
<td>Cooling</td>
</tr>
<tr>
<td>14</td>
<td>81</td>
<td>93</td>
<td>3</td>
<td>Cooling</td>
</tr>
<tr>
<td>15</td>
<td>81</td>
<td>87</td>
<td>3</td>
<td>Lighting</td>
</tr>
<tr>
<td>16</td>
<td>81</td>
<td>87</td>
<td>8</td>
<td>Heating / Hot Water</td>
</tr>
<tr>
<td>17</td>
<td>81</td>
<td>93</td>
<td>36</td>
<td>Refrigeration</td>
</tr>
<tr>
<td>18</td>
<td>90</td>
<td>87</td>
<td>0</td>
<td>Solar Thermal</td>
</tr>
<tr>
<td>19</td>
<td>86</td>
<td>93</td>
<td>8</td>
<td>Hot Water</td>
</tr>
<tr>
<td>20</td>
<td>86</td>
<td>100</td>
<td>0</td>
<td>Heating</td>
</tr>
<tr>
<td>21</td>
<td>100</td>
<td>87</td>
<td>19</td>
<td>Water Conservation</td>
</tr>
<tr>
<td>22</td>
<td>95</td>
<td>93</td>
<td>0</td>
<td>SmartRegs Compliance (T/F Question)</td>
</tr>
<tr>
<td>23</td>
<td>83</td>
<td>82</td>
<td>0</td>
<td>Sample Checklist</td>
</tr>
</tbody>
</table>

**Notes:** The bolded items represent those that were missed on at least 20% of all quality assurance inspections performed. The shaded cells are those items that were missed 10%–19% of the time.

The relationship of the exam scores for the inspectors with one or more audits to the average point discrepancy for the 2013 audits is shown in Exhibit 6. The point discrepancy number is the difference between what the initial inspector awarded and what the Populus inspector determined were the correct points for each category of the prescriptive path checklist. This means that the point discrepancy does not necessarily equate to the difference in score for the prescriptive path checklist, since it is possible for some errors to cancel each other out. For example, an audit may have determined that an inspector failed to award 10 points in one category, but over-awarded 10 points in another. In this scenario, the discrepancy is 20 points, but the inspector and auditor will have the same total score for the checklist.
The implementation of a new regulation is always problematic and time is needed to work through structural issues. There is a high probability that SmartRegs was passed to meet a political promise with little or no thought being given to implementation of the policy. This is evidenced by the fragmented implementation and oversight from adoption to the time this article was written. Once adopted, the SmartRegs program was assigned to an individual with no involvement with the creation and adoption of the policy. Four years later, the individual who took over the oversight after the adoption phase was no longer employed with the City of Boulder and a new person took over with no training or understanding of the historical reasons this regulation was put in place. In addition, the department with oversight is operating without the appropriate resources, direction, or support needed. Within this context, the outcomes of the program are in line with the resources provided.

The current oversight of the SmartRegs program provides few institutional quality controls as evidenced by the high failure rate of follow-up audits of previously inspected homes. Most of the quality control processes, education, training, inspections, and quality assurance for the prescriptive path are contracted to third parties who write their own training and test documents. It appears that pressure, either real or perceived, on the city council to meet the Climate Action Plan goals did not include a sufficient time allotment to properly plan the SmartRegs implementation strategy, pilot testing, and participant buy-in. As of March 9, 2015, 831 SmartRegs inspections had been completed with 7,089 total rental units found to be SmartRegs compliant (performance and prescriptive combined). Based on the U.S. Census (n.d.) from 2009 to 2013, there are approximately 20,971 renter-
occupied housing units in the City of Boulder. This number suggests that 34% of all occupied rental housing stock in Boulder is now compliant with SmartRegs. In order to meet the compliance deadline of December 31, 2018, the remaining 13,882 units need to be inspected at a rate of approximately 15 units per day. Given the current structure of the SmartRegs program, quality issues, and the limited number of inspectors, it is unclear if the process can accommodate the work required to meet the statutory compliance deadline.

The impact of SmartRegs on the cost of renting in Boulder has not been determined. In typical rental markets the market establishes an equilibrium rental unit value. In a case where regulation mandates efficiency upgrades to all rental units that are controlled through a licensure program, it could be assumed that all rents could rise as the compliance costs are passed through to the renter. This is the issue that Boulder was concerned with when SmartRegs was established to ensure that inefficiency costs were not passed on to the renters. Once the compliance deadline of 2019 passes, there is an opportunity to study the rental market in Boulder to see if the overall cost of renting has increased as a result of the SmartRegs requirements.

**Conclusion**

Based on the experiences of the EU EPBD and the ongoing impediments to that directives success as outlined by Burr (2012), it appears that there are similarities in the implementation of the SmartRegs program in Boulder: lack of standardization, rating system hard to understand, and poor inspector quality. SmartRegs research results suggest there is little to no impact of exam version on the test outcome (Exhibit 2); the overall passing score averages are within 1 percentage point for both test versions (80% for A, 81% for B). The impact of individual qualifications appears to be minimal as well. The average scores are within six percentage points for all groups, with the exception of the D-9 Version B group, which is 10 percentage points higher than the average (Exhibit 1). To address the first research question, “How is knowledge transfer lost between the SmartRegs training program and field inspector application?” it appears that the knowledge may not have existed to be lost. There appears to be eight main areas that the SmartRegs inspectors are consistently missing in the field determined by the discrepancy of points between the initial inspection and the audit. Of these eight areas, four have discrepancies of over 20% and the remaining four have discrepancies of over 10%. This may suggest a lack of standardization for the training process in these areas, difficulty in explaining certain construction methods by Populus, the company who wrote the training manual and the inspector certification tests. This brings us to the second research question.

In trying to determine “How does knowledge loss impact the accuracy and quality of the inspections measured by discrepancies between initial and follow-up inspections using the prescriptive path checklist in the field?” the analysis results highlight two main categories. The two categories with over 20% point discrepancy were the walls and windows/fenestration categories. These are also two categories in which exam takers scored the lowest percentages for both exam
versions. This may suggest that the inspectors are not grasping the concepts during the training sessions, and are continuing to struggle with the application of these concepts in the field. According to the quality assurance results for the water conservation category, more than one of every three SmartRegs inspections failed to correctly identify and assign proper point values. However, Populus inspectors noted that many of the qualifying components, such as low flow faucets and showerheads, had been removed from the time of the original inspection, which suggests results may have more to do with occupant behavior and preferences than inspector error. For the refrigeration category, more than half of all SmartRegs inspections failed to properly identify the type of refrigerator. This oversight is concerning given the fact that most refrigerators are marked with energy consumption information and inspectors only need to select the correct amount of points from a table that the inspectors are given.

The issue of wall and ceiling misidentification might be resolved in several ways. First, inspectors could perform a small destructive test of a wall or ceiling to verify the materials used. Second, new inspectors with failing exam scores in the eight problematic content areas could be required to visit several sites with more experienced inspectors.

There was no apparent trend of missed test question content areas and deficiencies found on follow-up audits, although in the case of the walls and windows/ fenestration categories, the exam averages were below 65% for all versions and these categories had two of the three highest point variances on follow-up audits. For the other six problematic content areas, anecdotal evidence suggests that the SmartRegs exam may not be an accurate measure of the skills needed as a SmartRegs inspector. Prior to the initial implementation phase of the SmartRegs regulation, the City of Boulder may not have spent sufficient time developing the education, validation, and examination processes to be successful. This assumption is supported by the outsourcing of all three areas to one company, Populus.

Having eight content areas where significant issues occurred raises the issue of examination validity. To date, the questions on the examinations have not been validated to ensure they actually measure the intended content area. Once this issue is resolved, the passing score on the examination should be reviewed to see if the score needed to pass needs to be increased. In some cases, the respondent took the examination multiple times prior to passing, which may also introduce exam related bias. To help eliminate this possibility there could be remedial education after the first exam on missed content areas, there could be a limit on the number of times the exam could be taken, or a mandatory waiting period between examinations could be instituted.

Similar to the case of the EU directive, a proper understanding of both the education and rating systems is necessary in order to develop an effective training and testing program. A review of the points assigned to each content area indicates that a passing score could be attained without understanding the eight problem areas identified by the audits. It may be helpful to review the test and make passing impossible without getting a majority of the eight questions correct. To help increase the understanding in these eight areas, the use of educational mock-up
building sections may be warranted. These could include several wall, ceiling, and floor sections based on the industry standards at several points in time to help inspectors anticipate what to expect when inspecting a home. The use of a continuing education requirement could also help inspectors learn from other inspector’s experiences and could be done live or using a virtual platform. An additional condition of licensure could include a requirement to perform a minimum number of inspections per year that meet a required accuracy rate. Finally, if a higher score on the exam means less point variance on audits, then the score to pass the certification exam could be raised to help limit the point discrepancies in the field.

References


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2014 AMERICAN REAL ESTATE SOCIETY
JOURNAL MANUSCRIPT PRIZE WINNERS

Journal of Real Estate Research
Best paper in 2014 volume as selected by the ARES membership.

Houses and Apartments: Similar Assets, Different Financials
Peter Chinloy, Prashant K. Das, and Jonathan A. Wiley
36:4, 409–34

Journal of Real Estate Portfolio Management
Best paper in 2014 volume as selected by the ARES membership.

Did the Recent Financial Crisis Impact Integration between the Real Estate and Stock Markets?
Kimberly F. Luchtenberg and Michael J. Seiler
20:1, 1–20

Congratulations to all the authors.
The American Real Estate Society proudly announces the following manuscript prize winners for research papers presented at the American Real Estate Society's 31st Annual Meeting in Ft. Myers, Florida, April 2015.


**CoStar Data**, sponsored by the CoStar Group: Green Buildings: Similar to Other Premium Buildings?, by Spenser Robinson, Central Michigan University, and Andrew Sanderford, University of Arizona.

**Housing**, sponsored by the Lucas Institute for Real Estate Development and Finance at Florida Gulf Coast University: Sentiment-based Predictions of Housing Market Turning Points with Google Trends, by Marian Dietzel, University of Regensburg.

**Industrial Real Estate**, sponsored by the NAIOPI Research Foundation: Industrial Real Estate Cycles: Markov Chain Applications, by Richard Evans, University of Memphis, and Glenn Mueller, University of Denver.

**Innovative Thinking “Thinking Out of the Box,”** sponsored by the Homer Hoyt Institute (HHI): Asset Pricing, Spatial Linkages, and Contagion in Real Estate Stocks, by Stanimira Milcheva, University of Reading, and Bing Zhu, University of Regensburg.


**Mixed Use Properties**, sponsored by the NAIOPI Research Foundation: Valuing the Conversion Option Afforded by Form-based Zoning in Different Economic Environments, by Keener Hughes, University of North Carolina-Charlotte, and Dustin Read, Virginia Tech.

**Office Buildings/Office Parks**, sponsored by the NAIOPI Research Foundation: The Quadruple Bottom Line: Tenant Views of Corporate Responsibility in Green Office Buildings, by Robert Simons, Cleveland State University, Spenser Robinson, Central Michigan University, Eunkyu Lee, Cleveland State University, and Albert Bragg, Cleveland State University.

**Property/Asset Management**, sponsored by the Institute of Real Estate Management (IREM): Which Green Office Building Features do Tenants Pay for: A Study of Observed Rental Effects, by Robert Simons, Cleveland State University, Spenser Robinson, Central Michigan University, and Eunkyu Lee, Cleveland State University.

**Real Estate Brokerage/Agency**, sponsored by the National Association of Realtors (NAR®): Bargaining, Mortgage Financing and Housing Prices, by Zhenguo Lin, Florida International University, Yingchun Liu, University of North Texas, and Kun Bian, Longwood University.


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**Real Estate Investment**, sponsored by the Education Foundation of the CCIM Institute: The 4% Rule: Does Real Estate Make a Difference?, by David Downs, Virginia Commonwealth University, Greg MacKinnon, Pension Real Estate Association, and Eli Beracha, Florida International University.

**Real Estate Investment Trusts**, sponsored by the National Association of Real Estate Investment Trusts (NAREIT): Financial Flexibility and REITs Security Issuance Decisions, by Woei C. Wong, Universiti Utara Malaysia, and Joseph Ooi, National University of Singapore.

**Real Estate Market Analysis**, sponsored by CBRE Econometric Advisors: Know Thy Neighbor: The Impact of Cultural and Geographic Distance on Information Asymmetry, by David Harrison, University of Central Florida, George Cashman, Marquette University, and Hainan Sheng, Texas Tech University.

**Real Estate Portfolio Management**, sponsored by the Royal Institution of Chartered Surveyors (RICS): Determinants of Foreign versus Domestic Real Estate Investment: Property-Level Evidence from Listed Real Estate Investment Firms, by McKay Price, Lehigh University, and Nathan Mauck, University of Missouri-Kansas City.

**Real Estate Valuation**, sponsored by the appraisal Institute (AI): Illuminating the Impacts of Brownfield Redevelopments on Neighboring Housing Prices: Case of Cuyahoga County, Ohio, by Ayounng Woo, Texas A&M University, and Supje Lee, Han Yang University.


**Seniors Housing**, sponsored by the National Investment Center for the Seniors Housing and Care Industry (NIC): The Effect of Age-Restricted Housing on Surrounding House Prices, by Karen Gibler, Georgia State University, Tanja Tyvima, Tampere University of Technology, and Velma Zahirovic-Herbert, University of Georgia.

**Sustainable Real Estate**, sponsored by the NAIOPI Research Foundation: Financial Impact of LEED and Energy Star Certifications on Hotel Revenues, by Spenser Robinson, Central Michigan University, Arjun Singh, Michigan State University, and Prashant Das, Eco hoteliere de Lausanne.

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Determinants of Demand (Fall, 1991): Sponsored by NAR.
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Real Estate Investment (Fall, 1992): Sponsored by the Pension Real Estate Association.
Corporate Real Estate (Fall, 1993): Sponsored by the International Association of Corporate Real Estate Executives (NACORE).
Real Estate Brokerage (Winter, 1995).
REITs (1995: Vol. 10(3/4)): Sponsored by the National Association of Real Estate Investment Trusts (NAREIT) and Equitable Real Estate Investment Management.
International Real Estate Investment (1996: Vol. 11(2)): Sponsored by Jones Lang Wootton USA.
International Real Estate Investment (1997: Vol. 13(3)): Sponsored by Jones Lang Wootton USA.
REITs (1998: Vol. 16(3)): Sponsored by the National Association of Real Estate Investment Trusts.
Corporate Real Estate (1999: Vol. 17(3)): Sponsored by NACORE International.
Cycles in Real Estate (1999: Vol. 18(1)): Sponsored by PricewaterhouseCoopers and SynerMark Investments.
Corporate Real Estate (2001: Vol. 22(1/2)): Sponsored by NACORE International.
Multifamily Housing (2003: Vol. 25(2)): Sponsored by Freddie Mac.
Issues For Inner-City Real Estate Markets: (2003: Vol. 25(4)): Sponsored by the Real Estate Research Center of Morehouse College.
Chinese Real Estate Markets: (2012: Vol. 34(3)).


1996: Megatrends in Retail Real Estate (co-sponsored by ICSC: 378 pages).

1997: Seniors Housing (sponsored by the National Investment Center for the Seniors Housing and Care Industries: 248 pages).


2006/8: Indigenous Peoples and Real Estate Valuation Issues (co-sponsored by the Appraisal Institute Education Trust and the Appraisers Research Foundation).

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CoStar Group will provide a $2,500 manuscript prize for the best research paper presented at the ARES Annual Meeting that uses CoStar data. CoStar has comprehensive, detailed property level information and up to 15 years of historical data in most major markets throughout the U.S. and U.K. They currently track approximately 1.6 million commercial properties totaling 30 billion square feet and have verified comparable sales data on approximately 1.3 million sales transactions—all property types, including retail, multifamily, hospitality and land. Anyone interested in obtaining CoStar data for research purposes should contact:

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JRER Legacy Awards Winners

The American Real Estate Society (ARES) Legacy Awards are for the three best papers published in the *Journal of Real Estate Research (JRER)* in selected years. The awards are $25,000, $10,000, and $5,000. The 2012 Awards below were determined by the votes of the *JRER* Editorial Board. The awards cover the period 2009–2011.

<table>
<thead>
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<th>Year Published</th>
<th>Amount</th>
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<tbody>
<tr>
<td>2011</td>
<td>$25,000</td>
<td>Nasser Daneshvary, Terrence M. Clauretie, &amp; Ahmad Kader</td>
<td>Short-Term Own-Price and Spillover Effects of Distressed Residential Properties: The Case of a Housing Crash</td>
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<tr>
<td>2010</td>
<td>$10,000</td>
<td>Gary Pivo &amp; Jeffrey D. Fisher</td>
<td>Income, Value and Returns in Socially Responsible Office Properties</td>
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Journal of Sustainable Real Estate
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Journal of Sustainable Real Estate

The American Real Estate Society announces a call for papers for the 8th volume of the Journal of Sustainable Real Estate (JOSRE). Authors are encouraged to submit original research that can help investors, developers, appraisers, lenders, asset managers, elected government officials, and land use regulators improve their strategies, decision making, and understanding of the impact of sustainable real estate practices. Topics and questions of interest include, but are not limited to, the following:

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- Can we learn anything from some of the incentive systems versus requirement systems in terms of effectiveness and efficiency?

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- What financing mechanisms are out there to help with sustainable investments? What impediments?
- How do insurance costs vary for sustainable buildings?

Hi-Performance Building Systems
- What is the impact of green buildings on worker productivity and morale, or retail sales, and benefits that go beyond energy savings? Can these be valued? Do they or will they eventually translate into rent?
- How have building management systems evolved and what is the state of the art? Why does it take so long for property owners to embrace new building management systems and to connect all the features and systems in a building?

Corporate Green and Sustainable Strategies and Policies
- How many public and private companies have green policy statements? How has this affected real estate decisions?
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- What are the new technologies and strategies affecting water consumption? Are they cost effective?

Evaluating Retrofit and Improvements versus Payoffs
- What is the ideal timing to invest in green features? Can green features be packaged into ideal combinations?

Net Zero and Living Building Challenge Case Studies, Strategies and Lessons Learned
- What can we learn from net zero and or net water buildings?
- Are the strategies used in the living buildings challenge applicable to the private sector?

All manuscripts are subject to anonymous double-blind review by practicing professionals and academicians. Manuscripts must be written to be understandable by institutional real estate investors; lengthy formulas and mathematics should appear in an appendix. Applied empirical studies will be given preference. Style guidelines are available online at www.josre.org and on the ARES website www.aresnet.org. Submissions are preferred in MS Word or PDF format. DEADLINE: March 31, 2016 (continuous online publication). Authors should submit their manuscript to Myla Wilson, the managing editor, at mwilson@sandiego.edu or greenjournal@sandiego.edu and to Norm Miller at nmiller@sandiego.edu.

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All submitted manuscripts are subject to double-blind peer review by members of the journal’s Editorial Board and other real estate scholars and professionals. Electronic submissions are strongly encouraged, either as email attachments, CD-ROM or disk. Preferable word processing format is as a PDF or Microsoft Word file. Paper submissions require four copies of the manuscript. The JHR style is similar to the Journal of Real Estate Research (see www.aresnet.org or a copy of the journal for a style guide). Final revisions must be in Word, WordPerfect or other acceptable word-processing program.

Manuscripts should be original, unpublished works not under publication consideration anywhere else. Manuscripts should be submitted via the automated author submission system for the journal at: http://www.editorialmanager.com/jhr.

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Call for Papers

Journal of Real Estate Practice and Education

The American Real Estate Society announces a Call for Papers for the Journal of Real Estate Practice and Education (JREPE). The purpose of the JREPE is to motivate research in real estate practice and education and encourage excellence in teaching. It provides a basis for the exchange of innovative opinions and research results among real estate practicing professionals, educators and researchers internationally.

The goal of the Journal is to make a significant advancement in the teaching and learning of real estate practice and education. The contributions from its content will provide an essential source of information on the teaching of real estate and become critical to the understanding of practice and education in the real estate area.

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Four hard copies of the manuscript should be submitted along with an electronic file in Microsoft Word or WordPerfect 6.0. Editorial guidelines printed in a current issue of the Journal of Real Estate Research should be followed. The JREPE is published biannually.

Manuscripts should be submitted via the automated author submission system for the journal at: http://www.editorialmanager.com/jrepe.

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Call for Papers

Journal of Real Estate Portfolio Management

The Journal of Real Estate Portfolio Management (JREPM) is a publication of the American Real Estate Society (ARES). The Journal's purpose is to disseminate applied research on real estate investment and portfolio management. JREPM endeavors to publish research covering all four quadrants of the real estate universe (private equity, public equity, private debt, and public debt), and strives to present research covering real estate markets globally. A goal of JREPM is to publish research that is both academically sound and of value to practicing institutional real estate investment professionals. The Editorial Board of JREPM is interested in expanding the frontiers of scholarly research in real estate investment and portfolio management and is willing to work with any potential author who is developing new and exciting ideas appropriate for publication in the Journal.

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1. “Longer Articles” are the standard and will comprise the majority of papers in each issue. They are expected to provide original research and insights on issues related to commercial real estate using rigorous methodologies.
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Both types of papers will undergo a blind review process. Peng Liu (Cornell University), Greg MacKinnon (Pension Real Estate Association), and Simon Stevenson (University of Reading), the editors of the journal, strongly encourage submissions from both the academic and practitioner research communities in both Longer and Shorter Articles sections.

For ARES members there is no charge for submitting a manuscript. For non-members, a submission fee in the amount of one year’s academic membership dues is required and should be made payable to ARES. An annual membership is included in this fee. Submission via email is required. Initial submissions should be in Word or PDF format. All submissions and other correspondence should be sent to: jrepm@cornell.edu.
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Journal Objectives
The Journal of Sustainable Real Estate (JOSRE) is an official publication of the American Real Estate Society (ARES). JOSRE is committed to publishing the highest quality analytical, empirical, and clinical research that is useful to business decision-makers in the fields of real estate development, economics, finance, investment, law, management, marketing, secondary markets, and valuation. Theoretical papers that fail to provide testable or policy implications are discouraged. Data used in empirical research must be thoroughly documented and sufficient details of computations and methodologies must be provided to allow duplication. Authors are encouraged to provide data (at a reasonable cost) for replication purpose should such a request arise.

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Submission Requirements
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Each manuscript should include at the end of the text, a non-technical summary statement of the main conclusions.

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Illustrations must be titled and numbered consecutively as exhibits with Arabic numbers. Please check that the text contains a reference to each exhibit. Verify that all numerical amounts add up to totals shown in the tables and that significant digits are rounded to no more than 2 or 3 numbers. All figures need to be sharp, clear and laser-quality. Exhibits in the final version must not be in color.

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Acknowledgment
Authors may include a brief acknowledgment. It should appear after the references.

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