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We are pleased to present the fifth volume of the *Journal of Sustainable Real Estate*. We continue to believe that electronic journals will prove superior to hard copy journals in several ways; authors can use color in pictures and charts, and embed links and even videos. We accept, edit, and publish papers within a given year’s volume as they are processed and then format them into a final issue.

We continue to benefit from the financial support of CoStar for this publication, but next year will also receive support from the Land Economics Foundation with a special issue on environmental factors affecting real estate. Volume 6 will be printed as well as online and will include two guest editors, Frank Clayton and Dan Winkler.

In this volume we have some papers on behavior such as the one by Wilkinson, Der Kallen, and Kuan, one on efficiency of LEED credits and the question of gaming the system by Mehdizadeh, Fischer, and Celozza, one on residential property and the feasibility of reduced greenhouse gas emissions by Sewalk and Throupe, one on the willingness to pay for green set in Sweden by Zalejska-Jonsson and a similar topic studied in Switzerland by Wiencke, one on the adoption of green technology by Malkani and Starik, one on transportation efficiency, walkscores, and sustainability by Pivo, one on European energy efficiency and revenue impact for owners by Bonde and Song, one on transpired solar air collectors compared to solar cells for efficiency and cost/benefits by Sewalk, Liston, and Maher, and one on deep retrofits in Toronto by Alita Jones.

We thank all of you who read, discuss, disseminate and submit new papers to this journal.

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The Relationship between the Occupation of Residential Green Buildings and Pro-environmental Behavior and Beliefs

Author Sara J. Wilkinson, Paul Van Der Kallen, and Leong Phui Kuan

Abstract The United Nations strives to promote a healthier society and to develop sustainability, with initiatives such as the New Green Economy, which is part of the United Nations Environment Programme (UNEP). This paper uses a survey of owners and occupiers, using two conceptual frameworks known as the Four Myths of Nature and place theory to investigate whether living in “green” buildings induces behavioral changes leading to a greener society. The results show that it is not possible to conclude that green buildings are inhabited by green occupants, and that physical design and green development alone can harness the attitudes and behaviors associated with green citizenship. Thus, policymakers and developers should not exclusively rely on a green built environment to promote green behavior.

Conventional buildings, which are those constructed with an inefficient use of resources, are an indirect cause of disruption to the natural ecosystem and a way in which humans are inducing climate change (Daily, 1997). Sustainability issues that need to be addressed, which can be addressed in green building design, construction, and occupation, include a reduction in the world’s freshwater supply and natural resources, along with degraded energy flows (Yudelson, 2007). In addition, the political processes of many countries have been occupied with the introduction of the so-called ‘green equation,’ which posits that “environment plus green building equals sustainable future” (Thaler and Sustein, 2008). Over the last two decades green buildings have become a dominant political discourse in many countries (Carter and Ockwell, 2007), with policymakers and governments believing that green buildings create incentives for improved consumer knowledge with regard to low carbon living and green lifestyles (Chan, Qian, and Lam, 2009). Although this study explored occupiers of green and non-green residential stock in Malaysia, the findings may be replicated in other countries. Malaysia has a population around 30 million people, and is a federal constitutional monarchy. The gross national product of Malaysia has grown on average 6.5% per annum for the last 50 years. This strong economic growth and a mature property market
with green building rating tools made it worthwhile to examine occupier attitudes and behaviors in the Malaysian green residential property market. It is posited that research exploring the relationship between the occupation of green residential buildings and pro-environmental behavior and beliefs is important as it can assist policymakers in more targeted and effective decision making.

Research Questions

This paper evaluates the green citizenship characteristics of green homeowners and/or occupants. The variables used to measure these concepts are pro-environmental attitudes and behaviors as represented by environmental beliefs, attitudes, and actions. Although these variables represent a low number of predictors in a complex array of variables, measuring them is of interest because of their importance in predicting pro-environmental cognition and behavior. The research questions the paper seeks to answer are as follows: (1) Are the green citizenship characteristics of occupants of residential properties improved after buying and/or occupying a green building? (2) To what extent do occupants exhibit the characteristics of ‘green citizenship’ with high levels of pro-environmental beliefs, attitudes and behaviors?

The Relationship between Green Buildings and Occupant Behaviors and Attitudes

Green building involves the construction of resource-efficient buildings with innovative technologies to reduce energy and water consumption and improve waste management (Chan, Qian, and Lam, 2009). However, for green buildings to deliver sustainability, occupants need to possess pro-environmental awareness to recognize the ability of green buildings to address negative environmental impacts (e.g., the use of high embodied energy materials or the over consumption of energy leading to excessive building-related CO₂ emissions). Furthermore, these occupants need to be able to use the resource-efficient technical constructs of green buildings optimally (Hostletler and Noiseux, 2010), and therefore pro-environmental behavior is needed to complement these constructs (Dobson, 2007; Williams and Dair, 2007). For the purposes of this research, occupiers are deemed to include renters or buyers. In order to be perceived as ‘green citizens’ (Exhibit 1), occupiers have to demonstrate a strong relationship between their pro-environmental cognitions and behaviors (Dobson, 2007; Martinsson and Lundqvist, 2010). According to Thaler and Sunstein (2000), when green buildings are occupied by green citizens, a ‘green’ living framework is realized and a successful ‘contractual relationship’ between the occupants and the environment is established. At this point, technological fixes can be reconciled with social transformation to realize the so-called ‘green equation.’ Conversely, if occupiers of green buildings are not green citizens, it is considered that green building will have fallen short of its implied socio-political objectives (Thaler and Sunstein, 2000).

To date, there has been little understanding of whether green building occupants were originally green citizens, and/or if green buildings act as a catalyst
converting individuals to green citizens. Most literature does not examine the relationship between green buildings, occupants, and green behavior; although there are standalone studies that provide analytical concepts and theoretical insights into the above and these studies were the starting point for this research. In Kilbourne, Beckmann, and Thelen (2002), Youngentob and Hostetler (2005), Marris (2006), Hostetler and Noiseux (2010), and Wilk (2010), the emphasis is given to deriving an average score on the green attitudes and behavior of green building occupants. This literature illustrates ways to analyze green attitudes and behavior via the institutional framing implicit in the dominant environmental and social paradigms but does not relate pro-environmental attitudes and behavior to green citizenship.

Vaske and Kobrin (2001) proposed that green buildings may influence occupants’ green citizenship using place theory. Place theory posits that a person’s responses towards the surroundings will impact their subjective norms towards the formation of pro-environmental cognition and behavior (Vaske and Kobrin, 2001). As green buildings consist of architectural structures that are capable of suggesting positive environmental cues, a link will be formed between the occupant and the environment (Stokols and Shumacker, 1981). In place theory it follows that as the occupant becomes more attached to their green building, this affection is strengthened as positive cognitional, emotional, and behavioral responses are developed. Consecutively, the occupant subconsciously develops the characteristics of a green citizen (Stokols and Shumacker, 1981). Place theory proponents suggest that green citizenship is developed through the formation of a ‘green’ self-identity and the continual association with green building may cause occupants to distinguish themselves from the public (Berg and Nycander, 1997). Furthermore, occupants are likely to label themselves as ‘green citizens’ and to maintain a positive moral stance and ‘green citizen’ identity; and in this way, a

Exhibit 1 | Theoretical Framework of Green Citizenship, Cognition, and Behavior

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<th>Non-green Citizens</th>
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<td>Negative environmental behavior consistent with negative environmental cognition</td>
<td>Pro-environmental behavior inconsistent with negative environmental cognition</td>
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Source: Dobson (2007).
person who buys or lives in a green building is ‘transformed’ into a ‘green citizen’ (Berg and Nycander, 1997).

There are arguments contradicting the notion that buying a green building and being associated with green buildings increases pro-environmental attitudes and behaviors. Mazar and Zhong (2010) found that the pro-active effects of green buildings could be reversed and argued that, people engaged in pro-social and ethical behavior only when their ‘green’ identity was scrutinized. Though people preferred to have a positive moral self, maintaining it came at a cost, because social and ethical dilemmas involve conflicts of interest (Mazar and Zhong, 2010). This is because real life is made up of multiple interrelated constructs that literally disable people from living up to their stated commitments or consistently pursuing neither their own interests nor those of others. As a result, people’s cognitive abilities to make decisions are modified by other constraints (Merritt, Effron, and Monin, 2010). Thus, once an individual’s moral self has experienced the ‘lift’ from the good deed that comes with a moral credential (such as buying a green building), people perceive that they have acted virtuously towards the environment, which can license them for subsequent inaction (Bernabau and Tirole, 2011). Even if their green home purchase is not situational and may be motivated by certain norms and attitudes, people may counteract such a good deed by denying further social responsibilities once their perceived duty is accomplished; such a psychological response is called the licensing effect (Sachdeva, Iliev, and Medin, 2009).

According to Schwarz and Thompson (1990), green beliefs can be represented by individuals risk perception towards the environment. They propose four ordinal categories to represent four archetypal views on the vulnerability of the environment using interpretation on the cultural theories of risk (Exhibit 2). These views are labeled as the Four Myths of Nature: (1) nature benign (low risk perception); (2) nature capricious (neutral risk perception); (3) nature tolerant (moderate risk perception); and (4) nature ephemeral (high risk perception).

The myths of nature are founded in theoretical reasoning and include views on nature, views on resources, views on how to make ends meet, environmental risk perception, and preferences for strategies to manage environmental risks (Schwarz and Thompson, 1990). For the nature benign group, the individualists’ myth of nature, the system is robust and resilient: The ball always finds its way back to the bottom of the basin (Exhibit 2). Nature is perceived as a stable and global equilibrium, and resources are expected to be abundant. This is associated with the belief that resources as well as needs are controllable. Environmental risks are seen as opportunities; individuals adhering to nature benign thinking believe new technological solutions will arise to solve environmental problems, which is the techno-centric approach discussed by Wilkinson (2013) that invariably leads to weak sustainability. On this basis, individuals are less troubled by environmental problems and furthermore they do not feel responsible for the problems and their solutions by changing their behaviors. Those holding this worldview (individualists) are believed to be risk seeking (concerning the environment). According to Schwarz and Thompson (1990), the nature benign stance justifies individualistic social relations. Individualists tend to create social sanctions that
defend their freedom to bid and to bargain in self-regulated networks with few prescriptions (Paton, 2011). They are opposed to collective control. Therefore, their risk management strategy is the market system (as opposed to government regulation); they strongly believe in market forces and in equal opportunity for all (Paton, 2011).

The fatalists or nature capricious myth captures those who view nature as an unmanageable system. In this paradigm, the ball will roll in any direction with unknown consequences (Exhibit 2). Nature is unpredictable, with needs and resources being controllable. Their risk perception is predicated on the belief that ‘what you don’t know cannot harm you’ and since all events occur inadvertently, learning and managing them is impossible. Consequently, humans have to cope with erratic events as they occur, and not surprisingly a nature capricious worldview justifies fatalistic social relations. The fatalists perceive life as a game of chance and their attitude to risk management is: Why make an effort? It follows that this worldview validates isolation and resignation to behavioral control. Fatalists are not consistent in thought and action as the modus operandi is focused on coping.

The nature perverse or nature tolerant is the so-called hierarchists’ myth of nature (Schwarz and Thompson, 1990), which is a more robust system to some extent.
In this model nature will take as much destruction as the authorities and experts say, with the ball finding its way to the base of the basin provided people respect the limits set by the authorities and experts (Exhibit 2). In this worldview, nature is seen as an unstable equilibrium with scarce resources. Where risks are concerned, the experts state what the acceptable risks are. In summary, hierarchists consider environmental problems can be controlled by government regulations based on experts’ knowledge on the limits to growth. As such the nature perverse or tolerant paradigm justifies hierarchical social relations. Sustainable growth is acceptable; for example, a policy that takes advantage of the perceived resilience of nature but respects the ‘known’ limits (Brundtland, 1989; Wilkinson, 2013). Their sustainable growth policy controls resources, as hierarchists contend that needs per se cannot be controlled. In addition, since only the experts understand the limits of growth, the hierarchical myth of nature justifies having regulations.

The nature ephemeral myth is an egalitarian myth characterizing a precarious, subtle equilibrium where the least nudge could result in disastrous consequences (Exhibit 2). Here nature has a limited equilibrium, dominated by the view that natural resources are depleting. The nature ephemerals do not hold that resources are controllable, whereas needs are. Overall it a risk-averse position as the perceived risks are inequitable, irreversible, and hidden, and consequently those holding this worldview are very concerned with environmental problems. They believe reducing their needs will contribute to the solution of environmental problems (Schwarz and Thompson, 1990). In this paradigm, egalitarian social relations are accepted. For egalitarians nature is sufficiently delicate to justify equal sharing of our one finite planet. Egalitarians prefer risk management strategies that advance equality of outcomes for present and future generations, thus adhering to the sentiments of the Bruntland definition of sustainable development (WCED, 1997). Given their belief that resources are depleting and are uncontrollable, the only solution available is to control needs and on this basis they seek radical changes in behavior and society. Overall, they have an ecocentric worldview sharing many characteristics with ecologists identified by Cook and Golton (1994) and Wilkinson (2013).

The myths of nature have been used to describe variations in environmental risk perception, risk judgments, and preferences for risk management strategies on a societal level (Schwarz and Thompson, 1990). These Four Myths of Nature refer to general beliefs toward environmental issues, influencing specific beliefs, attitudes, and norms; however, they are unrelated to behavior (Stern, Dietz, and Guagnano, 1995). In reality, people accept situations in contradiction of their myth of nature because this relation is mediated by other factors, such as the situational constraints (Dietz, Stern, and Guagnano, 1998).

**Research Method**

This is qualitative research that follows an inductive approach to generating research questions with a view to gaining a greater understanding of a concept or issue rather than hypothesis testing (Silverman, 2000). Subsequently, the formulation of research questions follows an inductive and not a deductive
approach. The inductive approach is derived from the literature review whereby a picture of the knowledge gaps, problems, and issues emerge as the researcher becomes more familiar with the topic area. The literature review identified which areas needed to be addressed in the surveys and enabled the researcher to compare whether practice and theory followed closely. The researchers commenced with the view that green building occupation and/or ownership and green behavior may be related. A further characteristic of qualitative research is the preference for meaning, trying to understand the world from the perspective of those studied (Silverman, 2000). One of the limitations of the questionnaire survey technique and this approach is that the questions may be interpreted differently by participants and that no clarification is possible. Furthermore a balance needs to be struck between open and closed questions; too many open questions extend the time required to complete the survey and may result in some participants partially completing the survey or providing superficial responses. Conversely if the survey is too short, the results may be limited in breadth and depth (Moser and Kalton, 1971). The advantages of the survey technique are that due to the standardization of the questions, bias is reduced and generally they are a relatively quick way of gathering data (Yin, 2003). However, response rates can be variable and, if low, it can be difficult for researchers to gather sufficient data to produce statistically reliable results (Robson, 2011). To minimize the issue of low response rates, the research population was identified before a sampling strategy was adopted to provide a representative sample. The research focused on an economically developed Asian nation with an established green building movement and a green building rating tool. Kuala Lumpur, the capital city of Malaysia, was selected, with a population comprised of 30% Chinese, 41% Bumiputera (native Malays), 10% Indian, 9% Euro-Asians, and 10% Middle Eastern, expatriates, and indigenous natives (Anon, 2010).

Malaysia has green building legislation and a rating tool, the Green Building Index (GBI), which was developed for Malaysia’s tropical climate, environmental and development context, and cultural and social needs. The GBI is the only rating tool for tropical zones other than Singapore’s Green Mark rated Scheme (BCA Green Mark) (Lijun and David, 2011) and is used interchangeably with the Singaporean BCA Green Mark to rate green buildings in Malaysia (Jamaludin, Inangda, Ariffin, and Hussein, 2011).

Two study sites, Mont Kiara and the Bangsar Townships, were chosen as a green and a conventional community, respectively. Both are exclusive, highly affluent residential suburbs, with many high value Green Mark rated and conventional apartments. From each site, a sub-division of green rated and non-green rated apartments was selected. The Mont Kiara subdivision contained one block of Green Mark rated apartments, 11 Kiara, and comparable conventional apartments. In Bangsar, the Bukit Bandaraya subdivision was selected with a Green Mark rated apartment block, and the remainder of the subdivision comprising conventional apartments. The conditions of the Green Mark rated apartments were similar, which rendered these apartments comparable controls that could be matched against the conventional apartments. The conventional apartments were control cases with comparable home values and a sufficient number of new home occupiers with a similar profile of socio-demographic backgrounds.
Newly occupied dwellings were selected because participants were required to remember when they first moved into their apartment. New home occupiers were those listed as owners of an apartment unit with a value between USD $573,400 and $3,170,000 and a sale date between December 2009 and June 2010. Participants were selected randomly through the developer’s sale database. One hundred surveys for each township, 200 in total, were distributed by the developer and returned by mail to the researchers. An overall response rate of 30% was achieved, with 59 usable surveys.

In line with best practices and prior to distribution, the survey was piloted on ten home occupiers to improve the final survey instrument. Different questionnaires were sent to individuals from green and conventional apartments. Survey A was given to green building occupants and survey B was given to conventional apartment occupants. Survey A had three parts. Section one investigated environmental beliefs, attitudes, and behavior. Section two asked the participant to self-report perceived changes on their environmental beliefs, attitudes, and behavior before and after occupation. The third section comprised a background check where the participants were asked to provide their gender. No other background checks such as income and education were required as it was assumed that individuals who could afford to live in the communities were of similar socio-economic backgrounds. Survey B had similar questions to Survey A, except the second section questions were omitted as no examination on before-after effects would be conducted on the control group. The surveys were undertaken in 2011.

**Data**

Three variables were investigated: green beliefs, attitudes, and behavior. The green beliefs variable is represented by the ‘risk perception towards the environment.’ Direct and indirect measurements were used to measure this item, as posited by Schwarz and Thompson (1990). The participants were asked to self-report their risk perception by identifying which of the four statements about the vulnerability of the environment best represented their beliefs. The four statements correspond to four ordinal categories in implied orders of 1, 2, 3, and 4. The categories represent the four archetypal myths on the vulnerability of the environment proposed by Schwarz and Thompson (1990) using interpretation on the cultural theories of risk and shown in Exhibit 2. In order to improve the reliability and objectivity of this measurement, an indirect measurement is used to indicate these myths of nature, so that every participant has the same indication on their level of risk perception. The vulnerability of the environment to threats was represented by the ease with which a ball can roll away from a landscape. Such measurement would result in higher degree of correspondence between the concept and the observed responses, because those who selected the same category will have the same level of risk perception. The level of deviation from one category to another category would be unambiguous (Schwarz and Thompson, 1990).

‘Concern towards the environment’ was used to represent the environmental attitude variable. The New Environmental Paradigm (NEP) scale measured environmental concern (Dunlap and Van Liere, 1978). This scale measured a broad
Environmental Attitudes as Measured by the New Environmental Paradigm

1. We are approaching the limit of the number of people the earth can support.
2. Human ingenuity will insure that we do NOT make the earth unlivable.
3. Humans were meant to rule over the rest of nature to fulfill their interest.
4. The balance of nature is very delicate and easy to upset.
5. If things continue on their present course, we will soon experience a major ecological catastrophe.

Pro-environmental Actions

1. Use energy-efficient light bulbs.
2. Use less air conditioning.
3. Segregates household waste to identify reusable items and dispose non-reusable items.
4. Avoid using toxic detergent.
5. Buy organic food.
6. Recycle newspapers.
7. Walk short distances (<3 miles).
8. Take short showers (<15 minutes).

Environmental worldview, which incorporated the norms and beliefs of justice and equality. NEP encompassed five underlying dimensions and facets of environmental concern, which included the extent of environmental limits to growth for human beings, the extent of human ingenuity to prevent natural catastrophe, the extent to which human beings regard themselves as the central and most significant entities in the universe (an anthropocentric worldview), human ability to upset the balance of nature, and the possibility of an eco-crisis. Five items, each representing a theme, were used and are shown in Exhibit 3. The participants indicated to what extent they agreed with each of the five statements, with answers given on a five-point scale, from 1 (strongly disagree) to 5 (strongly agree).

Environmental behavior was measured by ‘pro-environmental action,’ which covered multiple domains, frequencies, and impacts of actions (Stern, 2000). The Department for Environment, Food and Rural Affairs identified 12 ‘headline environmental impact actions,’ which involved both one-time and regular decisions made domestically and non-domestically (DEFRA, 2007). These actions related to three behavioral domains: energy use, water consumption, and waste behavior. As these headline actions are too broad to be measured, multiple measures were used to disaggregate these actions. These measures were derived from previous studies (Kreiger, 1998; Beatley, 2000) and addressed all environmentally-friendly lifestyles pertaining to the headline actions above. The pro-environmental actions that were measured in the survey are listed in Exhibit 4.
Exhibit 4 shows the pro-environmental measures that were used in the survey. Participants were asked to rate their frequency of involvement with these actions using a five-point scale, ranging from 1 (very rarely) to 5 (very often). It is noted that some green measures may vary from country to country. For example, the duration of a shower is based on the supply of water, cultural conventions, and norms. A 15-minute shower may appear long, for example, in Australia under the drought of 2002–2007; 3-minute showers were advocated by the federal and state governments to conserve water supplies (ABARES, 2012). Similarly, local total daily water consumption targets during the drought were based on local and state water levels and varied from state to state.

Analysis

The reliability of the questionnaire was tested using Cronbach’s alpha, a coefficient between 0 and 1 that is used to rate internal consistency, the correlation of items or a measure to confirm the reliability of multi-item scale (Peterson, 1994). A Cronbach alpha between 0.70 and 0.90 shows strong internal consistency and moderate correlation; if it is lower, the indication is that the variables are not correlated. The overall Cronbach’s alpha for all items was 0.843, while the individual Cronbach’s alpha of reliability for ‘risk perception towards the environment,’ ‘concern towards the environment,’ and ‘pro-environmental action’ were 0.80, 0.70, and 0.77, respectively. As they were greater than or equal to 0.70, the validity of the scale in the questionnaires was high.

In this study, responses from participants were measured using nominal and ordinal scales. Such measurement resulted in non-normal distribution of data, which deviated from normality. This anomaly in distribution was visible on the skew, kurtosis, and detrended normal plot measures from the frequency output from SPSS (see the Appendix). The Lilliefors Significance Correlation analysis was used to verify the non-normality in distribution. In this analysis, the Kolmogorov-Smirnov test and Shapiro-Wilk test were indicators of normality from the Lilliefors significance correlation analysis and were used to examine if the distribution deviated from normality. The Appendix shows significant values from both tests for all distributions were greatly below 0.05, indicating non-normal distribution. Therefore, non-parametric tests were required to analyse the data without error in interpretation.

The Wilcoxon-Mann-Whitney test is a suitable non-parametric test that compares two paired groups. The test calculates and analyses the differences between the pairs to ascertain if significant differences exist. In this case, the results showed there were no significant differences on the basis of gender. These two statistical tests confirm the robustness and statistical reliability of the research findings. The Wilcoxon-Mann-Whitney test was used to analyze the difference in distribution of data for the three variables. This test can be used to verify the validity of the proposition that occupiers in the green apartments in the sample have greater levels of pro-environmental cognition and behavior than residents in the non-green apartments. To prove that the distribution of the ‘green’ group was larger than the distribution of the ‘non-green’ group, the $p$-value test statistic of the Wilcoxon-
Mann-Whitney Test must be less than or equivalent to 0.05, with an upper tail critical value of 5%. That is, should there be a random drawing of a larger observation, there would be non-symmetry between populations in terms of their level of pro-environmental cognition and behavior.

A cluster analysis was used to classify the participants from green apartments into three groups. The first group comprised those who agreed buying into a green building had positive effects on their pro-environmental cognition and behavior. The second group agreed that buying into a green building had neutral effects, while the third group was participants who agreed that buying an apartment in a green building had negative effects on their pro-environmental cognition and behavior. This analysis tested the second question and segmented participants into a smaller number of groups for further examination of their environmental cognition-environmental behavior consistencies.

Finally, the three variables were converted into dichotomous variables by splitting the measurement scales at the sample median point. Participants whose minimum scores on all three variables were above the median score were classified as green residents; below they were classified non-green residents. However, not all participants had consistency in their minimum score on all three variables. For instance, people who scored high on belief might not score high on attitude and behavior; in other words, a respondent with green beliefs may not be green in attitude and behavior. Thus, it was important to examine the consistency between the minimum scores of all three variables amongst participants. The Kruskal-Wallis test was used because it was a robust test for non-normal distribution (Green and Salkind, 2008). The level of consistency would be reflected by the chi-square statistic for the Kruskal-Wallis test. A close approximation to 1 at a significant \( p \)-value of less than or equal to 0.05 represents high consistency between these three variables. The Kruskal-Wallis test result reflects the pattern of correlation between the minimum scores of all the variables. By understanding this pattern of correlation, participants could be classified into categories as per the green citizenship quartet shown in Exhibit 4.

**Results**

**Environmental Beliefs: Risk Perception on the Environment**

The participants were measured on the four myth perspective and could be either nature benign, nature capricious, nature tolerant or nature ephemeral. Nature benign people see the natural environment as robust and have low risk perceptions. Nature capricious individuals hold a neutral risk perception where nature is neither vulnerable nor invulnerable to risks. Nature tolerant people have a moderate level or risk awareness based on the view that natural environments are vulnerable to changes. Finally, nature ephemeral individuals perceive the natural environment to be very fragile and therefore facing high levels of risk. The results of the surveys showed most participants from green apartments subscribed to the nature ephemeral view (54.3%) or the nature tolerant view (45.7%) (Exhibit 5). No green building participants had nature benign or nature capricious views. Here, the
median split of sample that separated believers from non-believers was the third ordinal category of myth of nature. All participants from green homes were green believers. According to the cluster analysis, six people (17.1%) from green homes agreed that buying into a green building had positive effects on their environmental beliefs; the remaining 29 (82.9%) reported that buying into a green building had neutral effects on their beliefs. No one from green homes reported negative impacts. All who agreed about the positive effect of green building on their beliefs were green believers.

Fewer participants from non-green homes had the nature ephemeral (45.8%) or nature tolerant views (41.7%). Of the 24 participants from conventional apartments, there were a few outliers who had low or neutral risk perception on the environmental. Two (8.3%) participants thought that the environment was robust and not vulnerable to changes; one person (4.2%) did not have particular views about the vulnerability of the environment. Most (87.5%) were green believers while few (13%) were non-green believers (Exhibit 6).

All participants came to close agreement in terms of environmental beliefs. There were slightly more green believers from green homes compared to conventional homes; however, the Wilcoxon-Mann-Whitney test statistic with a $p$-value of 0.300 > 0.05 showed the difference was not statistically significant.

**Environmental Attitude: Concern Towards the Environment**

All participants had very close NEP score means above 4. Most participants from Green Mark rated homes had higher NEP scores across all NEP items as compared to participants from conventional (non-green) homes (Exhibit 7). The median split of sample that separated green attitude from non-green attitude was an average NEP score of 4. All those with average NEP scores above or equal to 4 were regarded as having a green attitude, whereas those scoring below 4 were regarded
as having a non-green attitude. Exhibit 8 shows there were more individuals with green attitudes occupying green buildings compared with conventional apartments.

According to the cluster analysis, six participants (17.1%) from green buildings agreed that buying into a green building had a positive effect on their environmental attitude; 82.9% reported that a green building purchase had neutral effects on their attitude. No respondents from green homes reported negative impacts of a green building on their attitude.
Although participants from the green apartments had a slightly higher NEP score, the result was significant for two items only: ‘the extent of human ingenuity to prevent natural catastrophe’ \((p = 0.034 < 0.05)\) and ‘human’s ability to upset the balance of nature’ \((p = 0.024 < 0.05)\). There were no statistical significant differences for the remaining items: ‘the extent of environmental limits to growth for human beings’ \((p = 0.156 > 0.05)\), ‘the extent to which human beings regard themselves as the central and most significant entities in the universe’ \((p = 0.815 > 0.05)\), and ‘the possibility of an eco-crisis’ \((p = 0.326 > 0.05)\).

**Environmental Behavior: Pro-environmental Action**

The combined scores on pro-environmental behaviors for both groups of participants were high. Both groups had high average scores on the eight headline pro-environmental actions. The average scores for each item were close without statistically significant differences, except for two items: ‘use energy-efficient light bulbs’ \((p = 0.004 < 0.05)\) and ‘walk short distances as an alternative for short trips’ \((p = 0.000 < 0.05)\) (Exhibit 9).

Exhibit 10 shows the participants from conventional apartments with green behavior equaled those from conventional apartments with non-green behavior. Conversely, the participants from green apartments with green behavior outnumbered those from green apartments with non-green behavior.

The cluster analysis showed six participants (17.1%) from green homes agreed that buying into a green building had a positive effect on their environmental behavior. Twenty-nine participants (82.9%) reported neutral effects on their environmental behavior and none reported negative impacts on their environmental behavior.

The results showed that the overall consistency of pro-environmental cognition and pro-environmental behavior was stronger amongst participants from green
apartments as compared to conventional participants (Kruskal Wallis test for internal consistency of green apartments; chi-square = 4.719; p-value = 0.03 < 0.05) was greater than that of conventional apartments (chi-square = 2.629; p-value = 0.105 > 0.05). This consistency was translated into a greater amount of green citizens (34.3%) from green compared to conventional apartments (29.2%),
## Exhibit 11 | Green Citizenship Amongst All Occupants

<table>
<thead>
<tr>
<th>Pro-Environmental Cognition</th>
<th>Non-Green Citizens</th>
<th>Green Citizens</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Green Cognition and Non-Green Behavior</em></td>
<td>◆ 17.1%</td>
<td>◆ 34.3%</td>
</tr>
<tr>
<td></td>
<td>□ 12.5%</td>
<td>□ 29.2%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-Green Citizens</th>
<th>Non-Green Citizens</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Non-Green Cognition and Non-Green Behavior</em></td>
<td>◆ 37.5%</td>
</tr>
<tr>
<td></td>
<td>◆ 34.3%</td>
</tr>
</tbody>
</table>

Negative Environmental Cognition

- ◆ Green Rated Apartment
- □ Conventional Apartments

Adapted from Dobson (2007).

As shown in Exhibit 11; however, non-green people from both groups were significantly greater.

## Discussion

Participants from the green apartments did not outscore those from the conventional apartments significantly in terms of pro-environmental cognition and behavior. This may be due to the similarity of their socio-economic background. The results confirmed findings from previous studies showing that a high level of socio-economic background is positively correlated with pro-environmental views (Mourato, Saynor, and Hart, 2004; Menges, Schroeder, and Traub, 2005).

The results did show that there were a higher proportion of participants from green apartments conforming to the characteristics of green citizenship. Therefore, there was stronger pro-environmental cognition and behavior amongst green building occupants. Nonetheless, a high proportion (65.7%) of green building occupants exhibited a disconnection between their pro-environmental cognition and behavior; the results do not support the proposition that green building occupants were ‘greener’ than conventional building occupants. In answer to the research questions, there is no conclusive evidence to confirm that occupants’ green citizenship characteristics improve after occupying or purchasing an apartment in a green building; however, there is evidence that there could be green benefits. The second question asked to what extent participants’ exhibit green citizenship.
In this case, marginally more people in green apartments displayed green citizenship, although the green citizens were a minority group in both green and non-green apartments.

One limitation of the study is that some of the actions recorded as pro-environmental may also be driven by economic drivers such as use of low energy light bulbs to reduce energy bills and this was not distinguished in the data collection. However, given that the properties were located in affluent residential areas, economic drivers are not believed to be high priorities for these individuals.

**Conclusion**

Overall, it is not possible from this study to conclude unequivocally that green buildings are inhabited by green occupants. As in previous studies (Kreiger, 1998; Beatley, 2000), this research could not confirm that physical design and green development alone can precipitate green behaviors and green citizenship. Even so, the study showed that a green built environment laid a foundation for green citizenship, given that no green home owners reported negative effects of green built environment on their pro-environmental cognition and behavior.

The research demonstrates that policymakers and developers should not rely on a green built environment alone to promote green behavior. Progressive educational programs and functional management systems should be implemented into the green built environment to ensure that the foundation for green citizenship laid down by green buildings can be enhanced in the long term. Government and policy leaders need to support the green building movement so that a genuinely green society can evolve for the purpose of a transition to a new green economy. One limitation of this research is that it does not follow the occupants over time and a longitudinal study could ascertain whether occupiers’ attitudes and beliefs change over time. In addition, the study could be replicated in other countries to determine whether levels of belief and attitudes towards green and non-green residential stock vary.
## Appendix

### The Lilliefors Significance Correction Analysis of Normality

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Apartment</th>
<th>Kolmogorov-Smirnov</th>
<th>Shapiro-Wilk</th>
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<tr>
<td></td>
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<tr>
<td>Risk Perception on Nature</td>
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<td></td>
<td>Non-green</td>
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<tr>
<td>Anti-exemptionism</td>
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<td>Non-green</td>
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<tr>
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</table>
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<td>Statistic</td>
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LEED and Energy Efficiency: Do Owners Game the System?

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Abstract By meeting a set of predetermined requisites and guidelines in the construction or retrofitting process, building owners are able to obtain a Leadership in Energy and Environmental Design (LEED) certification. Given that owners of LEED-certified buildings are often rewarded with financial incentives such as tax breaks and zoning allowances, it has been suggested that applicants for LEED certification take advantage of scoring credits that are easier to obtain, but that may not serve in the interests of the environment. In this paper, we evaluate the frequency with which building owners in California seeking LEED certification after the year 2009 applied the most energy-reducing measures to their buildings. The findings indicate that LEED applicants do not seem to display a selective bias against the LEED rating system score credits deemed as particularly energy-friendly.

The Leadership in Energy and Environmental Design (LEED) program was created in 1998 by the U.S. Green Building Council. Its self-proclaimed goal is to “provide building owners and operators with a framework for identifying and implementing practical and measurable green building design, construction, operations and maintenance solutions” (USGBC, 2012). To date, LEED-certified buildings can be found in 135 countries. The program is voluntary, and standards are verified and approved by third parties.

Four levels of LEED certification exist: Certified, Silver, Gold, and Platinum. Certification level is dependent on the total amount of points achieved, with a 110-point LEED rating system scale assessing commercial buildings and neighborhoods (a minimum of 40 points is required). Residential homes are assessed on a 136-point scale, with a minimum of 45 points required to obtain certification.

In many ways LEED has been successful, heightening awareness of the design and life-cycle assessment of buildings. Buildings that are LEED-certified typically have lower operating costs, less waste to send to landfills, greater savings in water and energy use, lower greenhouse gas emissions, and greater health benefits for inhabitants (Quirk, 2012). To date, over 12,400 buildings can be found in the LEED Certified Project directory, and this excludes certified residential homes (USGBC, 2012). A study of 121 LEED-certified buildings showed that the median energy use intensity (EUI) of these buildings lay 24% beneath the national average for similar buildings (Turner and Frankel, 2008). Energy reductions are a particularly important component of the LEED program. According to the U.S.
Department of Energy (DOE), more than 40% of human energy consumption takes place in buildings (USDOE, 2012). Unless electricity usage is connected to a metering system, it may be difficult for many inhabitants to analyze their energy consumption and consequently to seek out ways to reduce it. LEED seeks to make such action more accessible by dedicating the largest proportion of its total credits to the reduction of energy within buildings. From integrating metering systems to increasing renewable energy sources, LEED applicants are able to take a variety of measures to ensure more sustainable, energy-efficient buildings.

The modern renown of the LEED certification as well as some of its benefits may be involved in altering its original intent of environmental impact reductions. Specifically, certain news articles cast doubt on the fact that individuals applying for LEED certification may not be trying to reduce an impact on the environment, but rather are looking for an easy way to save money (Frank, 2012). A vibrant example is “How to Cheat* at LEED for Homes,” a report offering guidance on the easiest ways to collect points towards LEED certification (Seville, 2011). This process of “gaming the system” may have far-reaching implications. A LEED certification qualifies building owners for tax rebates, zoning allowances, and other incentives in hundreds of cities. This may make the certification of LEED buildings a question of economizing, not of reducing environmental impact. If building owners intentionally add a point to their LEED certification rating system scores by installing a bike rack, looking at the potential to game or manipulate the LEED system by going after the lowest cost points, even when they do not use a bike, LEED’s purpose of achieving sustainability may become obsolete. This is especially true as other city and state building codes require more effective energy-reducing measures, which may become obsolete.

Determining whether such perks motivate LEED certification is complicated for newly constructed buildings. This is because in contrast to LEED, which is a voluntary form of green building regulation, many cities and states now have mandated building codes that force new buildings to adhere to minimum standards of energy consumption and sustainability. For instance, the state of California has established CalGreen, the first mandatory statewide green building code in the United States. Created in 2011, CalGreen shares many mandates with the recommendations on the LEED rating system (CBSC, 2012). Furthermore, cities within the state have their own ordinances to promote environmental sustainability, an example being the San Francisco Green Building Ordinance, which requires that newly constructed residential and commercial buildings adhere to elements of green building. These and other recent forms of building regulation have narrowed the gap between newly constructed and LEED-certified buildings; therefore, newly constructed buildings may be less helpful in evaluating whether factors unrelated to environmental benefits may prompt the LEED certification process.

The LEED for Existing Buildings: Operations & Maintenance (LEED EB O&M) Rating System has criteria for buildings that are not meant to undergo major renovations. The standards are based on the operating performance of the building, independent of its initial design. The fact that the stock of the existing office space in the U.S. greatly outnumbers the new office stock added each year allows
LEED-EB O&M to have the greatest influence on the green office market (Blumberg, 2012). An assessment of each building is made by determining whether the building has fulfilled all prerequisites required for LEED certification, as well as a minimum amount of points, contained within six distinct categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation in operations. The type of LEED status achieved is based on the final number of points: Certified: 34–42 points, Silver: 43–50 points, Gold: 51–67 points, and Platinum: 68–92 points. Over the course of initial LEED certification, all prerequisites and credits must be enacted for a minimum of three months (except for Energy & Atmosphere Prerequisite 2 and Credit 1, which have durations of one year).

Buildings that are certified through LEED EB O&M have been constructed before certification. This means that their energy needs have also been previously defined, most often without the guidance of green building regulations. For the purpose of this investigation, LEED EB O&M certified buildings are used because their prior existence provided two relevant assumptions for measurement: (1) It can be assumed that LEED EB O&M certified buildings have relatively few energy efficiency measures in place, as these were not required by building codes at the point of their construction. (2) If energy efficiency measures are not in place, it would be expensive for building owners to upgrade to such measures. This may provide an incentive for them to resort to cheaper, less energy-reducing credits to gather the required number of points for LEED certification. Analyzing LEED EB O&M certified buildings was therefore seen as the best way to evaluate whether LEED certification recipients may have been less motivated by LEED’s most important contribution, energy efficiency, than by the opportunity to save money through financial incentives.

**Methodology**

Our aim in this study was to utilize project information from LEED EB O&M certified projects to assess the frequency of measures deemed to be most helpful in reducing building energy consumption. By assessing LEED EB O&M rating system scale scores for projects in California, this analysis sought to answer the following questions: What is the frequency with which the most energy-reducing measures found in the LEED EB O&M rating system scale were applied to certified projects in the state of California? Statistically, how does the frequency of the identified energy-reducing credits change as LEED certification level (Certified, Silver, Gold, or Platinum) changed for these certified projects?

A list of LEED EB O&M certified projects in California was obtained from the LEED Certified Projects Directory. Data gathering and analysis underwent the following steps:

1. Data on LEED EB O&M projects within California were isolated and categorized by certification level from the LEED Certified Projects Directory.
2. Among the identified LEED EB O&M projects, those containing a PDF attachment with the project’s exact rating system scale scores in each category were extracted and imported as an .xlsx format file into Microsoft Excel. Of the 229 identified LEED EB O&M projects evaluated in 2009 or later, 91 featured these attachments.

3. We input data into Excel to record the presence or absence of each identified energy-reducing credit, as well as the LEED certification level of the project. In the Appendix, we explain how these energy-reducing credits were identified.

4. Graphs were created comparing energy-reducing credits and the percent of projects in each LEED certification level that applied them. These were used to analyze the frequency of energy-reducing credits for each category, as well as the relationship between LEED certification level and the observed frequency of energy-reducing credits.

**Results**

No clear absence of any of the nine identified energy-reducing credits could be found among the surveyed LEED-certified projects. Though certain credits were less frequently enacted than others, there was no credit that was avoided by every project. In comparison to the other credits, Existing Building Commissioning (both Implementation and Ongoing Commissioning) had extremely low rates of adoption across all certification levels except Platinum, which is illustrated by Exhibit 1.

In addition to Existing Building Commissioning, the use of on-site or off-site renewable energy had extremely low adoption rates. Not one of the surveyed buildings at the LEED Certified level adopted an energy metering system, the only credit for which one entire certification level failed to obtain an identified credit, as seen in Exhibit 2.

However, it must be noted that the available data were constrained by the fact that only 91 construction projects were available for data collection. Moreover, projects were unevenly distributed among certification levels, with 8 LEED Certified, 29 Silver, 49 Gold, and 5 Platinum level buildings. This implies that confidence in results should be lower for the certification levels that are represented in lower numbers.

Despite this concern, a general trend could be observed that as certification increased to the next higher level, the percentage of buildings at that level had consistently higher rates of adoption of nearly every credit surveyed. Exhibit 3 conveys this well by summarizing rates of adoption of energy standards, identified by the percentage below average energy consumption, for the Optimize Energy Performance Credit.

Identified energy-reducing credits that seemed least affected by certification level were Sustainable Purchasing, Durable Goods: Electric, at which Gold-certified
**Exhibit 1**  | Rates of LEED EB O&M Certified Buildings with Existing Building Commissioning Credit

![Bar chart showing rates of LEED EB O&M certified buildings with commissioning credit.](chart1)

**Exhibit 2**  | Rates of LEED EB O&M Certified Buildings with Energy Metering System Credit versus Metering Accomplished

![Bar chart showing rates of LEED EB O&M certified buildings with energy metering system credit.](chart2)
buildings yielded the lowest percent adoption rate. Certified and Silver buildings were even at approximately 35% adoption. In fact, this credit was the only one that did not follow the trend of higher rates of adoption at higher certification levels (Exhibit 4).

**Discussion**

Most of the results indicate that the number of and the identified energy-reducing credits were not unpreferentially treated in the buildings’ LEED certification processes. With the exception of LEED Certified buildings and System Level Metering, all energy-reducing credits were represented among the certification levels. This suggests that applicants for LEED EB O&M certification were not affected simply by financial incentives, but that energy reduction is still a significant reason for LEED certification (Graebert and Fischer, 2011). The general trend that as certification level increased, adoption of the energy-reducing credits increased, makes intuitive sense. Higher levels of certification require more credits, and many of these credits are found in the promotion of energy efficiency.

**Economic Feasibility of Enacting LEED Credits**

A tentative explanation of the trend seen in LEED certification level and adoption of energy-reducing credits relates to the economic feasibility of enacting credits: adopting LEED certification standards requires money, and the availability of money limited the possible number of credits enacted, as well as the eventual
certification level of the building. The U.S. EPA examined five different cost-effectiveness tests used by different states as primary or secondary consideration: (1) participant cost test (PCT); (2) program administrator cost test (PACT); (3) ratepayer impact measure test (RIM); (4) total resource cost test (TRC); and (5) societal cost test (SCT). These tests, which are commonly used across the country by different states, are used to evaluate the cost effectiveness of energy efficiency (EPA, 2008). In California, the marginal costs are low for some of the mandatory energy efficiency measures yet elsewhere the costs of attaining more energy-efficient items might be different.

Furthermore, it could be that the chosen credits were actually not expensive for owners to apply in their buildings. The cost of applying energy-reducing credits in LEED EB O&M certified buildings was not assessed, due to the lack of detailed information and the potential variability of such a cost, depending on building type. This analysis focuses on energy reduction because it is one of the most important parts of the LEED program; it spans at least three of its six categories and is a less specific enforcement goal (compared to water use or waste disposal, for instance). Costs for energy-reducing credits may not have been high for building owners, incentivizing them to apply precisely these credits.

**Owners Understand Long-Term Benefits of Energy Efficiency**

Given the expectation that financial incentives would motivate building owners to forgo the most drastic energy-reducing measures, one possibility that could explain the negation of this hypothesis as shown by the observed trend is related to the owners’ understanding of the long-term benefits. Owners were focused on long-term benefits, thus comprehending that any reduction in energy would pay off in
the long run. Reductions in energy consumption precede reductions in energy bills, and when considering the life-cycle of a building, it is clear that better energy measures will save money in the long run. Therefore, energy-reducing credits may have presented owners the same financial incentives as tax breaks.

**Trends Not Readily Captured by the Data**

It is important to remain skeptical of the results given the relatively small sample size, especially for Certified (8) and Platinum (5) buildings. Unfortunately there were no further projects available for data collection in the state of California, and it may be beneficial in the future to consider a larger region for data analysis (i.e., the entire U.S.). In this case, however, the effect of differing state-wide building codes must also be taken into account. To make the results of this experiment more applicable to LEED-certified buildings, it would also be helpful to combine them with data from other LEED certification systems, such as LEED for New Construction.

Understanding the dependence of energy efficiency measures could provide more insight into owners’ adoption of energy-reducing credits. Many energy efficiency measures are dependent on one another. For example, owners could invest in a more efficient HVAC system; however, they would need to improve the insulation and windows to realize the full benefit of the new system. The data available do not allow for separation of these investment decisions.

**Deviation from the Observed Trend**

One deviance from the general trend of certification level and credit adoption lay in Sustainable Purchasing, Durable Goods: Electric. The purchasing of energy-efficient electrical appliances saw significantly higher rates in Certified and Silver buildings than in Gold buildings. Whether this is an anomaly due to lack of sufficient data is questionable, but it could indicate that this is an area where economic feasibility was not as much of a factor as personal preference. Although not necessarily related to the preexisting hypothesis of achieving financial gain through LEED certification, it may serve as another avenue for future exploration.

**Conclusion and Recommendations**

The trend we observe shows that as LEED certification level increases, the number of energy-reducing credits adopted increases. The results indicate that building owners do not display selection bias against energy-reduction measures when pursuing LEED certification. These findings could indicate that owners pursue energy-reducing measures due to their financial feasibility; both the understanding of the long-term benefits and that the cost of implementing these measures may not be as high as first thought. Further exploration into a larger data set may reveal trends not readily apparent in our data. This data set could include a larger region (e.g., the entire U.S.) or buildings certified as either LEED Existing Buildings or LEED New Construction. Further work will allow for a better understanding of
building owners’ motivation to adopt energy reduction measures and whether or not they have bias toward “easy” credits to achieve financial incentives associated with LEED certification.

**Appendix**

**Identification of Effective Energy-reducing Credits Chosen for Evaluation**

As our aim was to determine the extent to which energy reduction measures are applied for LEED certification, the credits responsible for such reductions needed to be identified. No exclusive study assessing the criteria and their individual impacts on energy reduction could be found, and such a study would likely be difficult to provide due to the high interconnectedness of the criteria. However, using the USGBC’s own explanation of the intentions of each criterion (USGBC, 2008), as well as an independent assessment by Scheuer and Keoleian (2002), a consistent profile could be established of the credits most prone to reduce energy use.

An additional factor was that applicants for certification should be able to recognize that the credit dealt with energy reductions. For this reason, three of the six categories (Water Efficiency, Indoor Environmental Quality, and Innovation in Operations) were excluded from the identification of credits.

Nine credits were ultimately identified from the three remaining categories (variations of the same credit are displayed in parentheses):

**Sustainable Sites**

1. **Alternative Commuting Transportation, Reduction (10%, 25%, 50%, 75%)**—intent on reducing pollution, land development, and automobile use for commuting. Can be achieved by facilitating mass transit, bicycles, carpools, or alternative/electric vehicles. Reduces energy use outside of building.

**Energy & Atmosphere**

2. **Optimize Energy Performance, (In increments of 2%, from 17% to 45% above national average)**—according to ENERGY STAR Performance Ratings, reduce total energy use of the building, based on a benchmark of comparable buildings. Twelve months of energy data is required.

3. **Existing Building Commissioning, Implementation**—implement improvements and projects to ensure that the building’s major energy-using systems are repaired, operated, and maintained effectively for optimal energy performance. Includes the implementation of low-cost operational improvements, staff training on energy efficiency, updating
the building plan, and retrofitting the building. Identified as significant in maintaining long-term building energy efficiency.

4. **Existing Building Commissioning, Ongoing Commissioning**—continuing to monitor and apply changes in building maintenance and repair to ensure optimal energy efficiency. Must include a building equipment list, performance measurement frequency, and steps to respond if energy efficiency is not at an optimal level. Identified as significant in maintaining long-term building energy efficiency.

5. **Performance Measurement, System Level Metering (40%, 80%)**—develop a breakdown of energy use and employ a system-level metering of at least 40% of the total expected annual energy consumption of the building. This provides information on how energy is consumed in the building, enabling the building to make energy consumption changes based on the available data.

6. **Renewable Energy, (On-site 3%/Off-site 25%, On-site 6%/Off-site 50%, On-site 9%/Off-site 75%, On-site 12%/Off-site 100%)**—recognize and implement more environmentally-friendly sources of energy, either on–or offsite. Solar, geothermal, wind, biomass, and biogas technologies are all applicable. Offsite energy sources are defined by the Center for Resource Solutions Green-e Energy program’s products certifications requirements (Center for Resource Solutions, 2012).

7. **Emissions Reduction Reporting**—identify, track, and record emissions reductions delivered by energy efficiency, renewable energy, and other building emissions reduction measures, using a third-party voluntary reporting or certification program (i.e., EPA, ENERGY STAR). This makes data tends available that can help with energy reduction.

**Materials & Resources**

8. **Sustainable Purchasing, Ongoing Consumables: (40% of purchases, 80% of purchases)**—purchases that are regularly made for use in operations & maintenance of buildings are based on an environmentally preferable purchasing (EPP) policy. It should evaluate the items purchased for the building, identify more environmentally-friendly alternatives, and establish a policy to purchase these alternatives if economically feasible. This credit focuses on goods that are to be replaced, and it includes paper, toner cartridges, binders, batteries, desk accessories, etc. Such products consume less energy than their counterparts.

9. **Sustainable Purchasing, Durable Goods: Electric**—purchase of electrical appliances that are certified to fulfill energy-efficient standards, such as ENERGY STAR requirements. Includes refrigerators, ovens, microwaves, and vacuums. Directly reduces the use of energy in the building.

Some credits were not chosen simply because they are not reflective of the LEED certification process as a whole; for example, LEED O&M includes credits dealing
with solid waste management, while LEED for New Construction does not. So-called regional priority credits, which are credits that have specific importance in specific geographical areas, were likewise not taken into account in this investigation due to their lack of universality. Prerequisites were not considered simply because they are required measures of the certification process; thus, adherence to prerequisites reveals nothing about the independent decisions of the site owner.

References


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The Feasibility of Reducing Greenhouse Gas Emissions in Residential Buildings

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Abstract
The American Clean Energy and Security Act of 2009, the so-called Waxman-Markey cap and trade bill, proposed that all residential buildings be renovated to meet existing energy codes upon sale to minimize emissions. In this paper, we examine existing and suggested International Energy Conservation Codes (IECC) and how they compare to the proposed climate objectives. We follow this by calculating the costs to bring existing homes to current energy codes and review the effort needed to bring homes up to future codes based on an in-depth study of over 100 homes in the Denver Metropolitan Area. We find that requiring homes be upgraded to meet existing energy codes is not efficient on a cost versus energy savings/emissions effort for the individual owner unless the government allows large tax credits or imposes a significant carbon tax on carbon emissions. Measures that do make sense include requiring new homes be energy-efficient, energy-efficient light bulbs and appliances when replaced, and increased attic insulation.

To minimize the impact of global warming, the concept of updating homes to current and future energy codes is a valid one. However, no one has undertaken the task of examining in detail what it would cost to modify and improve the existing housing stock to bring it into compliance with the 2020 and 2050 emissions goals (i.e., 20% below 2005 levels by 2020 and a total reduction in emissions of 83% below 2005 levels by 2050) and the related energy codes to avoid the worst impacts of global warming. While contemplating the potential impact of global warming and the contribution from buildings, no one has examined the potential impact this could have on household valuation. In addition, the effect on the marketplace in terms of potential defaults, as it may be the case that focusing solely on improving the existing building stock to meet emissions goals could potentially undermine the value of homes and the related impact on net wealth.

This paper ties the concerns and reactions to climate change and energy consumption to policy implications. Specifically, how potential policy reactions affect the cost of compliance. We then examine if these costs will have an effect on the marketability of housing.

We first review the concern of climate change and policy reaction, followed by a review of energy codes and historical energy consumption. We then review
greenhouse gas (GHG) creation and proposed legislation, followed by an introduction of empirical housing data for study. Next is an analysis of these data and results, followed by a conclusion and suggestions for residential sustainability.

### Climate Change

#### Global Warming

Between 1990 and 2005, according to the National Resources Defense Council (NRDC) overall net GHG emissions in the United States increased 17% even though the intensity of GHG emissions (emissions per dollar of real GDP) decreased by 20% (NRDC, 2005). Current climate science led by the Intergovernmental Panel on Climate Change (IPCC) claims to have established a direct link between increasing GHG emissions that lead to climate change and global warming. “Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far-exceed pre-industrial values” (IPCC, 2007). According to the IPCC report, there is a “very high confidence that the global average net effect of human activities since 1750 has been one of warming.”

The IPCC further stated that unless the world begins immediately to reduce GHG emissions significantly, global annual average temperature will increase between 2.5–7.0°C above pre-industrial levels by the end of this century. According to the World Development Report (WDR) temperature increases on the order of 4°C are predicted to significantly increase the likelihood of irreversible and potentially catastrophic impacts, such as the extinction of 50% of species worldwide, inundation of 30% of coastal wetlands, and a substantial increase in malnutrition, diarrheal, and cardio-respiratory diseases (WDR, 2010). Even with public interventions, societies and ecosystems will not be able of adapt to these rapid climate impacts. Mitigation is, therefore, the only viable form of adaptation to climate change that is not already baked-in (Mehrotra, et al., 2009; World Bank, 2010). Addressing the issues of climate change will not be easy or inexpensive. The International Energy Agency (IEA) has estimated that it could total $45 trillion globally by 2050 (Bloomberg, 2008) to avert climate change.

In terms of the American public, public opinion may be in favor of reducing GHGs; however, there is a reluctance to spend money to achieve the goal. Sixty-two percent of Americans would favor immediate and drastic action to reduce global warming and 68% support a new international treaty requiring the U.S. to reduce its CO₂ emissions by 90% by 2050 (Emanuel, 2007). Eighty-one percent of Americans believe that the U.S. should take the lead in reducing GHG emissions, and 87% believe the industrialized countries including India and China need to take action immediately. However, only 48% of Americans are willing to spend additional money in gasoline taxes to achieve the goal of reducing GHG emissions and only 18% are willing to pay 50 cents or more in additional taxes per gallon of gas to reduce emissions (Rettig, 2007).

In order to avoid the biggest problems from climate change and global warming, it is necessary that nations move to prevent global temperatures from rising by
more than 2°C (3.6°F) above pre-industrial levels (Monbiot, 2007). According to the Intergovernmental Panel on Climate Change (IPCC), temperatures have risen 0.74°C in the last 100 years. Therefore, action needs to be taken to prevent the average global temperature from rising more than 1.26°C (IPCC, 2007).

**Limit Warming to 2°C to Minimize Climate Change**

If temperatures rise by more than 2°C, the most devastating and dangerous processes caused by climate change may become unavoidable (IPCC, 2007; Harvey, 2010). Some of the impacts would include: (1) the melting of the ice sheets of Greenland and the West Antarctic, which would raise global sea levels by up to 23 feet (IPCC, 2001); (2) Africa becoming a dry continent and coastal city (Shanghai, Manila, Buenos Aires, Lima, and others) aquifers being inundated by saltwater (Pearce, 2005); and (3) a severe risk of water shortages as glaciers melt, thereby imperiling people who depend on melt water (~2.3–3.0 billion people in western China, Pakistan, Peru, Canadian provinces, among others) (Parry, et al., 2001; Meteorological Office, 2005a). In addition, 95% of the world’s coral reefs are dying due to bleaching, resulting in the death of the coral as well as their ecosystems (Meteorological Office, 2005b).

Furthermore, global climate models indicate that above the 2°C temperature rise, three irreversible processes could occur that would cause significant global damage (Prentice et al., 2001; IPCC, 2007; America’s Climate Choices, 2011): (1) the Arctic tundra melts releasing methane, causing further global warming (Pearce, 2005); (2) the Amazon rainforest dies off as the climate in this region dries up releasing significant amounts of CO₂ (Cowling, et al., 2004; Meteorological Office, 2005c); and (3) methane deposits at the bottom of the oceans are released as ocean temperatures rise, further increasing temperatures (Flannery, 2005). While the models appear to indicate that a 2°C rise would be manageable, a rise greater than 2°C could result in uncontrolled rapid increases in temperature due to the three scenarios described above. It is therefore important that world leaders take action to stabilize the concentrations of GHG emissions in the atmosphere. In order to prevent these potential scenarios, it is necessary that developed (wealthy) countries reduce their GHGs emissions substantially, estimated in the 80%–90% range, by 2050 (Monbiot, 2006).

**Limiting CO₂ to 450 ppm**

In order to prevent a global temperature rise of no more than 2°C above pre-industrial levels, it will be necessary to stabilize the concentration of GHGs in the atmosphere at approximately 450 ppm in carbon dioxide equivalents (CO₂e). (IPCC, 2007). In 2009, the concentration in the atmosphere was 387 ppm and growing at a rate of 2–3 ppm per year. As of 2012, the concentration has increased to 396.8 ppm, as the world emitted 33.5 billion tons of CO₂e in 2011. The goal to achieve a level of 450 ppm would require reducing average annual emissions between 2012 and 2050 to no more than 18 billion tons of CO₂e per year, a reduction of 46.3% when compared to 2011 emissions.

To achieve the goal of 450 ppm, the immediate question of who could emit arose. This led to the concept of contraction and equity to bring equality in emissions
between nations, resulting in convergence and equal levels of emissions for developing and developed countries on a per capita basis by 2050 (Meyer, 2000). Under this concept, each country receives an allotment of 2.0 tons of CO$_2$ emissions per capita per year. The allotment’s assumption is that the global population will be 9 billion people by 2050 (Meyer, 2000). The level would need adjustment depending on global population levels. With annual emissions of 33.5 billion tons and 7 billion people, current average emissions globally are approximately 4.8 tons of CO$_2$e per capita per year. Australia, the U.S., Canada, Germany, Sweden, China, India, and Kenya emit 26.9, 23.5, 22.6, 11.9, 7.4, 5.5, 1.7, and 0.3 tons of CO$_2$e per capita per year respectively. Given that this implies developed countries need to significantly reduce emissions (50%–90%), while developing countries can continue to increase emissions, the greatest support for contraction and convergence occurs in developing countries (Africa, Asia, and South America), a significant reason that achieving a global solution is difficult. The European Parliament, however, decided to adopt the concept of contraction and convergence in full providing developing countries significant support (Scottish Parliament, U.K. Royal Commission on Environmental Pollution, 2005).

The Politics of Global Warming

The Kyoto Protocol, adopted in 2005, required member nations to reduce GHG emissions to 1990 levels by 2012 (United Nations, 1999). Furthermore, to limit the impact of climate change, many groups and countries have adopted the 2°C target, these include the International Climate Change Taskforce (in its report “Meeting the Climate Challenge”), the European Union (“EU action against climate change”), and more than 200 of the world’s leading climate scientists (the “Bali Declaration by Scientists”). The CO$_2$ emission levels of the majority of developed countries range from 12 to 27 tons per person-year. If the IPCC goal is to limit overall emissions per capita each year by 2050 to 2.0 tons (using contraction and convergence), the implication is that developed countries have to reduce their emissions level from between 12 to 27 tons today to only 2 tons per capita by 2050, which implies a decrease in the 80%–95% range. This has been the platform adopted by many politicians, including President Barack Obama.

Reducing GHG emissions to avoid the worst environmental consequences of global warming, the 2°C target will require a coordinated multi-faceted policy at the international, national, state, and local level. Emissions from all sources (buildings, transportation and industry/utilities) need to be taken into account to achieve the goals stated by politicians, as all activities that consume fossil fuels are contributing to the rapid rise of carbon emissions (IPCC, 2007; Harvey, 2010).

To achieve these goals, the European Union adopted the Emissions Trading Scheme (EU-ETS), putting in place a cap-and-trade system, with the objective of reducing emissions 20% by 2020 and by 50%–80% (depending on country) by 2050. During the 2009 Congressional Budget process, President Obama indicated that the Administration would work expeditiously with Congress to develop economy-wide reductions in GHG emissions to achieve a 20% reduction.
The feasibility of reducing greenhouse gas emissions from 2005 levels by 2020, and an 83% reduction from 2005 levels by 2050.\textsuperscript{15,16} To achieve these goals, proposals were put forth to reduce energy usage and therefore GHG emissions for each of the three primary sectors: buildings, transportation, and industry/power plants (Exhibit 1).

The U.S. Energy Information Administration (EIA) reported the following breakdown of emissions in its 2009 Emissions of Greenhouse Gases Report:\textsuperscript{17} (1) buildings account for approximately 40% of total emissions (of which residential housing comprises 22% and commercial buildings 18%); (2) utilities and industry account for 27%; and (3) transportation accounts for the remaining 33% (Exhibit 3).\textsuperscript{18}

**Energy and Codes of Buildings**

**Building Energy Consumption**

Buildings are the largest consumers of energy in the U.S., and for most countries, accounting for 41.2% of all U.S. energy consumption, with residential and commercial buildings accounting for 22.6% and 18.6%, respectively. This includes consuming approximately 70% of electricity used in the U.S. Energy consumption since 1990 and 2000 has risen by 30.7% and 8.5% respectively for the residential sector, and by 36.7% and 6.0% for the commercial sector (EIA, 2008).\textsuperscript{19} The U.S. Department of Energy (DOE) projects that by 2030 the energy consumed in the residential and commercial building sectors will be the same, as the commercial sector will have caught up to the residential sector.\textsuperscript{20}

The academic literature that has linked green real estate improvements and carbon emission reductions to real estate has primarily focused on commercial real estate (Binkley, 2007; Naucler and Enkvist, 2009). Another body of research and policy identifies and addresses energy efficiency potential examining building performance and possible energy conversion in the commercial building sector (Ashford, 1999; Huovila, Ala-Juusela, Melchert, and Pouffary, 2007; (Llewellyn and Chaix, 2007; Nelson, 2007; DiBona, 2008; Fuerst and McAllister, 2008; Miller, Spivey, and Florance, 2008; Eichholz, Kok, and Quigley, 2010). Commercial buildings and their related emissions and potential improvements have also been studied by international organizations (United Nations Foundation, 2007; World Business Council on Sustainable Development, 2009). While support of energy-efficient investments through policy has been also been discussed (Reed, Johnson, Riggert, and Oh, 2004). The value added of potential carbon markets to investments in commercial buildings energy efficiency is evaluated from the perspective of being able to capitalize on credits related to carbon emissions (Binkley and Ciochetti, 2010). The assumption being that commercial buildings could take advantage of a higher price for carbon emissions by monetizing emission reductions.

The literature regarding residential buildings is far more sparse but growing. The energy-efficient code adoption process is discussed in a case study of Boulder, Colorado’s SmartRegs Program where Boulder became the first city to require

### U.S. Energy-Related Carbon Dioxide Emissions by End-Use Sector, 1990–2008 (Million Metric Tons Carbon Dioxide)

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<tbody>
<tr>
<td>Residential</td>
<td>958.6</td>
<td>974.8</td>
<td>976.0</td>
<td>1,036.0</td>
<td>1,029.2</td>
<td>1,035.5</td>
<td>1,094.9</td>
<td>1,086.2</td>
<td>1,093.4</td>
<td>1,116.7</td>
<td>1,179.8</td>
<td>1,167.3</td>
<td>1,197.6</td>
<td>1,224.9</td>
<td>1,221.9</td>
<td>1,254.5</td>
<td>1,186.7</td>
<td>1,235.1</td>
<td>1,220.1</td>
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<tr>
<td>Commercial</td>
<td>785.1</td>
<td>786.3</td>
<td>787.6</td>
<td>813.2</td>
<td>827.6</td>
<td>845.1</td>
<td>876.0</td>
<td>919.8</td>
<td>939.7</td>
<td>952.2</td>
<td>1,013.1</td>
<td>1,019.5</td>
<td>1,018.0</td>
<td>1,026.1</td>
<td>1,043.3</td>
<td>1,059.6</td>
<td>1,034.9</td>
<td>1,070.3</td>
<td>1,075.1</td>
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<tr>
<td>Industrial/Utility</td>
<td>1,689.5</td>
<td>1,647.4</td>
<td>1,717.6</td>
<td>1,711.9</td>
<td>1,742.1</td>
<td>1,739.5</td>
<td>1,791.5</td>
<td>1,812.2</td>
<td>1,792.3</td>
<td>1,768.0</td>
<td>1,784.7</td>
<td>1,707.2</td>
<td>1,683.3</td>
<td>1,690.3</td>
<td>1,728.5</td>
<td>1,671.4</td>
<td>1,657.8</td>
<td>1,655.2</td>
<td>1,589.1</td>
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<tr>
<td>Transportation</td>
<td>1,586.9</td>
<td>1,566.4</td>
<td>1,587.9</td>
<td>1,610.7</td>
<td>1,651.9</td>
<td>1,682.2</td>
<td>1,725.4</td>
<td>1,743.8</td>
<td>1,779.6</td>
<td>1,828.4</td>
<td>1,872.7</td>
<td>1,851.4</td>
<td>1,890.7</td>
<td>1,897.4</td>
<td>1,958.9</td>
<td>1,988.7</td>
<td>2,014.3</td>
<td>2,025.7</td>
<td>1,930.1</td>
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<tr>
<td>Total</td>
<td>5,020.1</td>
<td>4,974.9</td>
<td>5,069.1</td>
<td>5,171.8</td>
<td>5,250.7</td>
<td>5,302.3</td>
<td>5,487.8</td>
<td>5,561.9</td>
<td>5,605.0</td>
<td>5,665.3</td>
<td>5,850.4</td>
<td>5,745.4</td>
<td>5,789.6</td>
<td>5,838.6</td>
<td>5,952.5</td>
<td>5,974.3</td>
<td>5,983.7</td>
<td>5,986.4</td>
<td>5,814.4</td>
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<td>Electricity Generation*</td>
<td>1,814.6</td>
<td>1,812.3</td>
<td>1,825.0</td>
<td>1,907.3</td>
<td>1,932.7</td>
<td>1,947.9</td>
<td>2,020.3</td>
<td>2,089.6</td>
<td>2,178.2</td>
<td>2,188.6</td>
<td>2,293.5</td>
<td>2,259.1</td>
<td>2,270.5</td>
<td>2,298.8</td>
<td>2,331.3</td>
<td>2,396.8</td>
<td>2,409.1</td>
<td>2,359.1</td>
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Source: EIA


*Electric power sector emissions are distributed across the end-use sectors. Emissions allocated to sectors are unadjusted. Adjustments are made to total emissions only.

### U.S. Energy-Related Carbon Dioxide Emissions Percentage by End-Use Sector, 1990–2008

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<tbody>
<tr>
<td>Building</td>
<td>34.7%</td>
<td>35.4%</td>
<td>34.8%</td>
<td>35.8%</td>
<td>35.4%</td>
<td>35.5%</td>
<td>35.9%</td>
<td>36.1%</td>
<td>36.3%</td>
<td>36.5%</td>
<td>37.5%</td>
<td>38.1%</td>
<td>38.3%</td>
<td>38.6%</td>
<td>38.1%</td>
<td>38.7%</td>
<td>38.5%</td>
<td>38.9%</td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td>33.7%</td>
<td>33.1%</td>
<td>33.9%</td>
<td>33.1%</td>
<td>33.2%</td>
<td>32.8%</td>
<td>32.6%</td>
<td>32.6%</td>
<td>32.0%</td>
<td>30.5%</td>
<td>29.7%</td>
<td>29.1%</td>
<td>28.9%</td>
<td>29.0%</td>
<td>28.0%</td>
<td>28.1%</td>
<td>27.6%</td>
<td>27.3%</td>
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<tr>
<td>Transport</td>
<td>31.6%</td>
<td>31.5%</td>
<td>31.3%</td>
<td>31.1%</td>
<td>31.5%</td>
<td>31.7%</td>
<td>31.4%</td>
<td>31.8%</td>
<td>32.3%</td>
<td>32.0%</td>
<td>32.7%</td>
<td>32.5%</td>
<td>32.9%</td>
<td>33.3%</td>
<td>34.2%</td>
<td>33.8%</td>
<td>33.2%</td>
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Exhibit 2 | Percentage of U.S. Primary Energy Consumption by Sector: 1949–2010

Source: http://buildingsdatabook.eren.doe.gov/, with modifications to the presentation of the data by the authors.

Exhibit 3 | U.S. Primary Energy Consumption by Sector: 1949–2010 (billion BTU)

Source: http://buildingsdatabook.eren.doe.gov/.
Exhibit 4 | Project Impacts of Building Codes Relative to Baseline (90A-1980)

Note: The 90A-1975, 90A-1980 and MEC 1983/86 are all identical in terms of the energy code (i.e., no energy savings). The savings from 90A-1980 to MEC92/93 is 10%. From MEC92/93 to MEC95 the savings is 2%. Moving from MEC95 to IECC 1998 it is 2%. From IECC1998 to IECC 2000, IECC2000 to IECC2003 and IECC2003 to IECC2006, the increase in efficiency was 1% each step, for a total of 3%. The IECC 2006 resulted in 15%–17% energy savings over 90A-1980. The goal is that by IECC 2012, the code should provide 30% more efficiency than IECC 2006 (i.e. use approximately 40% less energy than 90A-1980). IECC 2015 is planned to be 50% more efficient than IECC 2006, using 58% less energy than used in a home built to 90A-1980 standards. The source is: Codes to Cleaner Buildings. Available at: http://www.climatepolicyinitiative.org/files/attachments/160.

to energy-efficient retrofits for rental properties (Barrett, Glick, and Clevenger, 2011). The demand for green housing amenities is examined and it is noted that there is a lack of research in this area (Goodwin, 2011). Individual green features for homes research are expanded by an examination of dual-pane windows regarding improvements to property values (Aroul and Hansz, 2011). An ENERGY STAR rated home sells for a price premium (Bloom, Nobe, and Nobe, 2011). However, there are no studies examining the cost of bringing a home up to existing energy codes.

Building and Energy Code Legislation

Building and energy codes have traditionally been powers allocated to states and cities under the U.S. Constitution, as they are not enumerated powers granted to the federal government. In the early 1970s, states began the adoption of energy codes into their building codes due to OPEC I and II. The first code adopted in 1975 was the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard 90-75. The Council of American Building Officials (CABO) supported this code in 1977, following a public hearing and revision process sponsored by the Energy Research and Development Administration (a predecessor to the DOE). The code was updated in 1980 as Standard 90A-1980 (Exhibit 4) and adopted by the majority of states by the time the first national model code was adopted in 1992 (Heldenbrand, 2001).
The Energy Policy Act of 1992 created the Building Energy Codes Program (BECP) and mandated that the DOE play a role in the development of model codes and encourage states to adopt these. The first residential model code was the 1992 Model Energy Code (MEC) issued by CABO, which was updated in 1993 and 1995. CABO merged with other building associations to form the International Code Council (ICC) in 1998. The ICC energy code is commonly referred to as the International Energy Conservation Code (IECC). The ICC issued the first IECC in 1998, followed by updates in 2000, 2003, 2006, 2009, and 2012, with new codes planned for 2015. As shown in Exhibit 2, energy codes until recently have only required buildings to be marginally more efficient. During the 1980–2006 period, the DOE sought marginal improvements of 1%–3% per revision cycle. As a result, compared with the Standard 90A-1980, the 1992 MEC was 5% more efficient then, and by IECC 2006, a home built to this code was approximately 10% more efficient.

The goal for the DOE relative to energy codes has changed since the IECC 2006. Of note, since the spikes in energy prices that began in the early 2000s, Congress again has taken up the issue of energy efficiency. In 2007, Congress passed the Energy Independence and Security Act of 2007 (EISA 2007), requiring that the IECC 2009, 2012, and 2015 be 15%, 30%, and 50% more efficient than the IECC 2006. EISA 2007 amended the Energy Policy Conservation Act of 1975, Pub. L. 94-163 (42 U.S.C. 6291 et seq.), establishing energy conservation standards for consumer products and commercial and industrial equipment to improve energy efficiency in heating, cooling, lighting, refrigeration, and energy consumption of appliances (Energy Independence and Security Act of 2007). Regarding lighting, as incandescent light bulbs are very inefficient, this Act included a provision to phase-out the incandescent light bulb, beginning with the 100-watt in 2012 and ending with the 40-watt light-bulb in 2014. With a stated objective that light bulbs use 25%–30% less electricity by 2014 and be 70% more efficient by 2020.

Following EISA 2007, the 2008 Congress not only wanted to conserve energy but also wanted to move the U.S. towards similar legislation as that passed in the EU regarding climate change and global warming. This resulted in Congress’s consideration of the Waxman-Markey Climate Bill (HR2454, American Clean Energy and Security Act of 2009). The intent of the legislation was to set in place a plan whereby U.S. emissions would fall in correspondence to the goals set by the Obama Administration. This bill had provisions for the building, transport, and industry/power plant sectors (Exhibit 5).

In brief, the objectives for the transport sector are to raise the corporate fleet average economy (CAFE) of new cars and light trucks sold from 27.5/23.5 mpg in 2010 to 37.8/28.8 mpg by 2016. For the power sector, the Bill incorporated a national requirement for a Renewable Portfolio Standard (RPS) of 20%. This would require that 20% of delivered electricity come from renewable energy sources by 2020. The Waxman-Markey Bill died in the Senate. As a result, there is no legislation mandating a federal standard, however of the 50 states, 25 of them plus the District of Columbia have a RPS in place, five have nonbinding goals, and two have renewable power-generation production goals.
Regarding the building sector, the original legislative intent was for Congress to write the Waxman-Markey Bill in such a manner as to require that new building codes apply to the existing building stock as well as new construction in an attempt to address a significant portion of total emissions. The plan was to require building owners to update their building prior to sale. However, due to the National Association of Realtors (NAR) involvement, the bill that the House of Representatives finally passed did not include any provisions that applied to existing building stock, only to new construction.

**Relating Building IECC Energy Codes, ENERGY STAR, LEED, and HERS**

To achieve an ENERGY STAR v3 rating, a home built in 2011 was required to be 15%–20% more energy efficient than a home built to the 2009 IECC. The IECC 2012 requires an improvement of 15%–20% over the IECC 2009. Therefore, the energy efficiency of an ENERGY STAR v3 home built in 2011 would be approximately the same as a home built to the 2012 IECC energy code. Leadership in Energy and Environmental Design (LEED) is a program of the U.S. Green Building Council. LEED rates a building’s level of energy and resource efficiency, as well as its occupant and community health impacts. The Home Energy Rating System (HERS) Index is a scoring system established by the Residential Energy Services Network (RESNET, 2011). A home built to the HERS Reference Home (which is based on the 2006 IECC) scores a HERS Index of...
100, while a Zero Energy Home (ZEH) home scores a HERS Index of 0. A HERS Index of 100 = IECC 2006, 85 = IECC 2009, 70 = IECC 2012, 50 = IECC 2015, 75–65 = 2011 ENERGY STAR, and 0 = ZEH.

Research Question

Taking as the basis that the IPCC is correct in its analysis that carbon emission reductions are required to avert potentially irreversible climate change and global warming and the goal is convergence, then to achieve this goal it is necessary to reduce emissions from all sectors of the economy. If the U.S. needs to reduce GHG emissions by 83% and buildings, both residential and commercial, account for roughly 40% of total U.S. emissions, then it is not possible to achieve this level of reduction without major reduction contributions from existing buildings.

New construction typically adds to the existing building stock, rather than replace existing buildings. This means that new buildings add to the energy demand and more than likely increase emissions for the sector. Therefore, we anticipate that future legislation may need to consider total emissions and require that existing buildings comply with stricter energy standards to reduce the risk of climate change. Congress, in the original Waxman-Markey negotiations, attempted to address the existing building issues, however was unable to include this in the legislation that passed that House of Representatives. Congress did succeed in requiring increased fuel efficiency for new vehicles, more efficient building materials, and provided credits for “green” buildings and has taken steps towards addressing both homes and power production as sustainable.

The remainder of the paper will focus solely on calculating the cost of upgrading existing residential buildings to comply with the 2012 IECC. We examine the cost of updating the existing household stock to current and future energy codes. It takes as its starting point the fact that GHG emissions are a concern to global climate change, and that to reduce emissions it is necessary to not only build LEED and ENERGY STAR rated homes and buildings, but to reduce emissions from the existing household stock. In so doing, this paper considers the cost impact of legislation that could eventually require homeowners to bring their home into compliance with current and future energy codes prior to selling their home. The structure we assume is that non-compliance would potentially jeopardize someone’s ability to sell their home. By taking this step, Congress would be mandating that households minimize their use of energy to achieve emission reductions.

Buildings and GHGs

Buildings (Commercial, Residential, and Industrial) and GHGs

Buildings are responsible for close to 40% of emissions. Of this, residential buildings account for 22% of total emissions, spread over a housing stock estimated to be 130 million households. A residential focus may have appeared
### Exhibit 6 | U.S. Housing Stock by Time-Period Built

<table>
<thead>
<tr>
<th>Year Home Built</th>
<th># of Buildings (1000s)</th>
<th>% in Period</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 to 2009</td>
<td>7,319</td>
<td>5.6%</td>
<td>100.00%</td>
</tr>
<tr>
<td>2000 to 2004</td>
<td>9,160</td>
<td>7.0%</td>
<td>94.4%</td>
</tr>
<tr>
<td>1995 to 1999</td>
<td>8,821</td>
<td>6.8%</td>
<td>87.4%</td>
</tr>
<tr>
<td>1990 to 1994</td>
<td>7,064</td>
<td>5.4%</td>
<td>80.6%</td>
</tr>
<tr>
<td>1985 to 1989</td>
<td>8,801</td>
<td>6.8%</td>
<td>75.2%</td>
</tr>
<tr>
<td>1980 to 1984</td>
<td>7,479</td>
<td>5.7%</td>
<td>68.4%</td>
</tr>
<tr>
<td>1975 to 1979</td>
<td>13,747</td>
<td>10.6%</td>
<td>62.7%</td>
</tr>
<tr>
<td>1970 to 1974</td>
<td>11,054</td>
<td>8.5%</td>
<td>52.1%</td>
</tr>
<tr>
<td>1960 to 1969</td>
<td>15,270</td>
<td>11.7%</td>
<td>43.6%</td>
</tr>
<tr>
<td>1950 to 1959</td>
<td>13,230</td>
<td>10.2%</td>
<td>31.9%</td>
</tr>
<tr>
<td>1940 to 1949</td>
<td>7,942</td>
<td>6.1%</td>
<td>21.7%</td>
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<tr>
<td>1930 to 1939</td>
<td>5,828</td>
<td>4.5%</td>
<td>15.6%</td>
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<td>1920 to 1929</td>
<td>5,164</td>
<td>4.0%</td>
<td>11.1%</td>
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<td>1919 or earlier</td>
<td>9,234</td>
<td>7.1%</td>
<td>7.1%</td>
</tr>
<tr>
<td>Total</td>
<td>130,112</td>
<td>100.00%</td>
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reasonable to Congress to bring about change by requiring homeowners to update their homes to current energy standards based on the magnitude of potential homes and total energy saving potential.

In general, Americans own or rent a house, apartment or condominium (approximately 130 million housing units) and they commute to commercial and industrial buildings (approximately 4,800,000 commercial and 150,000 industrial units). As the focus of this paper is to examine the impact of legislation that would require one to update their home, it is necessary to gain an understanding of when these homes were built and which energy codes applied. Exhibit 6 illustrates the composite age of housing stock in the U.S.

Prior to the 1970s energy was considered cheap. As Exhibit 4 illustrated, energy codes were a reaction to the price increases of the 1970s. Most homes built, even after 1980, had minimal improvements in the building envelope (tightness of fit, insulation, vents, energy-efficient windows and doors). Rising energy prices increased demand for energy-efficient building materials, as well as encouraged legislation to require these items in residential buildings. Subsequently, local energy codes materialized requiring the construction of more efficient buildings.

Most new construction is due to the increase in the population and expansion of business, not to replace existing buildings. This further increases the challenge of reducing emissions, as it is not a question of simply replacing existing buildings.
with new more modern and efficient buildings. Existing stock also requires retrofitting to more energy-efficient features. This problem mimics the problem the utility industry faces, as the majority of buildings have an economic life of 40–100+ years. In addition, there is the potential that upgrades, unless mandated, may not be justified based on economic return on investment unless there are emissions limits with taxes or penalties imposed.

A building’s energy consumption is due to several factors. These include insulation in the walls and attic, tightness of fit on lighting and vents, lighting, door efficiency, HVAC, windows, and hot water heaters among others. The U.S. Environmental Protection Agency (EPA) created ENERGY STAR in 1992 as a voluntary labeling program to promote energy-efficient products, thereby reducing energy demand and GHG emissions. Using energy efficient appliances within buildings can significantly reduce the energy demands of buildings.

In 1995, the DOE calculated the following average energy needs for different types of buildings across the nation, as shown in Exhibit 4. In a residential building, the top four uses of energy are heating, water heating, cooling, and lighting. In a commercial building, the top four are lighting, heating, cooling, and water heating.

Replacing existing lighting with more energy-efficient lights (CFL or LED) may lead to energy savings depending on usage and may require movement sensors to achieve. A better-insulated building with glazed dual-pane windows and better-insulated walls and doors (including garage doors) can reduce the amount of energy used to heat and cool (HVAC). Replacing older electric or natural gas water heaters with new hybrid electric heaters can reduce the amount of energy to heat water. Of these, it is most common to replace older lights regularly (every year or two), while water heaters and HVAC may take 10–20 years before they are replaced. Replacing doors and windows happens rarely.

**Legislative Requirements**

To reduce GHG emissions sufficiently, it would be reasonable to assume that it would be necessary to improve the energy efficiency of existing residential and commercial buildings. Legislation to enact limits on GHG emissions from homes and buildings could reasonably take this approach. This was the original concept behind the Waxman-Markey Bill. The best way to limit GHG emissions is to limit energy consumption. In the U.S., electricity is produced from the following sources: coal 50%, nuclear 20%, natural gas 18%, hydro 7%, and other 5% (this includes oil, wind, solar, and others). Because coal produces very high GHG emissions, reducing energy usage, and therefore coal usage would reduce total emissions. As buildings consume approximately 70% of all electricity generated, improving existing buildings by bringing them up to current or future energy codes could potentially reduce energy demand and therefore emissions.

Every three years the IECC is updated. States and municipalities decide which IECC code to adopt; once adopted, the code only applies to the locality adopting the code. The various jurisdictions are also responsible for enacting and enforcing
the codes. This results in a lack of uniformity across the U.S. as several states allow the local municipalities to choose to adopt any energy code of their choice, as shown in Exhibit 7. When a state or municipality adopts an energy code, it is the energy code that homebuilders follow for new construction. The energy code does not apply to existing buildings. It potentially applies if there is a room addition. The new codes apply only to new buildings and major renovations of older buildings. In 2009, only Florida and Massachusetts adopted the latest energy code at the time, IECC 2009, while 13 states and territories were a decade behind or had failed to adopt a statewide energy code. As of 2011, this number declined to 11 as more states adopted the 2009 IECC.

The original Waxman-Markey Bill would have created a uniform energy code for the U.S. and require homeowners, whose homes were built prior to 2012, to upgrade their homes to the latest existing energy codes prior to selling their house. While this may make logical sense in terms of reducing emissions to avoid climate change, it would impose a significant burden on homeowners to update their existing homes. The burden would continue to increase as the energy code became stricter with each new iteration (2015, 2018, etc.). What is important is the realization that this could become a never-ending process of continually updating one’s house in order to make it marketable. Next, we present an empirical study of the effects of such a legislative initiative.

**Case Study**

The U.S. has eight climate zones; Alaska is the coldest and is Zone 8, while the southern part of the U.S. is Zone 1. The zones relate to the number of heating or cooling days. The total energy consumption and bill for a household between Zone 1 to Zone 6 varied by as much as 24% (Gajda and VanGeem, 2000). The 2012 IECC code requires that a home be just as energy efficient regardless of its location. We selected Denver as a good convenient starting point, as it is located in Zone 5, is in the middle of the country, and associated costs of upgrading a home are similar elsewhere, although the average home price in other markets vary.

**Data Set**

A total of 114 single-family residences were examined in Denver, Colorado to analyze the impact of legislation requiring homes to be brought up to current energy code standards. The homes ranged in value from $124,000 to $883,646 with an average price of $344,333 and a standard deviation of $188,608. We examined homes built between 1901 and 2010 (Exhibit 8). The data were acquired by selecting neighborhoods that had a mix of properties based on age and size. For each home, we created a record indicating its age, size, the number of window openings, doors, square footage, approximate market price, attic square footage, wall square footage, and lighting. Mean homes prices in metro Denver ranged from $120,000 to $840,000 during this sample period. The test sample although picked randomly is typical of the Denver metro market.
Note: The IECC updates the codes once per three years. Codes older than 2006 provide minimal energy savings. The source is found at: http://www.bpa.gov/Energy/N/Utilities_Sharing_EE/doc/BuildingCodesofTomorrow.pdf
Next, building product manufacturers were interviewed to estimate costs for windows, doors, insulation (installed in the attic and wall), as well as costs of energy-efficient lighting. This allowed for an analysis of the homes on an individual basis to ascertain an approximate cost for each home contained within the data set to conform to 2012 Energy Codes with energy-efficient upgrades.

When examining a building, for purposes of the energy code, it is necessary to look at the entire building envelope to examine how to bring a building into compliance with existing codes. The key items of a building are: (1) the thermal boundary (outer walls, ceiling, windows and floor), which is known as the shell or envelope, needs to be properly insulated; (2) doors (leading to the outside, includes garage and patio doors); and (3) lighting. In order to make an older home energy efficient, there are certain items that need to be considered: insulation in the attic and walls, windows and frames, doors (garage, sliding, and front and back doors), seals, lighting, appliances, and heating/cooling systems.

In the majority of cases, older homes do not have insulation that is up to par. This occurs for two primary reasons: insufficient insulation and old insulation that is no longer properly set. Upgrading attic insulation is relatively inexpensive compared to adding insulation inside walls after a home is built. Insulating walls may not be feasible and if needed we considered additional or different siding materials to emulate insulating walls. Older windows, both single and double-pane, and their frames made of aluminum or wood are not typically energy efficient; in many cases, the seals around the glass and frames leak. This requires that the entire window and frame be completely replaced, not simply replacing the glass in the frame. Many older homes have bad seals not only on lighting (i.e., air leaks into the attic through lack of sealing of light cans) but also on air conditioning, vents, heating, etc. Older homes typically do not have new energy-efficient lighting; therefore, the cost of efficient (and sealed) lighting, as well as new light bulbs were taken into consideration. The only items not taken into consideration were appliances (water heater, dishwasher, washer and dryer, computers, monitors, TVs, microwaves, etc.) and heating and cooling (HVAC).
systems. We did not investigate if these were energy efficient because these items have a lifecycle that is typically 3–15 years, after which they need replacement. We therefore kept them out of the analysis to minimize the need for interior inspections. Our goal was to upgrade all homes to 2012 IECC codes. Upgrading all of the appliances would bring the majority of homes up to 2015 IECC code but would result in significant additional cost estimates per home.

**Data Analysis**

We examined 114 homes individually as to what it would cost to bring them up to 2012 energy codes. Exhibit 8 shows the number of homes for each time period, as well as the total cost to update these homes. The costs include energy-efficient windows (double- or triple-pane with insulation), energy-efficient doors (or storm doors) and garage doors if needed (including patio doors), added insulation in the walls (or if needed additional or different siding material) and attic, and energy-efficient lighting. As noted previously, appliances were not analyzed, as these will be replaced as they age, but we did assume regular maintenance is performed.

Exhibit 9 is the square footage of the home compared to the year the home was built. We wanted to ensure integrity in these data, as we know that home size has increased over time in the U.S. This was a way to ensure that the data that we collected would indeed be representative of the greater housing market not only in Denver but also across the U.S. The data shows that the size of homes has increased over time.
To further examine the data set and ensure a representative data set, we graphed the data for costs in relation to size and age. Exhibit 10 shows the cost of remodeling or updating a home to 2012 energy codes. As expected, the newer the home the lower the cost of updating it.

Exhibit 11 shows the remodeling costs compared to the square footage of the home. A smaller home is more expensive to remodel than a larger home on a per square foot basis. If the proposed policy required one to upgrade their home without any credits, the policy would be equivalent of penalizing people who own an older home. Since it is more costly to update a smaller home as a percentage of its value than a larger home, this cost would transfer to those who are less able to pay.

The result of a mandatory policy of energy code compliance can have unexpected consequences. This result could lead to the option to abandon or lower maintenance going forward if one speculates that the costs to update will outstrip the equity value of the home. If the costs to remodel become greater than the equity value, the option to default becomes valuable and the homeowner may employ a strategy of “waiting to default” (Kau and Kim, 1994). Future defaults and a disincentive to maintain the property condition can result in the creation of distress or bank owned property and potential neighborhood effects for surrounding properties as suggested by Clauretie and Daneshvary (2009). This motivation to default based on the conversion cost to new energy codes is the backdrop for our analysis.
Results and Implications

A total of 114 single-family residences were examined in Denver, Colorado to analyze the impact of legislation requiring homes to be brought up to current energy code standards. The homes ranged in value from $124,000 to $883,646 with an average price of $344,333 and a standard deviation of $188,608. For the 114 homes, the average cost to update a home was $22,091. Assuming an average ownership of eight years, this would imply an annual cost of about $2,761 per year. If the average housing unit would incur a $22,091 upgrade cost, this implies that over time it could cost roughly $2.8 trillion to upgrade the 130 million housing units in the U.S. to the 2012 energy codes.

This estimate to upgrade to current code excludes major appliances and HVAC systems that would result in higher compliance costs. For instance, current code calls for 13 Seasonal Energy Efficiency Ratio (SEER) air conditioner rating in comparison to existing housing stock built with 10 (or lower) SEER requirements. It is very costly and difficult to improve existing housing stock beyond IECC 2015 energy codes. Although the Waxman-Markey Bill assumes that it is possible to reduce energy consumption continuously for a house, by the 2015 IECC, one is reaching the limits of feasibility (Exhibit 12).

This analysis looked purely at the option of renovating single-family residences, not the physical feasibility of doing so. Therefore, we acknowledge that the costs of approximately $2.82 trillion to achieve a 20% reduction in emissions over the time frame 2012 to 2032 are an approximation only for residential housing and
do not include the option to tear down and rebuild. It is important to note that not all buildings have the ability to be upgraded unless significant structural changes are made. For example, it is not possible to bring all older buildings up-to-date because of their building envelope; specifically, buildings built from older materials need to breathe. If brought up to existing code, these buildings can develop mildew, mold, rot, and other problems affecting their livability and structure. In some cases, it may be cheaper to tear a house down than to upgrade it due to these potential issues.

**Home Improvements**

Most home improvements are infeasible to piecemeal items; for example, a homeowner would not install one new window per month, as this would be costly: few if any discounts and separate delivery fees. These lump sum costs can come as a surprise to homeowners who may then elect to either not move, or give the home back to the bank if the energy code update puts the home in a negative equity position. Potential buyers can require additional inspections to ensure
compliance prior to purchase and hesitate to purchase if future energy code compliance appears costly. CoreLogic reports that 9.7 million borrowers have a negative equity position as of the first quarter of 2013. More critical is that an additional 2.1 million borrowers have less than 5% equity. These borrowers are among those likely to delay improvements or wait to default.

**Net-Zero Homes**

Constructing a home in an energy-efficient manner (insulation and building envelope) combined with using the latest appliances and devices that shutoff lights and appliances automatically can make a home very energy efficient—approximately 60%–70% more efficient than a typical home. However, the home still consumes electricity and energy. The goal of a “net-zero” energy consumption home is to reduce energy usage to a minimum (around a 60%–70% reduction to a HERS of 30) and then produce the needed energy with solar, wind or a geothermal exchanger. Note, a net-zero energy home still consumes energy; however, it produces as much energy as it consumes on an annual basis. This significantly reduces the energy load of the home on the electric grid; however, it does not eliminate the electric grid. The home typically provides power during the day and summer and takes energy from the grid during the night and winter, leveling electricity loads.

**Potential Energy Savings**

To calculate the potential cost of the energy savings, it is necessary to understand how electricity and natural gas are billed to consumers, since a large portion of our utility bills are fixed costs. The cost of electricity is composed of generation (60%), distribution (32%), and transmission costs (8%). With natural gas, there are two primary costs: the commodity cost and the transport or distribution costs. Since 2001, the commodity cost has been more than 50% of the total cost. With Xcel Energy, there are service and facility fees for both electricity and natural gas. These fees are $6.75 and $11.64 per home respectively. Many utility companies have gone this route to ensure that customers who use alternative energy (by installing solar, geothermal or wind systems) still pay fees to the power companies to use their distribution and power systems. Under the current system, users who have a net-zero home, but are still connected to the grid, see a lower rate of return due to the current cost structure, which requires them to pay a monthly connection fee. However, anticipated savings could change dramatically if public utility commissions (PUCs) decide to charge only for energy used (no connection or transmission fees, a huge incentive to save energy or use alternative energy) or choose to include larger flat fees for connecting to electric and natural gas services (a large disincentive for alternative energy and energy saving investments).

In regards to our case study, our objective was to make all homes compliant with the 2012 energy code homes. Doing so would make the homes approximately 40% more efficient than homes built to 90A-1980. Note this is approximate. On an HER basis, the average home in the U.S. is rated at 130, where the IECC 2006 home gets a rating of 100 (Exhibits 13 and 14).
Based on our calculations of the 114 homes, the average home in our sample would be 36%–44% more energy efficient if upgraded to the 2012 energy codes; for purposes of the calculations, we average and use 40%. Exhibit 4 showed the differences between the different energy code standards. The average electricity and natural gas bill in 2009 in the U.S. was $1,244 ($103.67 per month)44 and $906 per year ($75.50 per month) respectively, with the average household spending approximately $2,150 per year for an average size house (around 2,200 square feet).45 Using Xcel Energy’s fixed fees to calculate savings implied that the average electric and natural gas bills energy dollar savings would be $1,163 ($1,244 − $6.75*12) and $766.32 ($906 − $11.64*12) for a total of $1,929.32 per year. A savings of 36%–44% would equate to a savings of approximately $694.56 to $848.91 per year.

Challenges to 2050 Goals

There are two challenges to achieving a 2050 goal of reducing emissions by 83%. First, assuming every sector (housing, transportation, and industry/utilities) contributes equally, this implies that existing buildings would need to reduce net

Exhibit 13 | Comparison of Residential Energy Codes and Standards

Source: http://blog.rmi.org/blog_nice_house_but_is_it_legal.
energy consumption approximately 83% to reduce emissions by an equivalent level. Second, as we are aware, the U.S. population continues to grow and with it the demand for new buildings. Therefore, any new construction, to avoid increasing emissions would need to be net-zero energy, otherwise existing buildings would need to improve by more than 83% to account for the increased emissions from new buildings.

In order to achieve the 2050 goal, it would be necessary for the vast majority of dwellings to approach net-zero energy consumption. This would not only imply that all homes be upgraded in the future to the latest energy codes but that they also install either solar, wind, and/or geothermal (heat exchangers). In essence, the goal would be to move towards a high level of self-sustainability. While the price of solar, wind, and geothermal systems has come down in cost, it may be prohibitively expensive to plan to install these devices on all of the homes today, but may not be so in the future. The use of federal, state, and utility credits brings down the cost of these systems to the individual consumer; however, these costs are still borne by society as a whole and are very expensive.

A typical 7.8 KW solar PV system on a 20-year lease in Colorado will cost approximately $9,000 (all-inclusive);\(^4\) however, due to lesser tax credits, the same system will cost up to $23,000 in Arizona. The overall total cost of such a system approaches $48,000 before credits are applied. This type of system produces approximately $62–$80 of electricity per month, providing a homeowner in Colorado a 7.6% annual rate of return over 20 years. However, on a societal cost
basis is presently not worth the improvement, meaning this investment at the society level loses money providing a negative 7.2% annualized rate of return over 20 years.

Once a household makes energy code upgrades, replaces appliances with the latest ENERGY STAR versions, and installs solar or other alternatives, this in theory reduces electricity consumption to net zero. However, it would not mean true net zero since no storage is involved. Reducing electricity usage to net zero (Exhibit 14) would only result in reducing emissions by 65%–75% for the housing sector. Why? Because as mentioned, homes will need to be connected to the electric grid to continuously power lighting, HVAC, and other appliances that use electricity and natural gas. In addition, energy and electricity are needed to create and build all of the alternative energy systems installed on homes (i.e., wind turbines, solar panels, and geothermal exchangers), of which materials need to be mined, manufactured, transported, and installed.

**Alternative Use of Investment**

Our calculation of the average cost to update, $22,901, results in a savings of approximately $694.56–$848.91 per year. The average household savings would be $771.74 per year, which translates into a 3.37% return on capital invested over 20 years, which is higher than most checking, savings, and money market funds, and is higher than current U.S. government bond interest rates. We have not taken into account any credits that the government may offer homeowners to perform these upgrades. The 3.37% rate of return is calculated based on implementing all of the upgrades to comply with IECC 2012 codes. Replacing existing incandescent lighting with CFLs results in a rate of return of over 200%, the light cams as well as better sealing of 2% to 5%, windows (−3%) to 5%, attic insulation 5%–15%, doors (−1%) to 4%, solar 7.5% (with tax credits, potentially negative without), wall insulation or an additional wrapping −3%–5%, and so forth. So some of the upgrades are definitely worth considering regardless of tax policy, such as switching to more energy-efficient lighting and adding insulation to the attic. Other upgrades may cost more than they benefit the homeowner, as the energy saved is not worth the cost of the investment with existing energy prices.

All of the above are needed to comply with IECC 2012 codes. A partial list may suffice for a homeowner seeking to save on energy expenses. We also note that a home upgraded or built to IECC 2012 codes needs to have a fan continuously running to introduce enough fresh air into the house on an hourly basis.

**Conclusion**

Policymakers need to take into consideration the unintended consequences of legislative initiatives. The Waxman-Markey Bill is used to illustrate the effects of compliance with a strict ruling for energy codes. It is likely that the U.S. Congress and state legislatures will propose other sustainable energy initiatives going forward, such as Boulder, Colorado requiring rental unit upgrades to comply with the most recent energy codes prior to rental (Barrett, Glick, and Clevenger, 2011).
Research as to what a proposal could warrant and how the proposals would affect buyer and seller motivation in selling or owning a home needs to be taken into consideration. In addition, relaxing the conditions proposed in the Waxman-Markey Bill can lead to creative proposals to coordinate effective energy policy goals while maintaining housing quality and the stability of neighborhoods. This would include house price effects, effective use of tax incentives, and attainable compliance review and measurement for homeowners, as well as local and state officials.

Based on the cost estimates arrived at within this paper, it would be possible to calculate the minimum carbon tax that would provide positive returns to homeowners and encourage them to upgrade their homes to current or future energy code legislation. The risk is that in so doing, homes that are currently underwater in terms of value may be abandoned by their owners. Lastly, there is a need to focus on emissions for something other than single-family residences. Residential homes and commercial buildings are only as clean as the energy supplied to them. Utilities produce “dirty” energy account for 30% of total GHG emissions. If it were possible to change the power arriving to buildings, then the emissions from buildings would also change, leading to greater energy sustainability.

**Endnotes**

4. Carbon dioxide equivalent (CO$_2e$) is a method of converting the six primary global GHGs into a common unit of measurement in order to compare global and country emissions. The six primary GHG classes that are compared are: carbon dioxide (CO$_2$), methane (CH$_4$), nitrous oxide (N$_2$O), hydrofluorocarbon (HFC-23 to HFC-4310), perfluorocarbon (CF$_4$ to CF$_3$F$_3$), and sulfur hexafluoride (SF$_6$).
5. Other scientists are concerned that 450 ppm is too high, and that in fact 350 ppm should be the objective, including James Hansen of NASA's Goddard Institute for Space Studies.
7. Ibid.
8. Mathematically, 33.5 billion tons of CO$_2$ divided by 7 billion people results in approximately 4.8 tons of CO$_2$ per capita each year.
9. The Kyoto Protocol was viewed as a success and it was ratified as the only treaty to require carbon emission reductions to mitigate global warming. However, the treaty had many failures as it only applied to developed countries and not to developing countries. It also included “hot air” allocations to post Soviet countries. “Hot air” because many
of those countries entered sustained recession/depression economic conditions and their emissions declined substantially but their allocations were based on pre-treaty levels. To-date, Canada has decided to withdraw and few countries have met their compliance obligations. Because of increasing emissions among developing countries, the 34 countries who have agreed to a second commitment beyond Kyoto will only account for 15% of manmade CO₂ emissions. http://knowledge.allianz.com/climate/agenda/?1741/climate-change-policy-agenda-2012-what-future-for-kyoto-protocol.

10 http://www.climatechangetaskforce.org/.
17 http://www.eia.gov/oiaf/environment/emissions/carbon/.
19 Energy and emissions are closely related, although not all energy produces emissions. The largest source of carbon emissions come from the consumption and transportation of coal, oil, and natural gas. Additional emissions come from products such as cement. Note, once nuclear, hydroelectric, solar, and geothermal power plants are constructed, they emit very few emissions.
21 OPEC I, also referred to as the Arab-Israeli War and the Arab Oil Embargo, occurred in 1973–1974 when the Arab countries and Israel went to war. The U.S. and Netherlands supported Israel and we were subsequently embargoed by the Arab countries. Unlike in 1967, the U.S. had no spare production capacity, as U.S. oil production peaked in 1971. The result was the price of oil went from $3/barrel to $12/barrel, a quadrupling, and Americans waited in line to buy gasoline due to inefficient government allocation policies. Concurrently, U.S. natural gas production peaked, leading to natural gas shortages across the nation in 1973. This rapid increase in energy costs raised awareness that energy needed to be consumed more efficiently.
22 OPEC II, also referred to as the Second Oil Crisis, began with the Iranian Revolution, which fed into the Iran-Iraq war and Soviet invasion of Afghanistan, started at the end of 1978 and lasting into 1980. This would prompt President Jimmie Carter to give his “malaise” speech and ask everyone to turn down his or her thermostat. This would lead to the adoption of energy codes in buildings, primarily housing, at the local/state level, as well as national efficiency improvements in automobiles through the Corporate Fleet Average Economy (CAFE) standards.
23 From a low of $10–$12 per barrel of oil in 1998–1999, prices increased to $147 per barrel by the summer of 2008. This mirrored the percentage increase from $3 a barrel in 1973 to a range of $34–$39 a barrel by 1980–1981, as in both time periods prices increased by greater than 12 times. Following the collapse of the global economy in 2008, oil prices declined to $41 a barrel, but have since risen and have ranged from
$90–$120 per barrel for Brent crude. The average price in 2008 for Brent crude oil was approximately $97.66 per barrel, and in 2012 the average price was over $100.00 per barrel. See http://www.indexmundi.com/commodities/?commodity=crude-oil-brent&months=360.


30 http://www.usgbc.org/.


32 Ibid.

33 History of ENERGY STAR. Available at: http://www.energystar.gov/index.cfm?c=about.ab_history (last visited July 5, 2012).


37 Their paper modeled the energy usage of a 2,450 square foot house in five different cities (Miami, Phoenix, Seattle, Washington D.C., and Chicago). Heating degree-days ranged from 200 to 6,536 and average annual temperatures ranged from 50°F to 76°F. The total annual operating costs for electricity and natural gas for the homes ranged from $1,648 to $2,062, a maximum range of 24%. Chicago and Phoenix were the two most expensive cities, one for cooling and the other for heating, while Miami and Seattle were the least expensive. Geographically and by cost, Denver is between all of these cities.

38 SEER is used to approximate the actual cooling cost operation of an appliance based on the installed climate zone. See http://www.modular.org/Magazine/comfort10_03.aspx for more information.


The connection fees can reduce the annual rate of return on an alternative energy source system by between 0.8% (large system, close to 10 kW) to 2% (small system 2–3 kW) for the typical homeowner.

U.S. EIA, Residential Average Monthly Bill by Census Division and State. Available at: http://38.96.246.204/cneaf/electricity/esr/table5.html.

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Impact of Energy and Environmental Factors in the Decision to Purchase or Rent an Apartment: The Case of Sweden

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Abstract In this paper, I examine the importance of environmental factors in the residential property market. The paper presents results from a quasi-experimental study and survey responses from 733 occupants of green and conventional buildings. The findings show that energy and environmental building performance factors have rather a minor impact on the purchasing or renting decision. The findings indicate that when discussing the impact of energy and environmental factors on a customer purchase decision, the availability of information should be considered.

The greening of the built environment is a long process. The barriers decelerating green building development were often related to uncertainty and doubts about the financial feasibility and profitability of building green (Issa, Rankin, and Christian, 2009). Recent literature provides evidence against this skepticism, indicating that green-labeled buildings generate higher sales prices in both the commercial (Miller, Spivey, and Florance, 2008; Dermisi, 2009; Eichholtz, Kok, and Quigley, 2010, 2013; Fuerst and McAllister, 2011a,b; Kok and Jennen, 2012) and residential markets (Ott, Baur, Jakob, and Direkte, 2006; Addae-Dapaah and Chieh, 2011; Brounen and Kok, 2011; Mandel and Wilhelmsson, 2011).

However, there is some difficulty in separating the “green” variable from the other factors, such as building design, and consequently abstracting the impact that variables have on transaction prices. Moreover, it is also unclear whether the choice to purchase or rent a green building is the customer’s conscious choice related to a building’s green features. It is uncertain whether a potential buyer or tenant is being informed about the green aspects of a building and whether information about energy and building environmental performance is important to the customer.

Brounen and Kok (2011) concluded that customers take into account information extracted from the building energy certificate; however, a study conducted in New Zealand (Eves and Kippes, 2010) indicated that the public is generally aware of energy and environmental issues but these factors play a minor part in the final house purchase decision. Correspondingly, findings from studies in Germany, Singapore, and Australia indicate that house buyers seldom consider information about building energy and environmental performance to be an important factor.
in their decision-making process (Addae-Dapaah and Chieh, 2011; Amecke, 2012; Bryant and Eves, 2012). The research also shows that a potential apartment buyer (Addae-Dapaah and Chieh, 2011) may be unaware of green building labeling or confused about the difference between label ratings.

The literature also indicates that environmental awareness may not be a sufficient argument to motivate making more environmentally-friendly decisions (Raisbeck and Wardlaw, 2009). The research suggested that neither arguments about more individual aspects like “improved livability,” “cost savings” or “other people’s opinion,” nor arguments of greater scale, such as “concern for future generations” can be considered significant enough to motivate investing in the construction of sustainable houses.

The focus of this paper is on examining how the impact of energy and environmental building features are being factored into decisions to rent or buy apartments. The analysis is based on over 730 survey responses collected during a quasi-experimental study among occupants of conventional and green multi-family buildings in Sweden. The paper presents results from a study conducted on the Swedish residential market and contributes to the international literature on customer attitudes towards building sustainability features. The results contribute to the discussion on factors that may affect a prospective owner or tenant while they are searching for an apartment (Collen and Hoekstra, 2001; Earnhart, 2002; Jim and Chen, 2007; Reed and Mills, 2007; Chau, Tse, and Chung, 2010; Goodwin, 2011).

**Background**

**Brief Characteristics of the Housing Market in Sweden**

The Swedish housing sector consists of about 4.5 million dwellings; approximately 55% are multi-family dwellings and 45% single-family dwellings. Most of the multi-family dwelling stock is made up of rental apartments (nearly 70%) owned by private and municipal organizations, while one-third consists of owned dwellings, a Swedish form of condominium.

The rent system in Sweden is controlled and the annual charges in rents are the result of negotiations between the municipal housing companies and the Swedish Tenants’ Union. The rent levels in the private sector are set comparably to those in the municipal sector (Svensson, 1998; Lind, 2003; Atterhög and Lind, 2004; Wilhelmsson, Andersson, and Klingborg, 2011). Utility fees are usually included in the rent (except for household electricity consumption). The fees for heating and water consumption tend to be calculated based on generally-accepted norms, rather than related to actual consumption. By contrast, utility fees in condominiums are generally related to the household’s real consumption.

The difference in housing tenure relates not only to size of financial investment, risk, and profit or loss possibilities on the housing market, but also responsibility for and commitment to building operation and maintenance. In the case of
condominium apartments, the owners form an association, which is responsible for decisions regarding building services, maintenance, and renovation. The tenant is relieved of these obligations, as maintenance and renovation services are included in the tenant contract and are the responsibility of the house owning company (Lind and Lindström, 2011).

Considering that the Swedish housing market is characterized by a strong rent regulation system (Lind, 2003) and an accompanying queuing system, the decline in newly constructed rental dwellings (Exhibit 1) may affect the importance of factors impacting the decision to rent an apartment. It is possible that, in the case of low vacancy in housing stock and the limited availability of new dwellings, a potential tenant chooses an apartment because it is obtainable rather than because it satisfies needs and requirements. However, since the vacancy levels differ across Sweden (Klingborg, 2000; Wilhelmsson, 2002) the above scenario may apply only in some municipalities. Even though the local market analysis is outside the scope of this paper, the low availability of newly constructed dwellings may have an impact on customer decisions to rent.

**The Green Residential Market in Sweden**

The increasing awareness of and focus on energy and environmental issues on the residential market is best demonstrated by the construction of very low-energy housing. Currently, the Swedish Building Regulations expect that space heating in a residential building constructed in southern Sweden (e.g., Stockholm) should not exceed 90 kWh/m² annually (Boverket, 2011). Very low-energy buildings are often constructed to passive house standards [the Swedish standard was introduced by the Forum for Energy-Efficient Buildings (FEBY)] and are expected to have significantly lower energy demand for space heating, even down to 50% of the requirements stipulated by the Swedish Building Regulations. The Swedish Center
for Zero Energy Buildings estimated that by the end of 2012, approximately 2,000 highly energy-efficient residential buildings would be built and an additional 1,320 buildings would be under construction. These figures, however, represent only a small percentage of total residential building production.

At present, no residential buildings in Sweden are certified according to internationally-recognized environmental building schemes such as BREEAM; however, the Swedish scheme for environmental building (http://www.sgbc.se/certifieringssystem/miljoobyggnad) has attracted a few developers and residential owners. Environmental building (Miljöbyggnad) is a voluntary certification process. The building environmental evaluation focuses on three areas: energy, indoor environment, and materials (Malmqvist et al., 2011). The assessment process has adopted a rating system where different credits are assigned depending on which performance targets the building has achieved. Finally, the credits gained during the assessment are added together and determine the environmental building (Miljöbyggnad) certification level. Depending on the energy and environmental goals achieved, the building can be granted brown, silver or gold certification. The environmental building assessment (Miljöbyggnad) has been developed and adjusted to Swedish norms and standards, enabling the relatively easy applicability of the (Miljöbyggnad) requirements in a building construction process.

Another environmental building scheme emerging on the residential market is Nordic Ecolabel (http://www.svanen.se/en/). The eco-labeling is determined through environmental analysis from a lifecycle perspective. The label is already known for eco-certifying various group products from appliances through furniture to building material. The label recently introduced environmental certification for building and the scheme slowly gaining popularity among housing developers in Sweden.

Method and Data Collection

Study Design

The data presented in this article are part of a four-year study aiming at capturing differences in the apartment purchasing and rental decision, overall satisfaction, and perception of indoor environment among occupants living in green and conventional buildings. This paper focuses only on factors contributing to the purchasing and rental decision and the analysis; results regarding the remaining data are presented in other articles (Zalejska-Jonsson, 2012, 2013).

The research was designed as a quasi-experimental study (Bohm and Lind, 1993; Nyström, 2008) in which green and conventional residential buildings were selected and paired in such a way that building characteristics were comparable and only differed in their energy and environmental performance. Care was taken to select cases that match as closely as possible in regard to building production year, building location, size, and potential customer segment.
Firstly, we have chosen the green building objects. *Green building* was defined as a building designed and constructed with high energy efficiency or environmental goals. Only buildings with a very low energy requirement (calculated space heating lower than 60 kWh/m² annually), and buildings registered or certified according to a building environmental scheme were considered. Secondly, we have selected conventional buildings (i.e., the control buildings). It was imperative that the *control building* was constructed according to current Swedish Building Regulations, but did not aim at better environmental or energy performance. The study focused only on newly constructed multi-family buildings.

**Data Collection**

Data collection was conducted in three rounds. The first data collection took place in 2010 and included three pairs of multi-family buildings. The data collection in 2012 was divided into collection periods: late spring (three pairs) and early autumn 2012 (four pairs). The studied cases included multi-family buildings with rental apartments (owned by municipal companies) and condominiums, with apartments owned by tenants (Exhibit 2).

**Survey Design and Questionnaire**

The survey questionnaire was divided into four sections and consisted in total of 33 questions investigating factors affecting the decision to purchase or rent an apartment, respondents stated willingness to pay for green buildings, and occupants’ satisfaction. In this section, we describe only the questions that are relevant to the article.

The first section examined the importance of different factors that could have an impact on occupants’ decisions to purchase or to rent the apartment. The factors were selected based on the extensive literature describing preferences in choice of residence. Respondents were asked to indicate how the following factors contributed to their apartment purchase or rental decision: location, price, apartment size, apartment design, calculated low energy consumption, environmental factors (other than energy), accessibility to public transport, and limited choice of available apartments. Respondents could choose one of the following answers: decisive, important but not decisive, less important, and unimportant.

In the second section, respondents were asked to indicate what information regarding building energy and environmental performance they had received before purchasing or renting the apartment. Respondents were given a list that included items such as expected annual energy consumption, and environmental or climate certification. Respondents could also indicate other information in the comment box. Additionally, in the later part of the questionnaire, respondents were asked to indicate what they perceived as the meaning and value of building environmental certification. The final section of the questionnaire included demographic questions that were used to analyze the data.

The survey was addressed only to all adult occupants (i.e., occupants who at the time of the data collection were at least 21 years old). This constraint was imposed
to ensure that the responses represent the choice of the individual rather than that of the parents or the guardian.

The survey was sent by regular mail. The envelope was addressed to individuals and the material inside included cover letter, survey questionnaire, and return envelope. The particulars (name and address) were obtained from a publicly accessed online database. People invited to participate in the survey could submit their answers in paper form using the return envelope or answer online using the link indicated in the cover letter. All participants were offered a gratuity in the form of a scratchcard costing approx. €0.3. Only respondents who submitted their contact details received a letter of appreciation and a gratuity. All participants were ensured that responses would be treated as anonymous. In order to fulfill this promise, the names and other details were kept confidential and filed separately.

The participants were asked to answer the survey within 10 days. A reminder was sent to non-respondents two weeks after the first invitation letter. The survey was
addressed to 1,753 persons and 733 responses were received, which resulted in a 42% response rate. Detailed information about the response rate for each building and tenure is presented in Exhibit 2.

Statistical Analysis

In the first stage of the analysis, descriptive statistics were used. In the second step, the statistical difference in responses from occupants of green and conventional buildings was evaluated using the Mann-Whitney (rank sum) test. Thirdly, statistical models were applied. The literature shows that the demographic factors may impact environmental behavior and perception of energy efficient measures (Barr, Gilg, and Ford, 2005; Nair, Gustavsson, and Mahapatra, 2010). The statistical models applied to the data are described as a function of the following variables: age (age), gender (if women = 1), whether the household was a family with children (family = 1), number of occupants per dwelling (occupants), dwelling size described as number of rooms (room), apartment tenure (if condominium = 1) and environmental profile (if green = 1). The independent variables are importance of energy factor for apartment choice (Model 1) and importance of environmental factors for apartment choice (Model 2).

The impact of individuals’ characteristics on the importance of energy and environmental factors for the decision to purchase or rent an apartment was tested with logistic models. The ordered logistic regression was chosen due to the nature of the data, which has ordered categories, measuring opinion and frequency using a rated scale so that responses are ordered (Borooah, 2001). A Brant test for a parallel regression assumption was conducted for each regression. The proportional odds assumption was satisfied in both models and the use of ordinal logistic models was justified.

The results are reported in the form of odds ratios and are interpreted in this paper as the likelihood of energy or environmental factors being important in the decision to purchase or rent an apartment if the predictor variable is increased by one unit while other variables are kept constant. The statistical analysis was performed in STATA. In order to test the internal consistency of the data, a Cronbach alpha test was conducted and the computed coefficient of 0.67 was considered satisfactory.

Limitations

There are certain limitations in the study. The analysis is largely based on the stated personal opinion of respondents. Consequently, the results may include errors related to the formulation of the questions, respondents’ subjective opinions, and their selective memory (Schwarz and Oyserman, 2001). Moreover, responses might be affected by post-purchase rationalization, and therefore they may inaccurately describe the impact of certain factors on the decision to purchase (or rent) an apartment.

Secondly, the quasi-experimental approach was introduced to ascertain the comparability between paired buildings; however, each property is unique, in
design or location, for example. Consequently, the uniqueness of each property imposed a certain limitation on the degree to which paired buildings could have been matched. Thus, certain compromises had to be made when pairing buildings (e.g., for geographical location, size of the estate or number of dwellings).

Finally, the information regarding participants' income was not collected. Consequently, the financial status of the families was not included in the analysis, which may affect the results computed from statistical models (omitted variables bias).

**Results**

**Description of Respondents**

Gender distribution is very similar in the subgroups green and conventional-owned dwellings and green and conventional rental apartments: ~55% respondents were females. There are certain differences in age distribution among respondents between the subgroups (Exhibits 3 and 4). The largest group of respondents in green owned apartments was between 31 and 40 years old (37%), whereas in conventional buildings, this group of occupants accounted for only 18%. There was a higher percentage of older respondents (over 60 years old) living in owned than rental apartments. The Mann-Whitney (rank sum) test indicated that there is a statistically significant difference in respondents' age between condominiums and rental apartments, but no statistically significant difference was found between green and conventional buildings. The difference between building tenure groups may be related to various factors such as occupants’ financial status and financial security, family situation, or health.

Approximately 35% of the respondents living in rental apartments, both green and conventional, are families with children. The proportion of families with children
Factors Impacting the Apartment Purchasing or Renting Decision

The analysis reveals that the most important factors considered in the respondents’ decision to purchase and rent were apartment size and location (Exhibit 5). Considering that the search for a new apartment is often prompted by lifestyle changes such as starting a family, going through a divorce or changes in health, it is understandable that apartment size would have the highest importance and it had the highest mean value among all responses (3.34), with 3.37 for owned apartments and 3.33 for rental apartments. Exhibit 5 shows determinants for apartment purchase or rental, expressed as mean values and ranked from the most to least important.

The second most important factor was building location; however, the mean values for location and apartment size differ only marginally. The location of the buildings relates not only to geographical position but also to the sense of familiarity and social life. Many respondents indicated in their comments that their choice of apartment search area was strongly related to the fact that they wanted to stay close to family and friends.

The importance of factors that people consider in the decision to buy (or rent) an apartment might be affected by the characteristics of the local market. Exhibit 6 presents mean values for factors as indicated by respondents living in the paired buildings. The results show that even though importance ranking of factors may vary, the top four factors affecting purchase/rental decision are the same (i.e., dwelling size, design, location, and access to public transport). The energy and environmental factors still had a minor impact, and ranked not higher than fifth place.
**Exhibit 5** | Mean Values for Factors Impacting Purchase and Rental Decisions

<table>
<thead>
<tr>
<th>Factor</th>
<th>All Buildings</th>
<th>Condominium</th>
<th>Rental Apartments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Apartment Size</strong></td>
<td>3.34</td>
<td>3.37</td>
<td>3.33</td>
</tr>
<tr>
<td></td>
<td>(0.63)</td>
<td>(0.62)</td>
<td>(0.64)</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td>3.28</td>
<td>3.34</td>
<td>3.24</td>
</tr>
<tr>
<td></td>
<td>(0.60)</td>
<td>(0.56)</td>
<td>(0.63)</td>
</tr>
<tr>
<td><strong>Apartment Design</strong></td>
<td>3.08</td>
<td>3.21</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>(0.71)</td>
<td>(0.65)</td>
<td>(0.74)</td>
</tr>
<tr>
<td><strong>Access to Public Transport</strong></td>
<td>3.11</td>
<td>3.26</td>
<td>3.01</td>
</tr>
<tr>
<td></td>
<td>(0.77)</td>
<td>(0.69)</td>
<td>(0.80)</td>
</tr>
<tr>
<td><strong>Price/Rent</strong></td>
<td>3.00</td>
<td>3.27</td>
<td>2.81</td>
</tr>
<tr>
<td></td>
<td>(0.69)</td>
<td>(0.58)</td>
<td>(0.69)</td>
</tr>
<tr>
<td><strong>Estimated Energy Consumption</strong></td>
<td>2.61</td>
<td>2.76</td>
<td>2.52</td>
</tr>
<tr>
<td></td>
<td>(0.86)</td>
<td>(0.82)</td>
<td>(0.88)</td>
</tr>
<tr>
<td><strong>Distance to Work</strong></td>
<td>2.58</td>
<td>2.46</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td>(0.94)</td>
<td>(0.99)</td>
<td>(0.90)</td>
</tr>
<tr>
<td><strong>Environmental Factors (other than energy)</strong></td>
<td>2.51</td>
<td>2.54</td>
<td>2.50</td>
</tr>
<tr>
<td></td>
<td>(0.85)</td>
<td>(0.82)</td>
<td>(0.87)</td>
</tr>
<tr>
<td><strong>Limited Choice of Available Apartments</strong></td>
<td>2.43</td>
<td>2.22</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>(1.03)</td>
<td>(0.97)</td>
<td>(1.04)</td>
</tr>
<tr>
<td><strong>Distance to School</strong></td>
<td>1.96</td>
<td>1.97</td>
<td>1.96</td>
</tr>
<tr>
<td></td>
<td>(1.08)</td>
<td>(1.10)</td>
<td>(1.07)</td>
</tr>
</tbody>
</table>

Notes: For purpose of analysis, factors are ranked from highest to lowest impact; 4 = decisive, 3 = important but not decisive, 2 = not very important, 1 = unimportant. Standard deviations are in parentheses. The number of observations is beneath the standard deviations.

The Mann-Whitney test was conducted to examine the difference in responses received from occupants living in condominiums and rental apartments. The results indicate that responses between occupants differ significantly in many respects (Exhibit 7). Not surprisingly, the price had a more decisive impact on the decision when purchasing compared to renting an apartment: 35% of apartment owners indicated that price played a decisive part in their apartment choice; only 11% of tenants indicated the same. Energy consumption was found on a statistically significant level to be more important for owners than for tenants.
### Exhibit 6 | Mean Values for Factors Impacting Purchase and Rental Decision, by Paired Buildings

<table>
<thead>
<tr>
<th>Factor</th>
<th>All Buildings</th>
<th>Pair 1</th>
<th>Pair 2</th>
<th>Pair 3</th>
<th>Pair 4</th>
<th>Pair 5</th>
<th>Pair 6</th>
<th>Pair 7</th>
<th>Pair 8</th>
<th>Pair 9</th>
<th>Pair 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>3.34</td>
<td>3.52</td>
<td>3.32</td>
<td>3.37</td>
<td>3.40</td>
<td>3.21</td>
<td>3.41</td>
<td>3.27</td>
<td>3.29</td>
<td>3.35</td>
<td>3.30</td>
</tr>
<tr>
<td>Location</td>
<td>3.26</td>
<td>3.36</td>
<td>3.75</td>
<td>3.32</td>
<td>3.16</td>
<td>3.29</td>
<td>3.02</td>
<td>3.19</td>
<td>3.42</td>
<td>3.22</td>
<td>3.23</td>
</tr>
<tr>
<td>Access to Public Transport</td>
<td>3.11</td>
<td>3.16</td>
<td>3.00</td>
<td>3.51</td>
<td>3.15</td>
<td>3.40</td>
<td>3.23</td>
<td>2.98</td>
<td>3.40</td>
<td>2.60</td>
<td>2.68</td>
</tr>
<tr>
<td>Price</td>
<td>3.00</td>
<td>3.36</td>
<td>3.24</td>
<td>3.25</td>
<td>3.26</td>
<td>3.33</td>
<td>2.83</td>
<td>2.84</td>
<td>2.69</td>
<td>2.93</td>
<td>3.00</td>
</tr>
<tr>
<td>Design</td>
<td>3.08</td>
<td>3.43</td>
<td>3.35</td>
<td>3.16</td>
<td>3.22</td>
<td>3.00</td>
<td>3.00</td>
<td>2.80</td>
<td>2.95</td>
<td>3.10</td>
<td>3.41</td>
</tr>
<tr>
<td>Distance Work</td>
<td>2.58</td>
<td>2.80</td>
<td>1.90</td>
<td>2.52</td>
<td>2.31</td>
<td>2.56</td>
<td>2.80</td>
<td>2.80</td>
<td>2.71</td>
<td>2.14</td>
<td>2.33</td>
</tr>
<tr>
<td>Energy</td>
<td>2.61</td>
<td>2.79</td>
<td>3.02</td>
<td>2.88</td>
<td>2.93</td>
<td>2.32</td>
<td>2.37</td>
<td>2.25</td>
<td>2.54</td>
<td>2.81</td>
<td>2.89</td>
</tr>
<tr>
<td>Distance School</td>
<td>1.96</td>
<td>2.25</td>
<td>1.79</td>
<td>1.98</td>
<td>1.96</td>
<td>1.85</td>
<td>2.28</td>
<td>2.13</td>
<td>1.75</td>
<td>1.61</td>
<td>1.75</td>
</tr>
<tr>
<td>Environment</td>
<td>2.51</td>
<td>2.58</td>
<td>2.61</td>
<td>2.67</td>
<td>2.70</td>
<td>2.20</td>
<td>2.48</td>
<td>2.27</td>
<td>2.57</td>
<td>2.72</td>
<td>2.59</td>
</tr>
<tr>
<td>Limited Choice</td>
<td>2.43</td>
<td>2.05</td>
<td>2.54</td>
<td>2.35</td>
<td>2.37</td>
<td>2.00</td>
<td>2.61</td>
<td>2.67</td>
<td>2.50</td>
<td>2.54</td>
<td>2.45</td>
</tr>
</tbody>
</table>
**Exhibit 7** | Differences in Responses between Occupants Living in Condominium and Rented Apartments; and between Green and Conventional for Tenure-groups: Condominium and Rental Apartments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mann-Whitney Test For Difference between Condominium and Rental Apartments [p, probability]</th>
<th>Mann-Whitney Test For Difference between Green and Conventional Buildings [p, probability]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building location</td>
<td>0.0454**</td>
<td>0.636</td>
</tr>
<tr>
<td>Apartment price</td>
<td>0.0001*</td>
<td>0.485</td>
</tr>
<tr>
<td>Apartment size</td>
<td>0.479</td>
<td>0.461</td>
</tr>
<tr>
<td>Apartment design</td>
<td>0.0003*</td>
<td>0.525</td>
</tr>
<tr>
<td>Estimated energy consumption/cost</td>
<td>0.0004*</td>
<td>0.0001*</td>
</tr>
<tr>
<td>Environmental factors</td>
<td>0.455</td>
<td>0.663</td>
</tr>
<tr>
<td>Access to public transport</td>
<td>0.0001*</td>
<td>0.643</td>
</tr>
<tr>
<td>Distance to work</td>
<td>0.026**</td>
<td>0.444</td>
</tr>
<tr>
<td>Distance to school</td>
<td>0.938</td>
<td>0.026**</td>
</tr>
<tr>
<td>Limited choice of available apartments</td>
<td>0.0001*</td>
<td>0.859</td>
</tr>
<tr>
<td>Certification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of environmental certification for buildings</td>
<td>0.314</td>
<td>0.0006*</td>
</tr>
</tbody>
</table>

* Significant at $p \leq 0.01$.  
** Significant at $p \leq 0.05$.  

Mann-Whitney Test
Again, this is not surprising, considering that energy consumption relates to space heating, which is often included in the rental fee in Sweden. Interestingly, environmental factors have an equal and relatively low impact on the decision to buy or to rent an apartment.

The apartment design value seems to be more important when purchasing than when renting an apartment, the difference being statistically significant at \( p \leq 0.01 \) (Exhibit 7). One-third (33%) of apartment owners indicated apartment design as having a crucial impact on their decision to buy an apartment, compared with 24% responses among tenants.

As expected, the analysis indicated a statistically significant difference in opinion regarding the importance of availability of dwellings (Exhibit 7). The rental control, shortage of newly constructed apartments, and queuing system may explain the difference in responses.

The local context may also provide a better explanation for statistically significant differences between responses of occupants living in condominiums and rental apartments and between occupants of green and conventional buildings (Exhibit 7). The results of the Mann-Whitney test conducted on responses of occupants living in the paired buildings are presented in Exhibit 8. The results confirm that the purchase of an apartment is a very careful decision that depends on customers’ specific needs and requirements. The results indicate a difference in opinion regarding energy and environmental factors.

One of the limitations of the study is the difference in geographical location of paired buildings, as the green and the conventional building are not always situated in close proximity to each other. This is a case in pairs 3, 5, and 10, which may explain the statistical difference in opinion regarding the importance of distance to school. In the mentioned cases, green buildings were located in newly developed areas of the city.

**Difference between Green and Conventional Buildings.** We tested separately the difference between green and conventional building occupants’ responses within a particular tenure group (i.e., among occupants living in condominiums and rental apartments). According to the Mann-Whitney test, only energy, environmental factors \( (p \leq 0.01) \), and distance to school \( (p \leq 0.05) \) are statistically different between the two subgroups, green and conventional condominium (Exhibit 7). For rental apartment buildings, a statistically significant difference was found only for the energy and environmental factors.

The aspects related to building energy and environmental performance had greater importance for people living in green buildings. This may be related to the fact that people who choose to live in a green residence are more environmentally conscious and indicate more interest in those factors. Indeed, when respondents were asked to indicate their opinion on the importance of environmental certification for buildings, more than half of the respondents in green owned apartments (56%) indicated that environmental certification is important and that it may have a positive impact on building value (Exhibit 9). This opinion was shared by approximately one-third of the respondents living in conventional
## Exhibit 8 | Differences in Responses between Occupants Living in Green and Conventional Buildings, by Paired Buildings

<table>
<thead>
<tr>
<th>Factors</th>
<th>Difference between Green and Conventional</th>
<th>Pair 1 Condo.</th>
<th>Pair 2 Condo.</th>
<th>Pair 3 Condo.</th>
<th>Pair 4 Condo.</th>
<th>Pair 5 Condo.</th>
<th>Pair 6 Rental</th>
<th>Pair 7 Rental</th>
<th>Pair 8 Rental</th>
<th>Pair 9 Rental</th>
<th>Pair 10 Rental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>0.73</td>
<td>0.20</td>
<td>0.71</td>
<td>0.00***</td>
<td>0.47</td>
<td>0.00***</td>
<td>0.02**</td>
<td>0.24</td>
<td>0.14</td>
<td>0.40</td>
<td>0.92</td>
</tr>
<tr>
<td>Location</td>
<td>0.11</td>
<td>0.66</td>
<td>0.67</td>
<td>0.14</td>
<td>0.50</td>
<td>0.29</td>
<td>0.53</td>
<td>0.98</td>
<td>0.14</td>
<td>0.00***</td>
<td>0.04**</td>
</tr>
<tr>
<td>Design</td>
<td>0.65</td>
<td>0.37</td>
<td>0.04**</td>
<td>0.01**</td>
<td>0.04**</td>
<td>0.71</td>
<td>0.77</td>
<td>0.22</td>
<td>0.33</td>
<td>0.93</td>
<td>0.83</td>
</tr>
<tr>
<td>Access to Public Transport</td>
<td>0.86</td>
<td>0.25</td>
<td>0.32</td>
<td>0.60</td>
<td>0.29</td>
<td>0.47</td>
<td>0.46</td>
<td>0.33</td>
<td>0.00***</td>
<td>0.39</td>
<td>0.54</td>
</tr>
<tr>
<td>Price</td>
<td>0.02**</td>
<td>0.02**</td>
<td>0.58</td>
<td>0.07*</td>
<td>0.09*</td>
<td>0.55</td>
<td>0.74</td>
<td>0.78</td>
<td>0.22</td>
<td>0.00***</td>
<td>0.11</td>
</tr>
<tr>
<td>Distance to Work</td>
<td>0.82</td>
<td>0.34</td>
<td>0.43</td>
<td>0.37</td>
<td>0.46</td>
<td>0.31</td>
<td>0.85</td>
<td>0.97</td>
<td>0.66</td>
<td>0.67</td>
<td>0.40</td>
</tr>
<tr>
<td>Distance to School</td>
<td>0.27</td>
<td>0.47</td>
<td>0.32</td>
<td>0.00**</td>
<td>0.55</td>
<td>0.01**</td>
<td>0.46</td>
<td>0.70</td>
<td>0.12</td>
<td>0.81</td>
<td>0.08*</td>
</tr>
<tr>
<td>Energy</td>
<td>0.00***</td>
<td>0.00***</td>
<td>0.39</td>
<td>0.24</td>
<td>0.00***</td>
<td>0.00***</td>
<td>0.15</td>
<td>0.92</td>
<td>0.00***</td>
<td>0.46</td>
<td>0.21</td>
</tr>
<tr>
<td>Environment</td>
<td>0.00***</td>
<td>0.05*</td>
<td>0.43</td>
<td>0.21</td>
<td>0.00***</td>
<td>0.01**</td>
<td>0.02**</td>
<td>0.97</td>
<td>0.00***</td>
<td>0.92</td>
<td>0.40</td>
</tr>
<tr>
<td>Limited Choice</td>
<td>0.30</td>
<td>0.75</td>
<td>0.98</td>
<td>0.25</td>
<td>0.45</td>
<td>0.06</td>
<td>0.42</td>
<td>0.15</td>
<td>0.75</td>
<td>0.03**</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Notes: The table reports the results of the Mann-Whitney test. The results confirm that purchase of an apartment is a careful decision that depends on customer-specific needs and requirements. The geographical location of the building in reference to the city center and development of the neighborhood area could also have affected importance of factors.

* Statistically significant at \( p \leq 0.10 \).

** Statistically significant at \( p \leq 0.05 \).

*** Statistically significant at \( p \leq 0.01 \).
buildings (36%). A statistically significant difference in opinions was confirmed by the Mann-Whitney test ($p < 0.001$). On the other hand, there is no significant difference in responses received from occupants in rental apartments. Just over 40% of respondents living in green and conventional rental apartments believe that environmental certification for buildings is important and has an impact on building attractiveness (Exhibit 9).

However, it is important to distinguish between environmental literacy or environmental education (Stables and Bishop, 2001) and the asymmetry of market information. The first concepts relate to ecological awareness (David, 1974), understanding of, and taking action on, environmental issues. The latter refers to a situation where people’s access to information is “uneven.” It was clear from the study that information about building performance and environmental impact was generously presented to the prospective buyers of green buildings. On the other hand, the same information was less likely to be given to buyers and tenants of conventional buildings, unless explicitly demanded. Approximately two-thirds of the respondents who owned apartments in conventional condominiums indicated that they “do not know,” “do not remember” or “did not receive” any information about building energy or environmental performance. However, about 90% of the respondents living in green buildings remember being given information about expected energy consumption or the environmental impact of the building. Approximately 60% of occupants living in rental green apartments remember receiving information about building energy or environmental performance, whereas 85% respondents living in conventional rental apartments “do not remember” or “did not receive” such information. These results are in line with Bryant and Eves (2012), who suggest that the availability of information
Effect of Individuals’ Characteristics on Importance of Energy and Environmental Factors. The ordered logistic models were fit to the data to test the impact that individuals’ characteristics may have on the importance of environmental and energy factors in apartment purchase and rental decisions. The results reveal a 2.40 odds probability that energy is a more important factor for occupants of green buildings than conventional buildings (Exhibit 10), suggesting that if people perceive energy as an important factor, they are more likely to purchase or rent a green dwelling (odds ratio for the environment is 2.42). The results indicate that energy factors are more important for those who live in condominiums than for those who rent (1.85 odds probability). The results are not surprising considering that owners have full responsibility for energy bills. On the other hand, in the case of tenants, the space heating costs may be included in the rental fee and are often calculated as a fixed fee rather than related to actual consumption.

The analysis reveals that individual characteristics may have an impact on the importance of energy and environmental factors in the decision to purchase or
rent an apartment. The analysis shows that the energy and environmental factors are more important for female than male respondents (odds ratio = 1.36). The results reveal that the importance of energy and environmental factors increases for the older groups of respondents. The oldest respondents (age 50–60 and over age 60) are most likely to consider energy and environmental factors to be important in their decision to rent or purchase an apartment. The findings are in line with the results of the study conducted in New Zealand, which revealed that older housing buyers were most aware of the importance of energy and environmental aspects in the house purchasing decision (Eves and Kippes, 2010).

**Conclusion**

A quasi-experimental approach and results from a survey among occupants of green and conventional buildings were used to study the impact of energy and environmental factors on customer decisions whether to purchase or rent an apartment. The findings show that apartment size and location have the greatest effect on the decision to purchase or rent an apartment. The analysis indicates that perception of the importance of energy and environmental factors differs depending on apartment tenure and whether the respondent was living in a green or a conventional building.

Generally, the energy and environmental factors were found to have rather a minor impact on the purchasing or renting decision. The findings are in line with results from studies conducted in Germany (Amecke, 2012) and New Zealand (Eves and Kippes, 2010). The analysis also indicates that individual characteristics may have an effect on the impact of energy and environmental factors on apartment purchasing or rental decisions.

Our findings indicate that when discussing the impact of energy and environmental factors on a customer’s decision to purchase, information availability should be considered. Developers are more likely to inform prospective buyers about a building’s environmental performance when the energy or environmental impact gives a positive signal and may increase selling value. However, the market information asymmetry has consequences. First, potential buyers are informed of how exceptional green buildings are, yet they do not know what they can expect of conventional buildings. Second, the generously provided information creates specific expectations, which may have an impact on occupants’ overall satisfaction. Finally, since the environmental benefits are not observable directly and even questioned by earlier research, the customer may have reservations about environmentally profiled buildings. Customer scepticism may be reflected in the perception of a higher investment risk and lower willingness to pay.

**References**


———. Parameters Contributing to Occupants’ Satisfaction: Occupants’ Insights into Green and Conventional Residential Buildings. Working Paper, Department for Real Estate
This study is part of a research project SBUF, the Development Fund of the Swedish Construction Industry.
The Operating Expense Puzzle of U.S. Green Office Buildings

Authors
Nikodem Szumilo and Franz Fuerst

Abstract
Cost savings from efficiency gains are at the core of the green building business case. Significantly lower energy bills are said to be a major factor in the green rent premium observed in earlier studies. Our study tests this relationship by inferring energy costs from operating expenses for a large dataset of U.S. office buildings and relating them to rental rates. We find that eco-certification is associated with a higher than anticipated total energy expenditure, which is the opposite of its expected effect. While our dataset does not contain a direct measure of actual energy consumption, this result puts the cost-saving argument into question. By contrast, we confirm earlier findings of a green rent premium but it might be an effect of factors unrelated to a tenant’s operating expenses.

Energy efficiency is thought to bring a plethora of benefits that may affect buildings in different ways and have different financial implications for different market participants. However, the core effects of energy efficiency are claimed to stream from a reduced amount of energy used. The associated cost benefit has been claimed to be a key financial driver in making buildings energy efficient (Oikonomou, Becchis, Steg, and Russolillo, 2009). Office properties as the most liquid property markets should be quickest to take advantage of this fact. However, many office buildings in the United States are rented and their lease terms determine who would receive such benefits. In effect, finding out how those are transmitted to rents may be a key to unlocking the benefits of energy efficiency in real estate used by governments, corporations, and wider society.

This paper focuses on investigating how rents for office buildings in the U.S. are affected by changes in the costs of energy to those buildings. A sample of 2,760 buildings in the four largest U.S. office markets is used to relate rents and operating costs (including energy costs) to a set of hedonic characteristics of those properties based on the existing literature. Energy efficiency is approximated by certification by one of two leading protocols (LEED and ENERGY STAR) and a distinction is made between properties in which a tenant pays for energy and those where this responsibility remains with the landlord. Changes in energy costs are found to affect rents as expected, although the costs are higher for properties that are certified. A total premium for eco-certification is consistent with similar reports and a premium for benefits of certification other than related to energy costs is found to have an average value of 4.41%.
Background

Energy efficiency in office buildings is credited with an ability to offer many benefits to both tenants and owners. The most widely accepted, and perhaps the most intuitive of its effects is the cost-saving opportunity arising from the possibility of lower energy bills. In fact, it has been argued that this benefit alone should be enough to generate a positive net present value of an energy efficiency investment thus creating a general incentive to undertake such projects (Koomey, Webber, Atkinson, and Nicholls, 2001). The theory that assumes that the benefits of energy efficiency are greater than costs is generally accepted (Harvey, 2006), although questioned by some (ConSol, 2008).

Engineering Fundamentals

Assuming that energy efficiency is defined as using less energy to generate the same level of service, most researchers agree that energy efficiency leads to a reduction in energy use given constant demand for energy-based services. The fundamentals of such claims stem from engineering calculations of possible energy savings that indicate that various energy systems can achieve a possible reduction of as much as between 40% (Liu and Claridge, 1999) and 70% (CADDET, 1997; Withers and Cummings, 1998). In new constructions, the possible overall reduction in energy use falls within a range of 50% to 75% (Harvey, 2009) while the total reduction in the existing stock is possible at around 30% (Kats, 2003).

Additional Benefits

A number of additional intangible and difficult-to-measure effects have been found to be associated with energy efficiency. DeCanio and Watkins (1998) find evidence that some firms prefer energy certified buildings due to their effect on branding. They conclude that occupying energy-efficient offices is often a part of a comprehensive corporate social responsibility policy. In fact, Eichholtz, Kok, and Quigley (2010) suggest that this benefit may be so valuable to firms that it may be reflected in higher rents. The authors mention that energy efficiency may also affect employee productivity. General economic benefits associated with energy efficiency are expected to have an influence on the demand for such office space. Some evidence of such an effect has been found by Fuerst and McAllister (2011a), who found that energy-efficient buildings have lower vacancy rates. A higher sales value of such buildings has also been documented (Eichholtz, Kok, and Quigley, 2010).

The Benefit Transmission Mechanism

A distinction is often made between energy used to operate a building (site energy), which is reflected in operating expenses, and total energy use generated by a building including transmission, production losses, and delivery (source energy) (Eichholtz, Kok, and Quigley, 2010). This paper focuses on energy cost
changes thus site energy will be the main focus. Higher energy efficiency should result in a lower use of energy given a constant demand for energy-based services. Such cost saving is a real financial benefit that should be possible to capture by market participants. However, given the specific nature of multiple agency relations in the real estate market, the transfer of this benefit is not straightforward.

Should a tenant be responsible for an energy bill, they should be willing to pay a higher rent to occupy energy-efficient space as their total cost of occupancy would remain constant while other benefits (like increased employee productivity or lower volatility of bills) may be available (Fuerst and McAllister, 2011a). Consequently, should the obligation to cover the energy expense remain with the landlord, the rent should be reduced by the amount saved on that cost keeping the total cash flow to the owner at the same level.

Assuming that energy efficiency can provide reduction in energy bills [which constitute around 30% of total operating costs (Eichholtz, Kok, and Quigley, 2010)], this expense should decrease thereby lowering the total cost of occupying a building. This is illustrated in Exhibit 1, which shows the cash flow from tenant to owner (rent) depending on lease contract terms. Column 1 shows the baseline rent in a case where the owner covers the energy bill, represented by $EB$. Should this obligation remain with the tenant, the rent paid would be smaller by that amount while the total cost to the tenant would remain the same. Should the building in question be energy efficient, the electricity bill would reduce by $a$, resulting in a new electricity bill ($NEB$). In addition, a set of additional benefits (like marketing or health advantages) of eco-certification would increase the rent by $c$. From that it can be seen that if the owner pays for energy, the rent would be higher for certified buildings by $c$ but lower by $a$ ($c - a$) (columns 1 and 3). In this case, the benefit to the owner is a net rent consisting of the basic rent plus the monetary value of $c$ (if the tenant is willing to pay) while the tenant gains the

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**Exhibit 1** | Rent Paid to Owner and Lease Terms

<table>
<thead>
<tr>
<th>Certified building</th>
<th>Non-certified building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner pays for energy</td>
<td>Tenant pays for energy</td>
</tr>
<tr>
<td>$EB$</td>
<td>$EB$</td>
</tr>
<tr>
<td>$NEB$</td>
<td>$a$</td>
</tr>
<tr>
<td>$c$</td>
<td>$c$</td>
</tr>
</tbody>
</table>

Note: Columns represent total rent paid.
business benefits of \( c \). This assumes the basic rent required by the owner not to change after making a property energy efficient, which means that the owner would not attempt to exploit the efficiency cost saving by increasing the rent by this amount \((a)\). This can be expected to be the case in a competitive market if the cost of introducing efficiency is either ignored or amortized and included in energy bill changes \( a \). If the tenant covers electricity in a certified building the rent would increase by \( a \) as the total price that an occupant is willing to pay for office space remains the same as in column 1 but electricity bill is now smaller. In effect, the saving that a tenant makes on an energy bill is added to rent. Additional benefits of certification should also be considered, thus, in this case the rent would be higher by \((c + a)\) (columns 2 and 4). While tenants are willing to pay the same amount for the basic rent plus utility bills regardless of efficiency of the space the owner can expect to receive the same basic rent plus the efficiency cost saving \((a)\). In addition if the tenants are also willing to pay for the additional business benefits of efficiency \((c)\) then this amount would also be added to the total rent paid. Regardless of who pays for energy bills should tenants not be willing to pay for benefits of efficiency other than the cost savings then \( c \) should be zero.

A lower energy bill should translate into a lower operating expense (OpEx) as long as other charges remain equal or decrease. Generally, expenses, like general maintenance, are expected to decrease since solutions such as maximizing the use of natural lightning generate little or no additional costs (GSA, 2008). A lower OpEx should provide benefits to whoever is responsible for paying this charge.

There is some evidence that special features of a building are reflected in higher rents. For example, Doiron, Shilling, and Sirmans (1992) show that adding an atrium to a building increases its OpEx but also its rents. The author concludes that there is a direct rental premium associated with a building having a special feature. Given the number of intangible benefits associated with energy efficiency, a similar effect is expected for benefits other than cost savings.

In effect, it appears that the total effect of energy efficiency on rents is not as straightforward as it might seem. For the purpose of this paper, the benefits of energy efficiency can be divided by how they are expected to be transmitted to rents: energy cost savings designated as \((a)\) and transmitted through OpEx and other benefits described by \((c)\) and transmitted directly through certification premium independently of other variables.

**Alternative Concepts**

Not everyone agrees with the concept of the benefits of energy efficiency resulting in a direct cost saving and a phenomenon named a “rebound effect” is gaining currency in the mainstream economic literature. Sorrell and Dimitropoulos (2008) sum up the argument by relating the initial fall in energy prices due to lower aggregate demand to a subsequent rise of demand triggered by simple price elasticity of demand. There is historical evidence for this claim based on the introduction of efficient lighting bulbs in the first half of the twentieth century (Herring, 2006). Numerous market failures in the process of transmission of the
benefits to involved parties may also pose a challenge to generating full profits of increased energy efficiency (Brown, 2001). For example, it has been suggested that a premium on energy efficiency may be an effect of temporary overpricing, due to misinformation regarding the environmental performance of assets, rather than of an efficient market pricing (Reichardt, Fuerst, Rottke, and Zietz, 2012). In fact, some researchers state that energy efficient and/or eco-certified buildings do not generally use any less energy than their inefficient or non-certified equivalents (Scofield, 2009a) or that at least a part of the green building cohort has failed to live up to expectations of lower energy consumption (Wedding and Crawford-Brown, 2007; Newsham, Mancini, and Birt, 2009). The authors of these studies do concede, however, that the difficulty of achieving a perfect ‘apple-to-apple’ comparison across buildings makes it impossible to answer the question with certainty.

**Research Question**

The purpose of this research is to find if energy cost changes associated with energy efficiency improvements are influencing office rents. The question relates to a process that consists of a chain of interactions. Theory explaining why and how those elements are connected has been presented above. Three hypotheses have been constructed to examine this theory in the context of the research question.

**Hypothesis 1:** Energy-efficient properties have lower operating expenditures compared to inefficient buildings.

This hypothesis will indicate whether the effect of eco-certification on rent is expected to be transmitted via operating expenses.

**Hypothesis 2:** The combined effects of certification vary depending on who pays the energy bills.

Testing this hypothesis will show if the effect of energy cost change is indeed affecting rent. It can also validate findings of Hypothesis 1 should the results be consistent.

**Hypothesis 3:** If the rent effect of energy cost changes is isolated from certification, the remaining effects of certification are independent of who pays energy bills.

This hypothesis can show that eco-certification variable can proxy for changes in energy costs but also that this effect can be isolated based on who pays electricity bills. This can validate Hypothesis 2 should the findings be consistent.

**Current Literature**

A number of papers have investigated the effects of eco-certification on rents (Eichholtz, Kok, and Quigley, 2010; Fuerst and McAllister, 2011b, and others
mentioned later) but none has focused exclusively on isolating the impact of energy cost changes. While these have been estimated theoretically (Norford, Socolow, Hsieh, and Spadaro, 1994), their transmission to rents has not been investigated.

There is little research available on the topic of determinants of operating expenses in office buildings mainly due to the fact that aside from energy, few other cost items can be objectively measured independently of their financial value. Nevertheless, characteristics like size, number of floors, and others have been related to the amount of operating costs that a building can generate (Macsporran and Tucker, 1995). Pivo and Fisher (2010) claim that utility bills are 12.9% lower for ENERGY STAR certified offices but do not mention total operating expenses or present any evidence for that claim. Miller, Pogue, Saville, and Tu (2010) present evidence that energy certified buildings have higher operating costs, although their results are not statistically significant. The above evidence gives no support to Hypothesis 1 and shows the need for investigating the relation between eco-certification and operating expenditure.

The amount of research that finds financial benefits of energy efficiency is not large but is growing fast. Researchers have found significant rent premium at levels ranging from around 3% (Eichholtz, Kok, and Quigley, 2010; Fuerst and McAllister, 2011b) to as much as 15% and more (Wiley, Benefield, and Johnson, 2010). OpEx is rarely used as an explanatory factor in this research area and those papers that do adjust for this variable find relations to rent of a variable statistically significant (significant: Hendershott, MacGregor, and White, 2002; insignificant: Miller, Pogue, Saville, and Tu, 2010). Most of the papers mentioned above adjust for lease terms by introducing a dummy variable for a net/gross lease, which is sufficient for capturing an overall rental premium but does not enable capturing the changing sign of the alternations in rent related to changes in energy bills. In conclusion, there is some support towards Hypothesis 2 as a rental premium has been found many times and operating expenses have been shown to be a significant rent determining factor. Nevertheless, there is no previous research that adjusts for the effect of lease terms on the sign of the rental adjustment.

Research discussed above shows the aggregate effect of energy efficiency on rents and gives some support to Hypothesis 3. However, little research has been done on isolating the influence of individual factors like cost savings. In those papers that have attempted this task, the influence of OpEx on rent was not statistically significant (Miller, Pogue, Saville, and Tu, 2010). Other individual effects of energy efficiency have been found (e.g., occupancy rate in Fuerst, 2011a) but an influence on rent has not been separated from the aggregate rental premium. Although it has never been directly tested, Hypothesis 3 can be expected to hold only if the theory of transmitting the benefit of energy cost savings through operating costs is correct.

**Data**

Data used in this research has been provided by CoStar Group, Inc. This database provides detailed building level data on almost 3 million buildings in the U.S.
Due to database extraction constraints, a limited sample had to be selected. In effect, properties located in the four largest U.S. office markets have been selected as a sample. This has been guided by two assumptions regarding those markets. First, that the total size of a market is not correlated with building characteristics that are important for this research, thus reducing selection bias. Second, that bigger markets have a higher trading volume, are likely to be more liquid, and have a larger number of professional participants and in effect could be more efficient (Wang, 2000), thus finding an effect of cost savings would be easier to see in rent prices (Levine et al., 1995). Real estate markets in the U.S. have been ranked by size according to a CoStar market report for 2011:Q4 and the following four were at the top of this list: New York City, Washington DC, Los Angeles, and Northern New Jersey.

Although limiting the research to only four markets may negatively affect the appropriateness of the results to be generalized, diversity of the selected areas help mitigate this issue. Exhibit 2 presents the employment industries of each market as a percentage of total employment in the area. The five biggest industries of each market are presented. The figure indicates the industrial composition of selected markets and shows that breakdown of employment in most cities resembles an overall composition of industries in the U.S.; however, Washington DC provides diversity in the sample.

Diversity of geographical location provided variances in climate to which buildings in the sample are exposed. Diversification regarding characteristics of buildings such as age, size or number of stories also seems to be satisfactory (Exhibit 3). Moreover, there seem to be considerable differences between markets, indicating that key variables are not correlated with market size.

The sample was further limited to Class A, B, and C buildings to ensure only comparable substitutes of office space are included in the sample. Although this
### Exhibit 3 | Description of Variables and Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Dummy variable is 1 for properties based in New York City.</td>
<td>0.21</td>
<td>0.40</td>
<td>0</td>
<td>1</td>
<td>569</td>
</tr>
<tr>
<td>NY</td>
<td>Dummy variable is 1 for properties based in Los Angeles.</td>
<td>0.21</td>
<td>0.41</td>
<td>0</td>
<td>1</td>
<td>588</td>
</tr>
<tr>
<td>LA</td>
<td>Dummy variable is 1 for properties based in Washington.</td>
<td>0.33</td>
<td>0.47</td>
<td>0</td>
<td>1</td>
<td>911</td>
</tr>
<tr>
<td>DC</td>
<td>Dummy is 1 for 25% most expensive submarkets in a particular market.</td>
<td>0.27</td>
<td>0.44</td>
<td>0</td>
<td>1</td>
<td>733</td>
</tr>
<tr>
<td>S1</td>
<td>Dummy is 1 for 25%–50% of the most expensive submarkets in a market.</td>
<td>0.23</td>
<td>0.42</td>
<td>0</td>
<td>1</td>
<td>624</td>
</tr>
<tr>
<td>S2</td>
<td>Dummy is 1 for 50%–75% of the most expensive submarkets in a market.</td>
<td>0.26</td>
<td>0.44</td>
<td>0</td>
<td>1</td>
<td>718</td>
</tr>
<tr>
<td>Age</td>
<td>Dummy variable is 1 for properties built 4–3 years ago.</td>
<td>0.03</td>
<td>0.16</td>
<td>0</td>
<td>1</td>
<td>73</td>
</tr>
<tr>
<td>A1</td>
<td>Dummy variable is 1 for properties built 5–14 years ago.</td>
<td>0.11</td>
<td>0.31</td>
<td>0</td>
<td>1</td>
<td>296</td>
</tr>
<tr>
<td>A2</td>
<td>Dummy variable is 1 for properties built 29–15 years ago.</td>
<td>0.25</td>
<td>0.44</td>
<td>0</td>
<td>1</td>
<td>701</td>
</tr>
<tr>
<td>A3</td>
<td>Dummy variable is 1 for properties built 49–30 years ago.</td>
<td>0.26</td>
<td>0.44</td>
<td>0</td>
<td>1</td>
<td>709</td>
</tr>
<tr>
<td>A4</td>
<td>Dummy variable is 1 for properties built 69–50 years ago.</td>
<td>0.10</td>
<td>0.29</td>
<td>0</td>
<td>1</td>
<td>264</td>
</tr>
<tr>
<td>A5</td>
<td>Dummy variable is 1 for properties built 99–70 years ago.</td>
<td>0.16</td>
<td>0.37</td>
<td>0</td>
<td>1</td>
<td>450</td>
</tr>
<tr>
<td>A6</td>
<td>Dummy variable is 1 for properties built &gt;100 years ago.</td>
<td>0.09</td>
<td>0.28</td>
<td>0</td>
<td>1</td>
<td>242</td>
</tr>
<tr>
<td>OpEx</td>
<td>Annul operating expenditure per sq. ft. of a property.</td>
<td>$6.58</td>
<td>$5.41</td>
<td>$0.01</td>
<td>$48.1</td>
<td>2760</td>
</tr>
<tr>
<td>OP1</td>
<td>Dummy is 1 for properties certified in years 2008–2009.</td>
<td>0.04</td>
<td>0.19</td>
<td>0</td>
<td>1</td>
<td>104</td>
</tr>
<tr>
<td>OP2</td>
<td>Dummy is 1 for properties certified in years 2002–2007.</td>
<td>0.05</td>
<td>0.22</td>
<td>0</td>
<td>1</td>
<td>136</td>
</tr>
<tr>
<td>OP3</td>
<td>Dummy is 1 for properties certified in years 1998–2001.</td>
<td>0.01</td>
<td>0.10</td>
<td>0</td>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>OP4</td>
<td>Dummy is 1 for properties certified before 1995.</td>
<td>0.00</td>
<td>0.06</td>
<td>0</td>
<td>1</td>
<td>10</td>
</tr>
</tbody>
</table>
## Description of Variables and Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLA</td>
<td>Dummy is 1 if property is a Class A building.</td>
<td>0.21</td>
<td>0.41</td>
<td>0</td>
<td>1</td>
<td>577</td>
</tr>
<tr>
<td>CLB</td>
<td>Dummy is 1 if property is a Class B building.</td>
<td>0.49</td>
<td>0.50</td>
<td>0</td>
<td>1</td>
<td>1341</td>
</tr>
<tr>
<td>PlotS</td>
<td>Plot size in acres.</td>
<td>3.96</td>
<td>32.25</td>
<td>0</td>
<td>560</td>
<td>2760</td>
</tr>
<tr>
<td>St</td>
<td>Number of stories.</td>
<td>6.58</td>
<td>8.10</td>
<td>1</td>
<td>77</td>
<td>2760</td>
</tr>
<tr>
<td>Sizeb</td>
<td>Size of the property in sq. ft.</td>
<td>35.49</td>
<td>30.54</td>
<td>2.92</td>
<td>170</td>
<td>2760</td>
</tr>
<tr>
<td><strong>Lease</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EB</td>
<td>Dummy is 1 if tenant pays electricity.</td>
<td>0.37</td>
<td>0.48</td>
<td>0</td>
<td>1</td>
<td>1029</td>
</tr>
<tr>
<td><strong>Research-specific</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cert</td>
<td>Dummy is 1 if the property has an energy certificate.</td>
<td>0.09</td>
<td>0.29</td>
<td>0</td>
<td>1</td>
<td>251</td>
</tr>
<tr>
<td>EB_CE</td>
<td>Interaction of EB and Cert. Equals 1 if both variables are 1 and 0 otherwise.</td>
<td>0.02</td>
<td>0.14</td>
<td>0</td>
<td>1</td>
<td>52</td>
</tr>
<tr>
<td>Rent</td>
<td>Rent per sq. ft.</td>
<td>$27.41</td>
<td>$13.71</td>
<td>$3</td>
<td>$158</td>
<td>2760</td>
</tr>
<tr>
<td>EB_LnOPEX</td>
<td>Interaction of EB and Ln(OpEx). Product of multiplication.</td>
<td>3.95</td>
<td>3.07</td>
<td>0</td>
<td>48.1</td>
<td>977</td>
</tr>
</tbody>
</table>

Notes: All dummy variables take values of 1 or 0.

*a OpEx is recorded as an overall cost for buildings regardless of who is responsible for covering particular items of that bill.

*b Descriptive statistics for Size have been shown in tens of thousands.

may be a potential source of selection bias from the population of all offices, it seems to give a representative sample of the office market and limits statistical issues with the data.

The parameters defined above yielded a sample of 41,964 properties. However, many buildings in the sample had incomplete information on some of the features that are important for this research (like operating expenses or lease type). In effect, a sample of 2,760 observations with complete information on all variables presented in Exhibit 3 has been selected for the research. The omission of variables of interest in the remaining data was investigated to check for a selection bias but no issues were identified.

Operating expenses consist of all costs of occupancy including both fixed costs that do generally do not vary (e.g., insurance) and variable costs (e.g., utilities, maintenance) that change depending on occupancy and market conditions. Tax is not included. Most importantly for this research, the OpEx variable includes energy costs.
In the sample, over 30 types of leases determining who pays particular operating expenses in a building were identified. For the purpose of this research, these have been divided into two groups of leases: those that oblige the tenant to pay at least the electricity bill and others that leave this obligation with the landlord (energy charge is included in the rent). While the cost of electricity does not always account for the total cost of energy used in a building, it often is the biggest item on that bill (Perez-Lombard, Ortiz, and Pout, 2008). In results, in this paper the responsibility to cover the total cost of energy usage is approximated by an obligation to pay for electricity. Therefore, an approximation of the responsibility to cover the total cost of energy usage by an obligation to pay for electricity seems justifiable.

Exhibit 1 illustrates how the responsibility for paying energy bills is expected to affect rents in certified buildings. Should this be limited to paying for electricity, the effect would be different (Exhibit 4). Assuming that the total energy bill can consist of an electricity bill and a bill for any other fuel that a building is using (coal, oil, gas, etc.), the effect of the assumption that paying for electricity is identical with paying for total energy can be investigated. The difference to Exhibit 1 is that instead of a premium for total energy efficiency \((a = a_1 + a_2)\), there now is a smaller premium for electricity efficiency \((a_1 = a - a_2)\). When approximating responsibility for an energy bill with responsibility for an electricity bill, an assumption is made that \(a_2\) is negligibly small compared to \(a\). This is true as long as a reduction in electricity accounts for the majority of a reduction in total energy bills. Given that electricity expenditure per square foot has been reported to be on average more than three times the cost of any other fuel (EIA, 2011), it can be concluded that for the purpose of this research being responsible for a total energy bill can be reasonably approximated with being responsible for an electricity bill.
Two types of eco-certification are included in the CoStar database: LEED and ENERGY STAR. Despite differences in awarding certificates, both protocols include requirements on energy efficiency.

A further addition to the data has been made to control for an effect of submarket location. Using historical data from the CoStar database, a ranking of submarkets with historically highest rents has been created based on average rents over 10 quarters prior to the recording period of the remaining data (2012:Q2). Based on the results, the sample was divided into four subsamples reflecting the position of particular submarkets in their respective markets.

This research may be influenced by a self-selection bias of agents who have a high inherit demand for energy services being more likely to self-select into energy-efficient properties. While the considerable homogeneity of energy-based services required by office space use limits possible differences in the use of energy between various agents and makes this bias unlikely, it could potentially result in operating expenses being artificially inflated.

**Methodology**

It can be seen from Exhibit 5 that certified buildings have statistically significantly higher rents and operating expenses. However, as a number of other building features may influence this relation, this analysis does not show causality. Hedonic modeling will be used to control for the large number of factors that influence prices in real estate.

All three hypotheses require an estimation of a price controlled for building characteristics. This can be done using the following model (Ekeland, Heckman, and Nesheim, 2002):
Price\(_i\) = \alpha + \beta x_i + \varepsilon_i,

where \(x_i\) is a vector of explanatory characteristics of a building, \(\beta\) is a vector of respective parameters that are to be estimated, and \(\varepsilon_i\) is a normally distributed random error with a mean of zero. Regression constant is given by \(\alpha\) and coefficients assigned to each of the explanatory variables can be interpreted as the contribution of the respective characteristic to the total price.

**Analysis**

Hypothesis 1 requires an estimation of OpEx prices controlled for building characteristics. This can be done using the following model:

\[
\ln(\text{OpEx}_i) = \alpha + \beta_1 NY_i + \beta_2 LA_i + \beta_3 DC_i + \sum_{n=1}^{7} \beta_4 A_{ni} \\
+ \sum_{n=1}^{3} \beta_5 S_{ni} + \sum_{n=1}^{4} OP_{ni} + \beta_7 CLA_i + \beta_8 CLB_i \\
+ \beta_9 \ln(\text{Rent}_i) + \beta_{10}\ln(\text{PlotS}_i) + \beta_{11}\ln(S_t_i) \\
+ \beta_{12}\ln(\text{Size}_i) + \beta_{13}\text{EB}_i + \beta_{14}\text{Cert}_i + \varepsilon_i.
\] (1)

This model has been guided byMcsporran and Tucker’s (2010) paper on this topic. Location variables are a proxy for differences in building management standards, energy use practices, weather conditions, local regulations, and cost of maintenance services. Age variables proxy for the type of construction technology and materials used, as well as the design type of a building. Although building size is not expected to be a considerable driver of per square foot OpEx, other physical characteristics of a building control for important determinants of operating costs like differences in required heating, general maintenance, and use of lifts. Finally, additional dummy variables on lease type and certification were added. The \(\text{EB}\) variable controls for a contracted obligation to pay energy bills and is expected to have a negative coefficient if the tenant is responsible for it to proxy for a better incentive to control the use of energy. The certification variable determines the impact of eco-certification on operating expenses. Should Hypothesis 1 be true, this effect is expected to be significant and negative.

Hypotheses 2 and 3 require estimation of a rent model, although they include different variables. The rent model used in this paper is based on Fuerst and McAllister’s (2011a, b, c) work and adjusted to suit a slightly different sample. The following model is used:
Exhibit 6 | Combined effects of EB, EB_CE, and Cert on Rent

<table>
<thead>
<tr>
<th>Tenant Pays Electricity</th>
<th>Building is Certified</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Reduced by electricity bill (-EB)</td>
<td>Reduced by electricity bill (-EB), increased by energy efficiency discount (+a), and increased by other certification benefits (+c) (-EB + a + c).</td>
</tr>
<tr>
<td>No</td>
<td>Benchmark</td>
<td>Reduced by energy efficiency discount (-a) and increased by other certification benefits (+c) (c - a).</td>
</tr>
</tbody>
</table>

Note: EB is electricity bill, a is energy efficiency discount on that bill, and c is other certification benefits.

\[
\ln(Rent_i) = \alpha + \beta_1 N Y_i + \beta_2 L A_i + \beta_3 D C_i + \sum_{n=1}^{7} \beta_n A_{ni}
\]

\[
+ \sum_{n=1}^{3} \beta_n S_{ni} + \beta_6 C L A_i + \beta_7 C L B_i
\]

\[
+ \beta_8 \ln(PlotS_i) + \beta_9 \ln(S_t_i) + \beta_{10} \ln(Size_i)
\]

\[
+ \beta_{10} E B_i + \beta_{11} Cert_i + \beta_{12} E B _{C e r t i} + \epsilon_i. \tag{2}
\]

Use of similar models is popular in the real estate literature and the effects of all included variables are well understood. The lease variable is specific for this research and is expected to have a negative coefficient to reduce the rent if a tenant pays for electricity. The certification variable has also been added and is expected to have a positive sign to proxy for total benefits of eco-certification to tenants. While this base model is useful for validation of the parameters against literature, it has been altered in order to test individual hypotheses.

Hypothesis 2 is tested by adding EB_CE as an explanatory variable to the base model in order to explore the interaction between who pays the electricity bill and certification of a property. Should the hypothesis be true, the sum of coefficients is expected to have a variable magnitude (Exhibit 6). Tenant should be willing to pay lower rents if they need to cover electricity (-EB) but that discount should be smaller for energy-efficient properties (-EB + a). The combined effect in a certified property should also include other benefits of certification (-EB + a + c). Should the landlord pay for electricity, the rent should be reduced by an energy efficiency discount (-a) but increased by other benefits (+c). Since it is only possible to observe the combined effect of energy efficiency and other certification benefits through the coefficient of the certification variable, we can find the energy efficiency coefficient in the following way:
If \( x \) and \( z \) are defined by equations:

\[
z = -EB + a + c, \quad x = -a + c,
\]

then \( a \) can be calculated by:

\[
a = \frac{(z - x + EB)}{2}.
\]

Since \( a, z, \) and \( x \) can be estimated from regression 2 in the following way:

\[
z = \beta_{10} + \beta_{11} + \beta_{12} \quad x = \beta_{11} - EB = \beta_{10},
\]

\( a \) can be represented as:

\[
a = \frac{\beta_{12}}{2}.
\]

\( \beta_{12} \) is a coefficient of \( EB\_CE \) and the statistical significance of \( a \) is identical to that of \( \beta_{12} \).

\( EB \) indicates responsibility for the energy bill, thus its coefficient represents the total amount of that charge. Energy efficiency saving should naturally be lower than the total energy cost. In effect the reduction in energy cost due to energy efficiency denoted as \( a \) is expected to be positive and smaller than the coefficient of \( EB \).

Hypothesis 3 is examined by adding operating expense controls (\( ln(OpEx) \), \( ln(OpEx)\_EB, OP1, OP2, OP3, \) and \( OP4) \) to the model used in Hypothesis 2 and comparing the results of the tests. Including these controls should isolate the energy cost changes from the total certification benefit. In fact, it will be possible to test if energy cost saving is the only benefit of energy efficiency that depends on lease contract terms. Should that be true, the remaining effects should be independent of who pays the energy bills. The coefficients of the OpEx variables are expected to be consistent with the findings from Hypothesis 1 testing.

Should the \( PE\_CE \) coefficient be zero, it can be assumed that certification is no longer related to who pays the energy bills. Therefore, since energy costs are the only component of the certification premium that depends on \( EB \), it would follow that this component has been isolated from the certification premium and associated with effects of the OpEx controls.
Results

Hypothesis 1

Panel A in Exhibit 7 shows the heteroscedasticity-adjusted (White, 1980) results of a hedonic model relating annual operating expenses per square foot to appropriate variables discussed above. The overall fit of the model may seem quite low with only 44% of changes explained by independent variables but as related literature points out, the operating performance of a building is mainly determined by the quality and motivation of its management (Mcsporran and Tucker, 2010). As this aspect is difficult to quantify and doing so is not the primary focus of this work, this factor was not included in this model. In effect, the $R^2$ of 44% seems satisfactory for the purpose of identifying effects of eco-certification on OpEx.

The location of a building seems to have a big influence on OpEx with buildings in New York City being by far the most expensive to run and those in Washington DC not displaying a significant difference to those in New Jersey. Recently built properties have the lowest OpEx; however, the effect of the age of a building may have an insignificant impact on that cost unless the building is three to four years old. The location in a particular submarket has a more consistent effect, with operating costs decreasing for the middle 50% of the ranked submarkets and increasing for the top quarter with the bottom 25% as a benchmark. Compared to expenses recorded within the last three years, OpEx fluctuated with time giving an average increase of 50.2% in 2002–2007, and decrease of 31% between 1998 and 2001. The effect of the class of a building is considerable, with a premium for Class A (23.9%) being more than three times the premium of Class B (7.5%) against the baseline of Class C. The statistically significant effects of rent and plot size seem very small, with 1% change in either variable causing respectively 0.581% and 0.135% change in OpEx. As expected, while buildings with more floors seem to be more expensive to run, due to additional infrastructure maintenance, the effect of building size on OpEx may not be significant. As predicted, if the tenant is responsible for the electricity bill, operating expenses are lower.

Finally, the effect of certification is statistically significant at a 5% confidence interval; however, the sign of the coefficient is opposite to expectations. From Panel A in Exhibit 7, it would seem that for an energy-certified property, the operating expenses are on average higher by 11.2% than for non-certified buildings. This is an increase of around $0.69 in OpEx per square foot (based on average OpEx for the non-certified sample). Compared to the $0.39 (4%) increase found by Miller, Pogue, Saville, and Tu (2010), this seems reasonable, although, contrary to their research, here the result is significant. The data from Exhibit 7 seems not to support Hypothesis 1, thus eco-certification does not directly correlate to lower operating expenditure.

The lack of evidence for Hypothesis 1 indicates that lower energy costs may not be a direct result of energy efficiency improvements. However, the test looked at total operating expenses rather than energy costs, leaving room for additional
### Exhibit 7 | Heteroskedasticity-adjusted Regression Results

<table>
<thead>
<tr>
<th>Panel A</th>
<th>Panel B</th>
<th>Panel C</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Ln(OpEx)} )</td>
<td>( \text{Ln(Rent)} )</td>
<td>( \text{Ln(Rent)} )</td>
</tr>
<tr>
<td>Coeff.</td>
<td>Std. Error</td>
<td>Coeff.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>(-0.869)</td>
<td>(2.597)</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NY</td>
<td>(0.625)</td>
<td>(0.097^{***})</td>
</tr>
<tr>
<td>LA</td>
<td>(0.133)</td>
<td>(0.057^{***})</td>
</tr>
<tr>
<td>DC</td>
<td>(0.022)</td>
<td>(0.057^{***})</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>(-0.524)</td>
<td>(0.097^{***})</td>
</tr>
<tr>
<td>A2</td>
<td>(-0.255)</td>
<td>(0.097^{***})</td>
</tr>
<tr>
<td>A3</td>
<td>(-0.183)</td>
<td>(0.097^{***})</td>
</tr>
<tr>
<td>A4</td>
<td>(-0.166)</td>
<td>(0.097^{***})</td>
</tr>
<tr>
<td>A5</td>
<td>(-0.227)</td>
<td>(0.097^{***})</td>
</tr>
<tr>
<td>A6</td>
<td>(-0.025)</td>
<td>(0.097^{***})</td>
</tr>
<tr>
<td>A7</td>
<td>(-0.055)</td>
<td>(0.097^{***})</td>
</tr>
<tr>
<td><strong>Submarket</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>(0.123)</td>
<td>(0.055^{**})</td>
</tr>
<tr>
<td>S2</td>
<td>(-0.082)</td>
<td>(0.054)</td>
</tr>
<tr>
<td>S3</td>
<td>(-0.119)</td>
<td>(0.050^{**})</td>
</tr>
<tr>
<td><strong>OpEx</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OP1</td>
<td>(0.058)</td>
<td>(0.087)</td>
</tr>
<tr>
<td>OP2</td>
<td>(0.502)</td>
<td>(0.063^{***})</td>
</tr>
<tr>
<td>OP3</td>
<td>(-0.310)</td>
<td>(0.171^{*})</td>
</tr>
<tr>
<td>OP4</td>
<td>(0.102)</td>
<td>(0.170)</td>
</tr>
<tr>
<td>(\text{Ln(OpEx)})</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>(\text{EB_{LNOPEX}})</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLA</td>
<td>(0.239)</td>
<td>(0.075^{***})</td>
</tr>
<tr>
<td>CLB</td>
<td>(0.075)</td>
<td>(0.046)</td>
</tr>
<tr>
<td>(\text{Ln(Rent)})</td>
<td>(0.581)</td>
<td>(0.060^{***})</td>
</tr>
<tr>
<td>(\text{Ln(PlotS)})</td>
<td>(0.135)</td>
<td>(0.025^{***})</td>
</tr>
<tr>
<td>(\text{Ln(St)})</td>
<td>(0.275)</td>
<td>(0.048^{***})</td>
</tr>
<tr>
<td>(\text{Ln(Size)})</td>
<td>(0.001)</td>
<td>(0.034)</td>
</tr>
<tr>
<td>EB</td>
<td>(-0.120)</td>
<td>(0.045^{***})</td>
</tr>
<tr>
<td>Cert</td>
<td>(0.112)</td>
<td>(0.045^{**})</td>
</tr>
<tr>
<td>(\text{EB_{Cert}})</td>
<td>N/A</td>
<td>(-0.069)</td>
</tr>
</tbody>
</table>

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

Notes: The dependent variables are \(\text{Ln(OpEx)}\) and \(\text{Ln(Rent)}\). For Panel A, \(R^2 = 0.44\), F-stat. = 86.59; for Panel B, \(R^2 = 0.647\), F-stat. = 239.5; for Panel C, \(R^2 = 0.662\), F-stat. = 198.1.
factors that could have influenced the result. Testing Hypothesis 2 can help provide more information on how that process works.

**Hypothesis 2**

Panel B in Exhibit 7 shows heteroscedasticity-adjusted (White, 1980) regression results of a test described above. The basic model has good explanatory power, similar to the work presented by Fuerst and McAllister (2011c), as well as other similar research on the subject (Eichholtz, Kok, and Quigley, 2010). Most statistical data in the table is as expected as are all the usual real estate phenomena (e.g., the nonlinear effect of age). Both market and submarket locations are significant, with New York City again being the most expensive. Age discount is increasing initially but reduces as buildings are becoming classics. Furthermore, class and number of floors have, as expected, a significant positive influence on rents. The signs of the coefficients of plot size and building size are surprising and different to the results presented by Fuerst and McAllister (2011a, b, c) but they match results of other similar pieces of research (Eichholtz, Kok, and Quigley, 2010), which would suggest that the effect is different for different samples.

An average discount of 13.1% for paying electricity bills in non-certified buildings translates into $3.43 (based on average rent for the non-certified sample) and can be represented as 55.8% of an average OpEx (based on average OpEx for the same sample). Although this seems high against expectations of an energy bill to be around 30% of total OpEx, both the positive sign of the adjustment and the fact that its magnitude is lower than an average total OpEx are consistent with expectations. However, the combined results for responsibility for payment of an electricity bill and eco-certification are not as predicted. While it seems clear that a responsibility for electricity expenses is important for rents, certification of a building does not appear to always influence it (Exhibit 8). Energy-efficient buildings seem to generate higher rents if an owner is paying for electricity but there seems to be little change if that is not the case.

If the effect of energy cost savings is separated from other coefficients using equation (3), the resulting $a$ is equal to $-0.0343$. This indicates an overall negative effect of energy efficiency on rents of 3.43% independent of lease terms and a positive effect of other certification benefits ($c$) of 4.41%. This is consistent with the findings of the previous hypothesis, indicating that since certification is related to increased operating expenses, the financial consequence should be negative.
Although a rise in energy costs is not an expected result, it has been considered in the literature as one possible outcome (Herring, 2006) and supported by some evidence (Lin and Young, 2009; Scofield, 2009a, b). In effect, a conclusion that energy costs increase with certification seems plausible. Since energy cost change could be defined as a change in an energy bill minus a periodical amortization of costs of introducing efficiency, one explanation for a negative value of that effect would be that the costs outweigh the benefits. However, there is strong evidence of profitability of energy efficiency’s ability to decrease the total amount of energy units used given a constant demand for output. An increase in energy bills relative to expectations driven by increased output seems a likely explanation of a negative effect of energy efficiency improvements.

Findings of the test are consistent with the hypothesis that the effect of energy cost changes (in this case an increase) is dependent on the terms of lease contracts. In effect, Hypothesis 2 can be confirmed.

It could be argued that a factor unrelated to energy costs but related to certification and lease terms is influencing the results. The test for hypothesis 3 looks for the presence of such a factor.

**Hypothesis 3**

Panel C in Exhibit 7 presents the heteroscedasticity-adjusted (White, 1980) results of a regression based on a rent model including additional variables controlling for operating. As expected, the explanatory power of the model increases as OpEx is an important determinant of rents. Other explanatory variables are consistent with the results from Panel B.

The influence of operating expenses is significant but also, as expected, closely related to who pays the energy bills. Only measurements taken between 2008 and 2009 statistically influence rents; the year of recording does not seem to be a generally significant determinant of rents.

As expected, the interaction of certification and EB variables is no longer statistically significant after OpEx controls have been included. An association of certification with responsibility to pay for energy bills has been isolated and transferred to the OpEx variable. It would seem that energy costs have been isolated from the certification variable and associated with operating expenses. This gives support to Hypothesis 3.

**Discussion of Results**

In the previous section, all results were interpreted individually and validated against expectations. However, in order to answer the research question, all results need to be brought together in an attempt to form a coherent conclusion.

Hypothesis 1 seems not to find support in empirical evidence. In fact, the opposite seems to be true: certification increases operating expenses. As counterintuitive as this seems, it is not entirely unexpected. As mentioned above, explanations
suggested in the literature include an energy rebound effect, increased maintenance costs, self-selection effect, and increase in the overall use of utilities. From the test for Hypothesis 1, it is impossible to establish which of those, if any, is the real reason. Moreover, it is not possible to see if certification is causing an increase in energy use or an increase in other costs. While it is not clear what effect causes the increase in OpEx, there is a correlation between eco-certification and increased operating expenses. The results indicate that the hypothesis that eco-certification lowers operating costs should be rejected. However, although indicative, the evidence is not strong enough to support a claim that certification leads to higher OpEx. For the purpose of this paper, the fact that certification is associated with higher OpEx is sufficient basis to look into the transmission mechanism of that change to rent.

Hypothesis 2 assumes that rent effects of any changes in energy costs associated with certification would be dependent on who pays the energy bills. An empirical analysis finds evidence of an interaction between who pays the energy bills and eco-certification. Since energy costs are the only effect of such certification that is expected to interact with lease terms, this is indicative evidence of energy cost changes being included in the certification premium. Using equation (3), it was possible to isolate the change on energy bills, which has been found to be an increase. This is entirely consistent with the findings of Hypothesis 1. Should higher energy costs be associated with eco-certification, an increase in energy bills for certified properties is expected to be found. The result can be interpreted as an absolute increase in energy bills if costs of introducing energy efficiency are ignored or a reduction in energy bills of less than expected (relative increase) if they are accounted for.

It is possible that the relationship in Hypothesis 1 has been influenced by effects other than costs of energy. This would not be affecting the results in Hypothesis 2 tests as the EB control variable ensures that only energy bill-related effects are reflected. The matrix of effects that eco-certification and EB variables have on rent (Exhibit 8) is consistent with expectations from the methodology section (given the reverse effect of energy costs and results of Hypothesis 1 tests). In fact, an average increase in OpEx from non-certified buildings can be estimated at $0.69 psf (Panel A in Exhibit 7 and Exhibit 5) while the increase in rents associated with increased costs of energy can be estimated at $0.89 psf (Panel B in Exhibit 7 and Exhibit 5). A similar magnitude of those changes is consistent with the assumption of a common driver, like a change in energy costs, although a slight difference suggests that an additional factor may influence the relation. While Hypothesis 2 is confirmed, an analysis of its test results indicates an unexpected increase of energy bills in eco-certified properties. However, given the methodology used, this finding is only valid if changes in energy bills are the only component of a certification premium that is dependent on who pays the energy bills.

Hypothesis 3 was established to investigate this assumption. By controlling rents for OpEx, the energy change component of certification premium should be isolated as operating expenses are a far better proxy for that variable. In effect,
eco-certification should not have a link to who pays the energy bills. Empirical tests have found evidence that this indeed is the case. After controlling for OpEx, the $EB$ variable was no longer interacting with certification. The conclusion of that test is that energy bill changes are indeed the only component of the total certification premium that has previously been associated with who pays energy bills. Thus, conclusions from Hypothesis 2 are validated.

As stated in the research question, this research seeks to find if changes in the energy costs associated with eco-certification are reflected in rents. First, the findings indicate that eco-certification is associated with higher operating expenditure, but no direct link to energy bills could be made. Second, a relationship of eco-certification with who pays the energy bills has been discovered. A relative or absolute increase in energy bills for eco-certified properties has also been shown depending on how costs of introducing energy efficiency are accounted for. This indicates not only that eco-certified properties have higher than expected energy bills but that this effect is affecting rents. In this context, it would seem that the increase in operating expenditure from Hypothesis 1 can be indeed caused by an energy bill being higher than expected after introducing energy efficiency. However, the findings would not be valid if another factor associated with who pays the energy bills was affecting the eco-certification premium. The last test of this research showed that this was not the case and validated the findings of previous investigations.

**Conclusion**

This paper reports empirical evidence of changes in the energy costs that are associated with energy efficiency that affects rents in U.S. office buildings. A sample of the four biggest U.S. office markets was limited to 2,760 properties for which required information was available from the CoStar Group database. The energy efficiency of a building was approximated with having certification from LEED or ENERGY STAR and the responsibility of a tenant or owner for paying energy bills with a responsibility to pay for electricity.

The results indicate that the changes of energy costs associated with eco-certification have an influence on rents. The change is first reflected in the operating expenses of a building and how this charge affects rents. Although generally the sign of the effect on rent depends on which agent is responsible for paying energy bills, its magnitude remains constant.

Despite the counterintuitive negative effects of eco-certification both on energy bills and on total operating expenses, the certification effect on rental rates is positive. This suggests that the main benefits of eco-certification may not be related to reduced energy use but to other characteristics of eco-certified buildings. However, a strong caveat is in order given the indirect nature of our energy expenditure data and more reliable metrics of energy consumption, such as detailed meter readings, are necessary to confirm these preliminary findings.
Appendix

Data Selection and Selection Bias

As data in the CoStar database is normally recorded and disclosed at the discretion of the reporting party, there is a risk of a reporting bias in the data especially considering the sensitive nature of some information. Limiting the sample of 41,964 properties to observation that included the information required by the model (excluding OpEx) resulted in a sample of 7,561 buildings. No material correlation of the missing data has been found to other variables. In fact, only 9,465 properties reported their rents of which further observations had to be discarded due to a lack of data on important building characteristics. While this could potentially be a source of a self-selection bias caused by selective reporting, it is unlikely that owners of properties would intentionally and systematically withhold information on the size of their buildings or the number of stories or elevators (which is available publically anyway).

This is not the case for operating expenses. This piece of information is not only an indication of overall operating performance, important in comparing assets, but also an indication of the quality of how a building is maintained. In effect values that are considered by the owners to be above average or simply not favorable may not to be reported. This could potentially introduce a bias into the research and systematically lower the average reported value of operating expenses. In order to check for that bias, values of OpEx in the sample can be compared to similar data from other sources.

Exhibit A1 shows that the average OpEx in the sample is $6.58/sq. ft., with a standard deviation of 5.41. Surprisingly this is much lower than an average of just over $10/sq. ft. reported by Miller, Pogue, Saville, and Tu (2010), although rigorous statistical comparison is not possible as they do not report a standard deviation. The variation may arise from a difference in geographical locations. This piece of research looks at four markets while Miller, Pogue, Saville, and Tu looked at buildings from as many as ten. Exhibit A1 shows how much variance there is between individual locations in the sample of this research. Using NCREIF data for the period from 1999 to 2008, Pivo and Fisher (2010) reported a relatively high average expense of $11.58/sq. ft. However, their variable included all costs rather than just operating so included items such as tax. Given an average value of tax of $6.87/sq. ft. in the sample used in this paper, their findings can be easily reconciled with the OpEx from Exhibit A1. Jaffee, Stanton, and Wallace (2011) report an average of $7.7/sq. ft. over 5,092 observations in a dataset combing information from Trepp LLC and CoStar transaction service, which is also very close to the number from Exhibit A1. Furthermore, data from a report by BOMA (2009) is presented in Exhibit A1 and, where it can be directly compared, does not seem to show a significant difference from the reports of this research.

Operating expenses by location can also be broken down by class and is expected to show significant differences. From Exhibit A1, it would seem that this is indeed
The Operating Expense Puzzle

From a database of Whitestone Research, data on Class A office buildings for individual locations has been extracted. The results presented in Exhibit A1 are consistent with the findings of this paper and show no indication of a significant variance. Although no alternative external data from the researched locations could be accessed, a report from the Chicago market (Dermisi, 2008) gives a basis for comparison of differences between individual classes. Class A offices in Chicago paid $9.73/sq. ft., which is very close to the $9.87/sq. ft. found in this research. Other classes of buildings gave larger differences of Chicago’s $9.14/sq. ft. and $8.62/sq. ft. against $7.35/sq. ft. and $5.00/sq. ft. in the sample for Classes B and C, respectively. Although they may seem different, those variations fall well within the standard error of the averages reported in this paper.

As a result of the above analysis, it can be concluded that the OpEx data extracted from the CoStar database shows no indication of significant unexplainable differences to data reported from other sources. While access to external sources of relevant information has been limited, all comparable data that has been obtained can be reconciled with the results included in this research.

Exhibit A1 | Operating Expenses in Dollars per Square Foot

<table>
<thead>
<tr>
<th></th>
<th>This Research</th>
<th>BOMA (2009) Average Including All Classes</th>
<th>Whitestone Research Class A (2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NY (mean)</td>
<td>17.37</td>
<td>13.1</td>
<td>17.88</td>
</tr>
<tr>
<td>Std. Error</td>
<td>5.42</td>
<td>5.42</td>
<td></td>
</tr>
<tr>
<td>Obs.</td>
<td>89</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>DC (mean)</td>
<td>9.02</td>
<td>8.41</td>
<td>9.27</td>
</tr>
<tr>
<td>Std. Error</td>
<td>3.43</td>
<td>4.21</td>
<td>4.36</td>
</tr>
<tr>
<td>Obs.</td>
<td>286</td>
<td>498</td>
<td>911</td>
</tr>
<tr>
<td>LA (mean)</td>
<td>9.83</td>
<td>8.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.72</td>
</tr>
<tr>
<td>Std. Error</td>
<td>3.57</td>
<td>4.31</td>
<td></td>
</tr>
<tr>
<td>Obs.</td>
<td>93</td>
<td>274</td>
<td>588</td>
</tr>
<tr>
<td>NNJ (mean)</td>
<td>6.00</td>
<td>9.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.93</td>
</tr>
<tr>
<td>Std. Error</td>
<td>2.65</td>
<td>2.52</td>
<td></td>
</tr>
<tr>
<td>Obs.</td>
<td>109</td>
<td>336</td>
<td>692</td>
</tr>
<tr>
<td>All (mean)</td>
<td>9.87</td>
<td>6.58</td>
<td>8.11&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Std. Error</td>
<td>5.06</td>
<td>4.96</td>
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<tr>
<td>Obs.</td>
<td>577</td>
<td>842</td>
<td>2760</td>
</tr>
</tbody>
</table>

Notes: For data from this paper, a mean value is given first. For combined Los Angeles and Orange County and for Northern New Jersey only, no BOMA data was available thus related but not directly comparable values are shown.

<sup>a</sup>Los Angeles only

<sup>b</sup>Whole New Jersey

<sup>c</sup>All U.S.
References


We thank the CoStar Group for kindly providing the data needed to perform this analysis.
Willingness to Pay for Green Buildings: Empirical Evidence from Switzerland

Author Andreas Wiencke*

Abstract The demand for green buildings and to what extent firms will pay a premium price compared to conventional buildings is a lively debate. Policy instruments like the Swiss CO₂-enactment and the Swiss Building Program encourage and incentivize investments in energy-efficient properties. Based on a corporate real estate survey, I investigate the premium percentage price firms are willing to pay for green buildings. On average, Swiss corporations are willing to pay a premium price of 3.0% for leasing, 4.75% for purchasing, and 5.0% for retrofitting. Depending on firm characteristics, the premium price ranges from 1.3% to 7.9% compared to conventional properties. Firms from the building and financial service industries, as well as public corporations and authorities signal the highest willingness to pay.

Buildings are responsible for approximately 40% of energy consumption and for 24% of worldwide greenhouse gas emissions (IEA, 2006). However, the real estate literature points to a multitude of motivations to invest in energy-efficient properties. Economic and ecological benefits appear when firms try to reduce their energy, water, and waste consumption. With an investment in green buildings, firms hedge against rising energy prices and operating costs, as they try to reduce their ecological footprint (Eichholtz, Kok, and Quigley, 2010). In particular, commercial buildings can reduce their CO₂ emissions easily and to a large extent while investing in energy-saving measures. Moreover, green buildings set higher standards and create better environmental quality indoors, which might lead to an improved working environment, healthy working conditions, and increased employee productivity (Linn and Quintal, 2011). Another likely reason that corporations might increase their demand and be willing to pay for green buildings is acknowledged in terms of image and reputation. A better reputation allows firms to attract prospective employees and investors, and to charge higher sales prices for their business and products (Eichholtz, Kok, Quigley, 2010, 2013). Firms that invest in green buildings illustrate their ecological and social awareness, which is expected to be appreciated by their stakeholders. Some of these advantages and amenities are financially measurable, while others appear as intangible benefits. Therefore, analyzing the willingness to pay for green buildings is associated with a balancing costs and benefits.

In the aftermath of the 2012 United Nations Framework Convention on Climate Change in Doha (the Doha Amendment) and its resolution of a second Kyoto
Protocol, the Federal Council of Switzerland (Bundesrat) announced a revised CO\textsubscript{2}-enactment and climate change strategy for 2013 to 2020.\textsuperscript{1} Aiming to reduce greenhouse gas emissions by 20\% in the year 2020 compared to 1990, the real estate sector highlights a substantial part of the federal energy strategy in Switzerland (IEA, 2007; Bundesamt für Umwelt, 2010). It is expected that the real estate sector will contribute the majority (up to 40\%) in reducing greenhouse gas emissions, whereas 10\% is expected to come from traffic and 15\% from the industrial sector (Bundesamt für Energie, 2012). The CO\textsubscript{2}-enactment provides the yearly amount of approximately 200 million Swiss francs to support investments in energy-efficient residential and commercial real estate. The program has been enacted for the upcoming 10 years and it is estimated that more than 2 million tons of CO\textsubscript{2} will be saved within that period of time.\textsuperscript{2} The Swiss CO\textsubscript{2}-enactment allows for a CO\textsubscript{2} tax reduction or for an avoidance, when firms contribute significantly to a reduction of greenhouse gas emissions. Moreover, voluntary corporate initiatives and sustainable business behavior is an integral part of the Swiss carbon abatement strategy. Further investments in green buildings are expected and institutional regulation is only going to intensify.

In this paper, I investigate the premium percentage price that firms are willing to pay for green buildings in Switzerland. For the case of Switzerland there is relatively little evidence for private corporations and public authorities displaying a willingness to pay. Most studies related to the Swiss real estate market analyze the willingness to pay of homeowners or the potential of energy efficiency measures for the residential real estate market (Jakob and Madlener, 2004; Jakob, 2007; Alberini, Banfi, and Rameie, 2011). This study contributes to the literature and fills the gap for commercial real estate and for firms’ willingness to pay for green buildings. The analysis is based on the stated preferences of Swiss corporations.

The literature on green buildings provides empirical evidence for diverging lease and sale prices. Considering these differences, I distinguish between the decision to lease or buy (purchase) corporate real estate. The additional contribution of this paper is the analysis of the willingness to pay for a retrofit. A retrofit occurs when a firm increases the energy efficiency of a building. Moreover, I investigate the impact of firm characteristics, such as firm size, legal form, and industry on the willingness to pay. Besides industry-specific characteristics, it is interesting to examine whether there are any substantial differences between private corporations and public authorities. However, the case of Switzerland allows for a distinctive analysis of regional disparities. Due to the Swiss cantonal municipalities (Swiss cantons), I also control for regional differences in terms of Swiss Grand-Regions. Taking into account that the willingness to pay signaled by the surveyed firms is strongly related to their business behavior, I also shed light on firms’ attitudes towards sustainability in terms of economic, ecological, and social contributions.

Based on a 2013 survey, this study includes a sample of 145 Swiss corporations. This paper contributes to the literature, even though an analysis of stated preferences can be criticized because the responses are not real market or transaction-based data.\textsuperscript{3} Research findings illustrate premium prices that range from 1.3\% to 7.9\% on average compared to conventional properties. Moreover,
the research indicates that corporations from the building and financial service industries are among the firms that recognize the highest willingness to pay for green buildings. In addition, public authorities signal a substantial willingness to pay. With regard to the diverging investment horizons, I find that Swiss corporations are willing to pay a premium price of 3.0% for a lease, 4.75% for a purchase, and 5.0% for a decision to retrofit, on average.

The remainder of this paper is organized as follows. The next section provides a literature review and clarifies the empirical findings regarding the premium prices of green buildings as compared to conventional properties. I describe the methodology, including the descriptive and empirical analysis, in order to investigate the willingness to pay for commercial real estate in Switzerland. In the subsequent section, I describe the results and implications. Finally, the paper closes with concluding remarks.

Related Literature
The real estate literature provides a multitude of studies that deal with the analysis of premium rental and sales prices. Most studies focus on premium prices in order to investigate the financial benefits of green buildings compared to those of conventional real estate. Considering these diverging rental and sales price premiums, it is obviously a crucial distinction, whether firms want to lease or buy. One could expect that the decision to purchase is associated with a longer investment horizon as buying a property ties up a substantial amount of capital in contrast to leasing. Generally, long-term decision-making, including the decision to buy property, is associated with a higher willingness to pay.

Diverging Preferences and Inefficient Investments
Differences in stated preferences about the willingness to pay could result from the diverging interests of landlords and tenants. Investments in real estate sustainability suffer when price-sensitive decision makers do not directly benefit from energy savings and related amenities (Alberini, Banfi, and Ramseier, 2011; Eichholtz, Kok, and Quigley, 2011). This situation occurs when landlords or property owners do not occupy their own buildings (Alberini, Banfi, and Ramseier, 2011). Therefore, one could expect a significant difference between the decision to lease or to buy, especially because of market failures and other barriers (Kok, Miller, and Morris, 2012). Besides differences in the willingness to pay, a premium price, market failures, and barriers are responsible for inefficient spending in real estate, especially in the areas of sustainability and appliances (Jaffe, Newell, and Stavins, 2004). The so-called energy efficiency paradox describes the situation of inefficient investments, or simply the lack of investments, in energy-efficient technologies (Jaffe and Stavins, 1994a; Metcalf and Hassett, 1999; Klemick and Wolverton, 2013). This occurs although an investment appears to be appropriate, for ecological, social, and economic reasons (Jaffe and Stavins, 1994b; Jaffe, Newell, and Stavins, 2004). The real estate literature provides a multitude of explanations as to why decision makers do or do not invest in energy-efficient
properties. As Jaffe, Newell, and Stavins (2004) point out, it is generally a question of balancing costs and benefits. Costs appear to represent primary considerations, whereas benefits, such as energy savings and reduced energy bills, occur over a longer time horizon. Therefore, discounting future cash flows from energy-efficient investments is substantial in this context (Kats, 2003). Moreover, Jaffe, Newell, and Stavins (2004) provide an overview of the market and non-market failures that explain the energy efficiency gap. Among those explanations is the lack of information; information asymmetry between counterparties in concurrence with the principal-agent problem; transaction costs; uncertainty about future energy prices; or uncertainty about forthcoming technology developments (Hassett and Metcalf, 1993; Jaffe and Stavins, 1994b; Jaffe, Newell, and Stavins, 2004). Additionally, a low capitalization rate of energy-efficient investments is often proclaimed to be a significant barrier to investment (Houser, 2009). These barriers to an investment in concurrence with individual preferences indicate their impact on diverging stated preferences regarding the willingness to pay (Eichholtz, Kok, and Quigley, 2010, 2011). For some decision makers, it is appropriate to wait with an investment in energy-efficient technology and to delay the decision to invest. This also holds for individuals and firms.

Another reason for diverging preferences regarding the willingness to pay occurs when corporations outsource their properties, as they increasingly do (Eichholtz, Kok, and Quigley, 2010). Owning properties is becoming less common, especially in the third industry sector. Ownership of commercial real estate has decreased significantly, as pointed out by Brounen and Eichholtz (2005) and Eichholtz, Kok, and Quigley (2010). Although I do not control for varying effects across time, differences in the ownership of real estate assets indicate their impact on the willingness to pay.

Empirical Evidence on Premium Prices

In one of their initial studies, Eichholtz, Kok, and Quigley (2010) provide evidence on the economic value of green buildings. Based on real estate market transactions, they analyze more than 10,000 commercial buildings with a control sample of conventional properties. They use a geographical information system to control for diverging location preferences and for the overall quality of the building. The control building in their study had to be within a given radius of the corresponding certified building. Using ENERGY STAR and LEED office buildings from the CoStar database, they analyze rents, effective rents, and selling prices.

For the U.S. real estate market, the labels ENERGY STAR and LEED are well documented and describe certified properties or so-called green buildings. In collaboration with the U.S. Green Building Council and the U.S. Environmental Protection Agency, the CoStar Group developed a comprehensive database with Energy Star ratings and LEED certified buildings, which is a rich source for a multitude of real estate research. Whereas ENERGY STAR primary concentrates on energy efficiency, LEED describes a wider concept of sustainability attributes.

The findings of Eichholtz, Kok, and Quigley (2010) indicate a 3% rental premium per square foot, as well as a 6% premium price for effective rents. Distinguishing
between ENERGY STAR and LEED, they find a 3.3% premium rent for ENERGY STAR and a 5.2% premium for LEED properties. Using effective rents, the premium increases to 10% for ENERGY STAR and 9.4% for LEED. These findings correspond to the decision to lease addressed here. For the decision to buy, they find a selling price premium of 16% for green buildings on average. With regard to the characteristics of the ENERGY STAR and LEED programs, Eichholtz, Kok, and Quigley (2010) acknowledge that for ENERGY STAR labeled properties, the premium price is strongly related to energy-savings characteristics. However, they also conclude that the relative premium for green buildings is higher in low-cost and less expensive metropolitan areas. The percentage increase in rent or sales price is systematically higher in low-cost and more peripheral regions.

Fuerst and McAllister (2011) investigate the price effects of green buildings compared to conventional buildings, using hedonic regression analysis. Also for the U.S. commercial real estate market, they use CoStar data to measure the effect of labeled properties, both for rents and sales prices. They analyze price differentials between commercial LEED and ENERGY STAR labeled properties and conventional properties. They control for differences in property characteristics, such as age, quality in terms of building classes, building height, submarkets, and other amenities. To distinguish between rent and sales prices, they develop two hedonic regression models: a rent and a transaction price model. The transaction price model is used to estimate the premium price per square foot taken from real estate sales transactions. In contrast to their rent model, the sales price model additionally includes a time trend variable that controls for price inflation and other unobserved trends over time (Fuerst and McAllister, 2011). Moreover, the sales price model provides a control variable for market conditions at the time of sale. The sample includes approximately 200 LEED and 800 ENERGY STAR labeled properties, whereas 15,000 buildings were randomly selected from a control sample. They find a rental premium of 4%–5% on average for green buildings; the sales price premium is substantially higher and achieves up to 25%–26% on average.

Similar findings are provided by Miller, Spivey, and Florance (2008), who also use CoStar data. They control for property size, location, and age of the building. They use hedonic regression models to account for sales and rental prices. Although their findings support a positive impact of labeled properties on rents and sales prices, they are not significant at the conventional 10% level. This holds for both ENERGY STAR and LEED buildings. Nevertheless, they find a premium sales price of approximately 6% for ENERGY STAR buildings and about 10%–11% for LEED properties (Miller, Spivey, and Florance, 2008).

The findings of Wiley, Benefield, and Johnson (2010), analyzing ENERGY STAR and LEED properties in the U.S., support the aforementioned results. They find rental premium prices of approximately 7%–9% for ENERGY STAR buildings and 15%–18% for LEED buildings. With regard to a sales price premium, they find a $130 per square foot premium for LEED buildings and a $30 premium per square foot for ENERGY STAR properties. Fuerst and McAllister (2011) acknowledge that these findings might include another premium in addition to the
energy efficiency label. The premium price both for rent and sales might contain a premium for a preferred site and location. Although Wiley, Benefield, and Johnson (2010) use a dataset with properties from the same metropolitan area, they do not control for possible location differences. Beyond the lease or buy decision, the additional contribution of this paper to the real estate literature is illustrated in the case of real estate renovation and related stated preferences. National and international renovation rates are still too low to achieve global policy goals like the Kyoto Protocol (Jakob, 2007). As (Eichholtz, Kok, and Quigley, 2010) state, in the past decades the annual construction rate of new office buildings account for approximately 2% of the existing building stock. Without a significant rate of energy-efficient renovation, achieving global energy efficiency goals in the built environment would be unfeasible. For the case of Switzerland, Jakob (2007) estimates that energy-efficient renovations only account for 0.4%–0.8% of the total building stock per year. Moreover, the author investigates the drivers and barriers for an investment in energy efficiency or, more precisely, for the improvement of the buildings outer surface. For residential properties, he finds that renovations are much more driven by technical parameters and general housing activities, rather than by socio-economic factors such as income, age, and education. However, the renovation case is particularly interesting because building renovation is one of the key elements in achieving energy efficiency in the built environment (Kok, Miller, and Morris, 2012). Jakob (2007) emphasizes that the existing building stock has an even greater potential to reduce greenhouse gas emissions than do newly built properties.

Kok, Miller, and Morris (2012) analyze the economics of green retrofits. This is one of the first empirical investigations of premium prices for certified properties in terms of renovation cases. Using the CoStar data for the U.S. real estate market, they analyze premium rents and effective rents of LEED certified buildings after a retrofit. They compare rents and occupancy rates of certified and non-certified buildings in a controlled sample. Moreover, they investigate the achieved energy efficiency improvements after a retrofit, along with the related investment costs. The analyzed certification period is between 2005 and 2010. Using a survey among real estate managers, they account for the attitude towards the costs and benefits of green retrofits. The sample includes 374 properties in the U.S. office market. They find that the average premium rent for retrofitted commercial LEED properties is about 7.1% compared to non-certified properties. This finding is equivalent to a premium rent of $2 per square foot. Effective rents are approximately 9% higher, which corresponds to a $3 per square foot premium. The total dollar amount invested in retrofits, in their sample, is roughly $400 per median and $2 million per mean, respectively. The results differ significantly depending on the local real estate market. For example, the differences in premium prices are higher in New York City and Boston than in other markets, such as San Francisco. The results indicate that a retrofit makes sense in terms of the financial payback. On average, the benefits of energy-efficient renovations outweigh the costs of renovation. Deeper renovations improve the quality and competitiveness of the buildings and lower the opportunity costs. Data on real estate rental and sales price premiums are scarce. Most of the studies that provide empirical evidence on premium prices for green buildings are limited to the U.S.
real estate market. As with this paper, the following studies investigate the Swiss real estate market. So far, empirical studies for Switzerland are only available for the residential real estate market.

Instead of focusing on distinctive premium rent and sales prices, Alberini, Banfi, and Ramseier (2011) provide insight into homeowners’ preferences for energy efficiency renovations. They use a 2010 survey based on a conjoint choice experiment on Swiss homeowners in five cantons. Their 473 participants could choose between different energy-efficient renovation projects to account for upfront costs, monetary benefits from saving energy, time of amortization, and the improved thermal comfort. Interestingly, they find that the likelihood of investing in energy-efficient renovation projects increases with the amount of subsidy offered by the Swiss federal government. Although the available amount of subsidy accounts for only a minor part of the investment costs, this implicitly impacts the willingness to pay. Moreover, their study shows that decision makers care about the upfront costs of energy-efficient investments. Another finding from stated preferences indicates that the public’s attitude towards climate change plays a crucial role for the motivation to invest in renovations. Households that believe in the impact and importance of climate change are more likely to renovate and achieve the status of having a green building (Alberini, Banfi, and Ramseier, 2011). Also, expectations about future energy prices appear to be important in homeowners’ decisions. As Alberini, Banfi, and Ramseier (2011) point out, people who expect increasing energy prices for the next 20 years are more likely to invest in renovations. However, analyzing stated preferences of survey participants, uncertainty is a factor under consideration. Participants who are uncertain about future energy prices do not invest or invest with a substantially lower probability in renovation. Appraising costs and benefits, Alberini, Banfi, and Ramseier (2011) calculate a discount rate of 1.5 to 2.9, which indicates a balanced costs and benefits relation. Benefits such as future energy savings are not discounted very strongly by Swiss homeowners. These results show that related benefits are acknowledged and that there is a distinctive willingness to pay for green buildings.

Banfi, Farsi, Filippini, and Jakob (2008), in another well-documented study for Switzerland, investigate the willingness to pay for energy-saving measures in residential properties. This study provides evidence on the marginal willingness to pay derived from discrete choice models. Following an approach similar to the present paper, these authors use stated preferences to account for the willingness to pay under different assumptions and energy-saving characteristics. The participants in their final sample included 163 tenants and 142 homeowners from five Swiss cantons. Participants were asked to choose between maintaining their status quo and realizing different energy efficiency attributes. Implementing a choice experiment and using fixed effects logit models, the authors find that homeowners acknowledge pecuniary benefits resulting from energy savings. Moreover, they find a positive willingness to pay for environmental benefits, as well as for thermal, air, and noise comfort attributes. The authors also ascertain a marginal willingness to pay of about 1%–13% for both rented and purchased properties, depending on renovation attributes. For new buildings, the willingness to pay for enhanced façade insulation is approximately 3%. For a housing
ventilation system, the premium price ranges from 8% to 13%. Interestingly, they find that the willingness to pay for energy-efficient attributes is significantly higher than for related capital costs. Interpreting this finding and considering cost and benefits in relation to an investment decision, which manifest in the willingness to pay, the demand for energy efficiency investments appears to be higher than market supply. Or, the resulting marginal willingness to pay values is overestimated in this study, as Banfi, Farsi, Filippini, and Jakob (2008) suggest.

These above studies illustrate that corporate real estate decision makers value green buildings and they reveal a certain demand in the real estate market. The majority of the studies investigate a distinctive premium price for green buildings compared to conventional properties. These results hold for both commercial and residential properties.

In this paper, I investigate the willingness to pay for energy-efficient investments in the built environment. Moreover, I concentrate on quantifying the results of stated preferences regarding premium percentage prices and contribute to the debate of low adaption rates of energy efficiency investments. The paper documents to what extend premium prices occur for commercial real estate properties in Switzerland.

**Data and Methodology**

To investigate the willingness to pay for green buildings, I use data from a corporate real estate and sustainability survey in Switzerland. The survey was initiated by the Center of Corporate Responsibility and Sustainability at the University of Zurich in collaboration with CB Richard Ellis and DemoScope. The goal of the original survey was to determine whether or not energy-efficient properties exhibited a price premium. The 2013 survey was revised to quantify the willingness to pay for energy-efficient properties. Moreover, survey participants were asked about their attitude towards sustainability and its implementation in their business behavior. The participants were asked to assess the importance of economic, ecologic, and social sustainability from their perspective. Besides the sustainability issues, the survey was designed to detect regional disparities among Swiss corporations and their willingness to pay a premium for energy-efficient properties. In Switzerland, cultural differences are often cited as relevant; therefore, also the willingness to pay might lead to diverging results over different regions that are merged to Swiss Grand-Regions. The study ensured that firms from all over the country, or more precisely from all 26 cantons, were able to participate in the survey. With a distribution over all Swiss cantons, this study provides an additional contribution to related literature.

To analyze firms’ preferences and their willingness to pay both revealed and stated preferences is a common technical approach. Revealed preferences refer to a real observation of individual preferences and to a real market behavior. Therefore, revealed preferences are defined as a real-world evidence for individual choices. The analysis of premium prices of green buildings, actual choices, and real market behavior is often taken from real estate transaction data or from selling price
differences (Eichholtz, Kok, and Quigley, 2010). Due to the lack of data availability, stated preferences are used to account for hypothetical situations and questions on the willingness to pay. A prerequisite for using stated preferences is that the survey is purpose-designed. I use a stated preferences technique to investigate the willingness to pay for green buildings. With regard to the general methodology, I follow Kotchen, Boyle, and Leiserowitz (2013). They analyze the willingness to pay and policy instrument choices for climate change in the U.S. Based on a scale of given prices, households were asked about their willingness to pay for policy instruments aiming to reduce greenhouse gas emissions. Kotchen, Boyle, and Leiserowitz (2013) find that the willingness to pay depends on certain socio-demographic characteristics, especially on educational background, age, and income. Similarly, they controlled for household attitudes to climate change; specifically whether they believe if global warming is actually happening or not. I investigate firm characteristics and control for firms’ attitude on sustainability issues and whether or not they acknowledge the importance of sustainability.

Overall, roughly 1,000 Swiss corporations across all industry sectors were contacted by DemoScope. More than 100 survey participants started but did not fully complete the survey and were not selected for the analysis; 145 firms completed the survey. Although some of these 145 participants did not answer single questions, the data could be used for the analysis. The data collection was conducted in two stages. First, telephone interviews ensured a random sample of Swiss firms. This was necessary to recruit suitable contact persons in each firm with a distinctive knowledge and experience in real estate issues. Especially for larger corporations it was highly relevant to contact real estate professionals with sound information about the firms’ real estate portfolios. Also, contact persons should be able to comment on the business behavior and the general strategy of the firm. Additionally, a multitude of firm characteristics were recorded at this stage. Second, the participating firms could answer an online survey.

**Descriptive Statistics**

The descriptive statistics in Exhibit 1 provide an overview of the distribution of firm size, legal forms, and industry sectors of the surveyed firms. The majority of participating firms have up to 10 buildings in their real estate portfolios; 25% have more than 30 buildings. It is imperative to account for different legal types of the firms because of diverging investment requirements. Public corporations such as governmental institutions, non-profit organizations, and other public authorities do not follow a profit-maximizing strategy and are not part of a competitive market environment (Wiencke, 2013). Moreover, public authorities are among the most prominent owner-occupier and renters of energy-efficient properties (Eichholtz, Kok, and Quigley, 2011). Therefore, substantial differences might occur in their acceptance of a premium price for green buildings compared to private sector firms. Approximately 68% of the surveyed firms are large corporations with more than 250 employees. This is equivalent to 94 firms or more than 8% of all large corporations in Switzerland.

**Stated Preferences for Premium Prices.** To state their preferences towards the willingness to pay, participants were asked the following question: “Consider that you have to make a real estate lease, buy, or renovation decision. What are you
## Exhibit 1 | Summary Statistics

<table>
<thead>
<tr>
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<td>65</td>
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<td>10–20 Buildings</td>
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<td>20–30 Buildings</td>
<td>0.054</td>
<td>7</td>
</tr>
<tr>
<td>&gt;30 Buildings</td>
<td>0.264</td>
<td>32</td>
</tr>
<tr>
<td>0–1,000 sqm</td>
<td>0.152</td>
<td>16</td>
</tr>
<tr>
<td>1,000–10,000 sqm</td>
<td>0.229</td>
<td>24</td>
</tr>
<tr>
<td>10,000–50,000 sqm</td>
<td>0.324</td>
<td>34</td>
</tr>
<tr>
<td>50,000–100,000 sqm</td>
<td>0.124</td>
<td>13</td>
</tr>
<tr>
<td>&gt;100,000 sqm</td>
<td>0.171</td>
<td>18</td>
</tr>
<tr>
<td>Firms under Public Law</td>
<td>0.289</td>
<td>39</td>
</tr>
<tr>
<td>Firms under Private Law</td>
<td>0.711</td>
<td>96</td>
</tr>
<tr>
<td>International Firms</td>
<td>0.493</td>
<td>69</td>
</tr>
<tr>
<td>Employees (&gt;250)</td>
<td>0.681</td>
<td>94</td>
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<tr>
<td>Employees (&lt;250)</td>
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<td>Processing Trade Industry</td>
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<td>38</td>
</tr>
<tr>
<td>Building Industry</td>
<td>0.053</td>
<td>7</td>
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<tr>
<td>Commerce</td>
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<tr>
<td>Finance &amp; Banking</td>
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<td>33</td>
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<tr>
<td>Land &amp; Housing</td>
<td>0.068</td>
<td>9</td>
</tr>
<tr>
<td>Public Sector</td>
<td>0.144</td>
<td>19</td>
</tr>
<tr>
<td>Lake Geneva</td>
<td>0.072</td>
<td>10</td>
</tr>
<tr>
<td>Middlesland</td>
<td>0.159</td>
<td>22</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.101</td>
<td>14</td>
</tr>
<tr>
<td>Zurich Area</td>
<td>0.406</td>
<td>56</td>
</tr>
<tr>
<td>East</td>
<td>0.123</td>
<td>17</td>
</tr>
<tr>
<td>Central Area</td>
<td>0.130</td>
<td>18</td>
</tr>
</tbody>
</table>

Notes: The figures represent mean percentages and the absolute number of observation in each category. The overall number of participating firms is 145 for the year 2013. Deviations appear due to omitted answered questions by the participants. The industry sector classification follows the NOGA classification from the federal statistical office. Due to a lack of observations, the Information and Communication sector as well as Research and Development is not reported. For the Swiss Grand-Regions, Ticino is not reported due to a lack of observations.

willing to pay for energy-efficient or so-called green buildings compared to conventional properties? Please choose your preferred premium price.”

Exhibit 2 provides an overview of stated preferences for each case of a decision to lease, buy, or retrofit a property. On a given scale that ranges from 0% to 15% (or more) firms could select their preferred premium price in intervals of 2.5%. A literature review suggests that a scale between 0% and 15% is suitable and covers most of the findings of international studies that analyze premium prices for green buildings. The highest price category stands for a premium price of 15% or more.
The stated preferences in Exhibit 1 illustrate substantial differences between the different real estate decision cases. The 0% answer clarifies that firms are not willing to pay a premium price for energy-efficient properties. They value green buildings the same as conventional buildings. Interestingly, the bulk of participants indicated that they would not pay more for green buildings when they could lease new space for their corporation. Approximately 40% of the firms would not pay an extra amount of money for their new leased property. Substantially fewer firms are not willing to pay a premium price to buy a new property or to retrofit existing buildings. Additionally, the lower bound of price categories is much wider than the upper bound for the lease case (Exhibit 1). For the buy and retrofit cases, the stated preferences illustrate higher premium prices compared to the decision to lease. Comparing the willingness to pay on average for each decision-making process, participants are willing to accept a premium price of approximately 3% (lease), 4.75% (buy), and 5% (retrofit), as shown in Exhibit 3.

These findings are in line with the results from international studies on real estate premium prices. Most of the studies cited in the literature review use transaction data. Interestingly, the majority of these studies also indicate a higher premium...
sales price compared to a premium lease price. These findings indicate diverging preferences in terms of the investment horizon. Renting a commercial property might be associated with a shorter time horizon than buying a real estate. Owning real estate might indicate a stronger awareness of long-term sustainability issues like energy efficiency. Another reason for higher sales prices is associated with a stronger commitment to the property from a firm’s perspective. Moreover, property owners and tenants might have diverging interests in terms of energy efficiency investments. In order to explain the lower acceptance of lease premium prices, one could argue that a significant sustainability standard is already expected and that prospective tenants are not willing to pay an extra premium price. Due to a very low vacancy rate in the Swiss commercial real estate market, a firm’s primary interest is to obtain suitable property space.\footnote{Energy efficiency issues might occur secondarily and lead to a limited awareness of energy-efficient properties.} Surprisingly, the premium price for the case of renovation is even higher than the premium prices for leasing or buying a property. Taking into account that conventional renovations do not necessarily need to be energy efficient, participants were able to acknowledge their premium price for achieving a green building. These findings also hold for industry-specific willingness to pay. Exhibit 2 illustrates the stated preferences depending on the top four industries represented by the survey. In concurrence with former results, the non-acceptance of a premium price is again substantially higher for lease decision making compared to the other specifications.

To account for industry-specific differences on the willingness to pay, Exhibit 4 provides an overview. The results show that on average the premium prices ranges from 1.25% up to 7.9%. In line with previous results the highest acceptance can generally be found for the renovation case. Interestingly, the building industry, which also includes civil engineering, represents the highest willingness to pay for green buildings, on average. Moreover, the finance and banking industries and the public sector signal the highest acceptance of premium prices. With regard to the legal form, Exhibit 5 highlights the differences between firms under private and public law. Firms under public law account for substantially higher premium prices than firms under private law. These findings correspond to the often proclaimed pioneer role of public authorities, governmental institutions, and non-profit organizations to acknowledge their awareness of the importance of energy-


### Exhibit 4 | Industry-specific WTP

<table>
<thead>
<tr>
<th>Industry</th>
<th>Lease</th>
<th>Buy</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing Trade</td>
<td>2.647</td>
<td>4.779</td>
<td>5.214</td>
</tr>
<tr>
<td>Building</td>
<td>4.642</td>
<td>7.500</td>
<td>7.916</td>
</tr>
<tr>
<td>Commerce</td>
<td>1.250</td>
<td>3.214</td>
<td>2.875</td>
</tr>
<tr>
<td>Finance &amp; Banking</td>
<td>3.833</td>
<td>5.000</td>
<td>5.833</td>
</tr>
<tr>
<td>Land &amp; Housing</td>
<td>2.142</td>
<td>4.285</td>
<td>3.928</td>
</tr>
<tr>
<td>Public Sector</td>
<td>4.264</td>
<td>5.882</td>
<td>6.176</td>
</tr>
<tr>
<td>Total</td>
<td>2.975</td>
<td>4.786</td>
<td>5.063</td>
</tr>
</tbody>
</table>

Notes: The figures represent mean percentages of the willingness to pay for green buildings on a given 0% to 15% scale for (1) lease, (2) buy, and (3) retrofit decision making. Due to a lack of observations, the Information and Communication industry, as well as the Research and Development industry are not reported.

### Exhibit 5 | WTP and Legal Form

<table>
<thead>
<tr>
<th>Legal Form</th>
<th>Lease</th>
<th>Buy</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Law</td>
<td>3.882</td>
<td>5.526</td>
<td>6.250</td>
</tr>
<tr>
<td>Private Law</td>
<td>2.591</td>
<td>4.423</td>
<td>4.500</td>
</tr>
<tr>
<td>Total</td>
<td>3.000</td>
<td>4.784</td>
<td>5.063</td>
</tr>
</tbody>
</table>

Note: The figures represent mean percentages on a given 0% to 15% scale for (1) lease, (2) buy, and (3) retrofit decision making.

efficient properties. They signal a distinctive leading role to encourage private investments in green buildings, which is supported by these findings.

**Uncertainty about the Willingness to Pay.** An analysis of stated preferences indicates that firms can be uncertain about their willingness to pay and about their acceptance of a premium price. Eichholtz, Kok, and Quigley (2010, 2492) state that “both real estate developers and institutional investors are understandably uncertain about how far to go in implementing environmental investments, since the economic rationale for the development of sustainable buildings is based almost entirely on anecdotal evidence.”

Following Kotchen, Boyle, and Leiserowitz (2013), the analysis of a distinctive willingness to pay debate requires an investigation of how firms display uncertainty. It appears to be an expected outcome that uncertainty will harm investment decisions and might decrease the willingness to pay. As discussed above, a multitude of potential investment barriers lead to increased uncertainty by decision makers (Alberini, Banfi, and Ramseier, 2011). Although I do not
analyze the barriers to energy-efficient investments directly, study participants should be able to acknowledge their uncertainty about the topic.

Several reasons emerge for participants preferring to answer “don’t know” instead of signalizing a certain premium price. Indeed, I tried to reduce uncertainty in the sense of not asking the people who are not able to give a proper answer, because of limited knowledge or other reasons. It might provide valuable insights into firm decision making to analyze which factors impact the “don’t know” answer and which firm characteristics increase uncertainty over the willingness to pay. With regard to the different real estate decision making categories (lease, buy, retrofit), it turns out that uncertainty is relatively equally distributed. For the lease case, about 13% of the participants answered “don’t know,” whereas approximately 15% for the buy case and 14% for the retrofit case respectively. To account for an empirical analysis of uncertainty, estimating linear probability models did not lead to valuable results. There are no significant differences with respect to firm characteristics and industry sectors, and therefore these results are not reported here.14

**Empirical Analysis**

Censored regression models are used in the empirical analysis. Due to the survey design, which provides a range of possible answer categories, I use Tobit models for the regression analysis (Amemiya, 1973). The dependent variable, which is the stated percentage premium price, is a censored variable. It has a given lower bound including the null price premium for participants who are not willing to pay a premium price. Non-negative values are not possible. The highest value of the dependent variable is “15% or more,” so there is no censoring from above. A fundamental characteristic of the data is that there are observations for the premium price that are zero. Therefore, the linearity assumption and the method of ordinary least squares are not suitable. Following the theoretical Tobit model, I assume a latent dependent variable, which is equal to the observable dependent variable whenever the latent variable is non-negative (Amemiya, 1984).15

The latent variable can be written as:

\[ y_i^* = \begin{cases} y_i^* & \text{for } y_i^* \geq 0 \\ 0 & \text{for } y_i^* < 0 \end{cases} \]

The following estimation accounts for the empirical analysis:

\[ y_i = \beta_0 + \beta_1 \text{Build} + \beta_2 \text{Employ} + \beta_3 \text{Legal} + \beta_4 \text{Space} \\
+ \beta_5 \text{Industry} + \epsilon_i + \text{controls}. \quad (1) \]
I investigate the impact of distinctive firm characteristics on the willingness to pay. To account for different firm size measures, I use the number of buildings, the number of employees, and space measures (in sqm). Considering different space types, such as office, sales, or storage, space intensity is very diverging over different industry sectors. Firms might have a relatively small amount of employees but still use a large amount of space in square meters. This holds, for example, for storage or sales-intensive industries. Therefore, I control for diverse measures of firm size. The regression model also includes the legal form of the surveyed corporation to acknowledge differences in expected profit maximizing or non-profit business behavior. Additionally, the industry specification is part of the analysis.

Moreover, I analyze the impact of firm attitude towards sustainability in general. Fuerst and McAllister (2011) point out that so far there is little empirical evidence that commercial real estate prices are influenced by sustainability characteristics. However, I take this into account and control for sustainability issues. It might have an impact on the announced premium prices, whether firms signal a strong importance of sustainability in their business behavior, or if they negate this question. Participants were asked about their attitude towards sustainability in their business behavior. The notion of sustainability issues has been dismantled into the well-documented terms of economic, ecological, and social sustainability. I use a Likert scale with five possible answers: “Not important at all,” “Less important,” “Undecided,” “Important,” “Very important.” Despite a loss in information, I simplify the five categories to a dummy variable coded 1 when the answer given is at least “Important” and 0 otherwise.

To control for diverging stated preferences depending on regional disparities, I merge the Swiss cantonal municipalities to Swiss Grand-Regions. Firms from very prosperous regions might signal a higher willingness to pay for green buildings. The Swiss Grand-Regions “Lake Geneva,” “Northwest,” and “Zurich” account for the highest GDP rates, whereas the regions “Middleland,” “East,” and “Central” account for substantially lower GDP rates, as well as a lower diffusion of corporations. Therefore, it is important to control for heterogeneous Grand-Regions.

**Results and Implications**

The results of this paper are twofold. At a first stage, the descriptive statistics provide a decent overview of the stated preferences on premium prices and show the willingness to pay of the respondents. Second, the empirical analysis investigates the impact of industry-specific and firm characteristics on the announced premium prices.

The participants were asked to consider a real estate lease, purchase, or retrofit decision. The analysis implies diverging price announcements for each decision. Moreover, a substantial amount of participants reveal uncertainty about their willingness to pay for green buildings. Particularly, when participants consider a lease, instead of a purchase or retrofit decision, approximately 40% of the
respondents are not willing to pay a premium price for a green building. In contrast to the lease case, the non-acceptance rate of a premium price is about 15%–18% on average and appears to be similar for the decision to purchase or retrofit a property. The findings for leasing new properties imply that a distinctive energy efficiency standard is already expected without paying a premium price. When the supply of suitable commercial space already provides a decent green building standard including property labels and certifications, there is obviously no need to pay an extra amount for it. One the other hand, it might also imply that the respondents value the associated additional costs of a green building higher than the benefits.

The empirical analysis (Exhibit 6) indicates that participants with a larger amount of space acknowledge a higher premium price. For example, participants in the highest category of space usage (100,000+ sqm), indicate a 3.8% higher premium price than those with lower space intensity. These findings are significant at the 5% confidence level. The results remain significant when I control for the sustainability attitude and regional disparities. The results do not illustrate a significant impact of space intensity for the decisions to purchase or retrofit a property. Firms with more than 250 employees accept a higher premium price compared to smaller firms. The results are positive and significant, especially for the decision to buy a property. This finding is identified as important for employee-intensive industries such as the financial service or commerce industry in Switzerland. It indicates that green buildings are a relevant factor for industries that are attempting to attract highly-skilled people.

The results do not indicate that a larger property portfolio leads to a higher willingness to pay for a green building. On the contrary, the survey indicates that the results are negative for firms with more than 10 buildings. So, human capital, captured via the number of employees in a firm, has a stronger and more significant impact on the willingness to pay for green buildings than does the number of buildings in a firm’s property portfolio. Concluding, firms that are using more space reflect a positive and significant impact on the willingness to pay, whereas a larger amount of buildings do not support this finding. This might imply that firms that using more space are likely to be larger companies with CSR requirements and be financially able to pay more.

Participants under private law account for an assumed profit-maximizing business behavior, which is not the case for governmental institutions, public authorities, and non-profit organizations. Here, the insert dummy variable stands for public corporations. For all specifications, the variable Legal Form is positive but not significant in terms of the standard significance levels. This result is in line with the related literature that proclaims the importance of public sector authorities, for their implementation of green policies. This finding also corresponds with the industry specification of the public sector, which is not limited to the legal type of public law. With regard to industry-specific findings, the building industry sector has the strongest positive and significant impact on the willingness to pay. Participants from the building industry that consider leasing a property acknowledge a 4.7%–5.8% higher premium price for green property compared to other industry sectors. Also, an increasing impact on the willingness to pay occurs
**Exhibit 6 | Censored Regression Models of the Willingness to Pay**

<table>
<thead>
<tr>
<th></th>
<th>Lease</th>
<th>Buy</th>
<th>Retrofit</th>
<th>Lease</th>
<th>Buy</th>
<th>Retrofit</th>
<th>Lease</th>
<th>Buy</th>
<th>Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Buildings (&gt;10)</strong></td>
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</tr>
<tr>
<td></td>
<td>-1.847**</td>
<td>-1.129</td>
<td>0.063</td>
<td>-1.767*</td>
<td>-1.007</td>
<td>0.289</td>
<td>-1.841*</td>
<td>-1.951*</td>
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<td>(0.939)</td>
<td>(1.078)</td>
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<td>(1.065)</td>
<td>(0.940)</td>
<td>(0.989)</td>
<td>(1.157)</td>
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<td><strong>Employees (&gt;250)</strong></td>
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<td>2.124**</td>
<td>0.798</td>
<td>0.114</td>
<td>1.784*</td>
<td>0.134</td>
<td>-0.373</td>
<td>2.216**</td>
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<td></td>
<td>(0.866)</td>
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<td>(0.930)</td>
<td>(1.030)</td>
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<td><strong>Space</strong></td>
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<tr>
<td>1,000–10,000 sqm</td>
<td>0.655</td>
<td>-0.903</td>
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<td>(1.355)</td>
<td>(1.153)</td>
<td>(1.258)</td>
<td>(1.434)</td>
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<tr>
<td>50,000–100,000 sqm</td>
<td>3.033**</td>
<td>-0.839</td>
<td>-0.709</td>
<td>2.947**</td>
<td>-0.818</td>
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<td>(1.383)</td>
<td>(1.518)</td>
<td>(1.673)</td>
<td>(1.401)</td>
<td>(1.510)</td>
<td>(1.736)</td>
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<td>100,000+ sqm</td>
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<td>-0.77</td>
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<td>0.784</td>
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<tr>
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<td>(1.852)</td>
<td>(1.478)</td>
<td>(1.626)</td>
<td>(1.794)</td>
<td>(1.527)</td>
<td>(1.647)</td>
<td>(1.901)</td>
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</table>
Exhibit 6 | (continued)
Censored Regression Models of the Willingness to Pay

<table>
<thead>
<tr>
<th>Industry Sectors</th>
<th>Lease (1)</th>
<th>Buy (2)</th>
<th>Retrofit (3)</th>
<th>Lease (4)</th>
<th>Buy (5)</th>
<th>Retrofit (6)</th>
<th>Lease (7)</th>
<th>Buy (8)</th>
<th>Retrofit (9)</th>
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<tbody>
<tr>
<td>Building Industry</td>
<td>4.792**</td>
<td>3.928*</td>
<td>2.905</td>
<td>5.477***</td>
<td>4.621**</td>
<td>4.255*</td>
<td>5.786***</td>
<td>5.224**</td>
<td>4.243*</td>
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<tr>
<td></td>
<td>(1.989)</td>
<td>(2.131)</td>
<td>(2.426)</td>
<td>(2.014)</td>
<td>(2.194)</td>
<td>(2.411)</td>
<td>(2.039)</td>
<td>(2.172)</td>
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<tr>
<td>Commerce</td>
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<td>−1.593</td>
<td>−0.0247</td>
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<td>−1.646</td>
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<td>−0.500</td>
<td>−1.852</td>
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<td>(1.012)</td>
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<td>(1.244)</td>
<td>(0.994)</td>
<td>(1.047)</td>
<td>(1.204)</td>
<td>(0.989)</td>
<td>(1.029)</td>
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<tr>
<td>Finance &amp; Banking</td>
<td>2.828***</td>
<td>1.691*</td>
<td>1.704</td>
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<td>1.703*</td>
<td>1.672</td>
<td>2.878***</td>
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<td>(0.897)</td>
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<td>Land &amp; Housing</td>
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<td>−0.680</td>
<td>1.020</td>
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<td></td>
<td>(1.406)</td>
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<td>(1.704)</td>
<td>(1.372)</td>
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<td>Public Sector</td>
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<td>0.803</td>
<td>2.920***</td>
<td>1.557</td>
<td>0.773</td>
</tr>
<tr>
<td></td>
<td>(1.099)</td>
<td>(1.164)</td>
<td>(1.338)</td>
<td>(1.072)</td>
<td>(1.148)</td>
<td>(1.281)</td>
<td>(1.060)</td>
<td>(1.120)</td>
<td>(1.304)</td>
</tr>
<tr>
<td>Sustainability</td>
<td></td>
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<td></td>
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<tr>
<td>Economic/Sustain</td>
<td>0.813</td>
<td>0.425</td>
<td>1.401</td>
<td>0.489</td>
<td>0.849</td>
<td>1.397</td>
<td></td>
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<tr>
<td></td>
<td>(0.949)</td>
<td>(1.050)</td>
<td>(1.156)</td>
<td>(0.950)</td>
<td>(1.041)</td>
<td>(1.202)</td>
<td></td>
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</tr>
<tr>
<td>Ecological/Sustain</td>
<td>−0.148</td>
<td>0.0966</td>
<td>−0.554</td>
<td>−0.0714</td>
<td>0.122</td>
<td>−0.529</td>
<td></td>
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<tr>
<td></td>
<td>(0.846)</td>
<td>(0.909)</td>
<td>(1.010)</td>
<td>(0.835)</td>
<td>(0.886)</td>
<td>(1.028)</td>
<td></td>
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</tr>
<tr>
<td>Social/Sustain</td>
<td>1.524*</td>
<td>1.421*</td>
<td>2.527***</td>
<td>1.400*</td>
<td>1.272</td>
<td>2.566***</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(0.788)</td>
<td>(0.847)</td>
<td>(0.940)</td>
<td>(0.776)</td>
<td>(0.827)</td>
<td>(0.953)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
### Exhibit 6 (continued)

Censored Regression Models of the Willingness to Pay

<table>
<thead>
<tr>
<th>Swiss Grand-Regions</th>
<th>Lease (1)</th>
<th>Buy (2)</th>
<th>Retrofit (3)</th>
<th>Lease (4)</th>
<th>Buy (5)</th>
<th>Retrofit (6)</th>
<th>Lease (7)</th>
<th>Buy (8)</th>
<th>Retrofit (9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middleland</td>
<td>-1.975</td>
<td>-1.769</td>
<td>0.258</td>
<td>(1.402)</td>
<td>(1.806)</td>
<td>(1.829)</td>
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<tr>
<td>Northwest</td>
<td>0.174</td>
<td>-0.208</td>
<td>1.399</td>
<td>(1.674)</td>
<td>(2.034)</td>
<td>(2.159)</td>
<td></td>
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<tr>
<td>Zurich</td>
<td>-1.308</td>
<td>-2.928*</td>
<td>0.252</td>
<td>(1.343)</td>
<td>(1.713)</td>
<td>(1.725)</td>
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<tr>
<td>East</td>
<td>-2.422</td>
<td>-0.623</td>
<td>0.551</td>
<td>(1.470)</td>
<td>(1.866)</td>
<td>(1.915)</td>
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<td></td>
</tr>
<tr>
<td>Central</td>
<td>-0.902</td>
<td>-1.625</td>
<td>-0.224</td>
<td>(1.511)</td>
<td>(1.857)</td>
<td>(1.929)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo R²</td>
<td>0.059</td>
<td>0.041</td>
<td>0.034</td>
<td>0.073</td>
<td>0.051</td>
<td>0.057</td>
<td>0.086</td>
<td>0.069</td>
<td>0.059</td>
</tr>
</tbody>
</table>

Notes: The dependent variable is the censored response to the question “What premium price are you willing to pay for green buildings compared to conventional buildings?” each for lease, buy, and retrofit decision making. The industry sectors follow the NOGA classification. The omitted variable for space is <1,000 sqm. Processing Trade is omitted for industry sector and Lake Geneva for Grand-Region. The number of observations for columns 1, 3, and 4 is 90; for columns 2, 5, and 9 is 88; for 6 and 7 is 89; for column 8, it is 87. Standard errors in parentheses.

* $p < 0.10$.

** $p < 0.05$.

*** $p < 0.01$. 
for the finance and banking industry, as well as for the public sector. These findings hold, even when we control for different sustainability attributes and regional disparities. This complements Eichholtz, Kok, and Quigley (2010), who point out that firms from the finance, insurance, and real estate industry signal a substantial interest and willingness to pay for green buildings. The industry-specific findings indicate that labor-intensive industries and industries with a distinctive awareness of representative space account for the highest willingness to pay. The impact of image and reputation could be associated for the financial service industry, which has an extensive awareness of customer relationships.

**Conclusion**

The contribution of this paper to related literature is twofold. First, it is the first investigation of green building premium prices for the commercial real estate market in Switzerland. Second, in addition to an analysis of the willingness to pay for leasing or buying, the survey participants were asked about their willingness to pay for a decision to retrofit a property.

The impact of the built environment on CO$_2$ emissions is incontrovertible. The Swiss CO$_2$-enactment aims to encourage and incentivize investments in green buildings. Considering the impact of commercial properties on greenhouse gas emissions, to understand which firm characteristics and industry specifications determine the willingness to pay, is imperative to policy makers and investors. The findings indicate that diverse firm attributes determine the acceptance of a premium price for green buildings. As reinforced by descriptive statistics, substantial differences emerge in the decision-making process, in terms of whether firms intend to buy, lease, or retrofit a property.

The decision to retrofit a property reveals the interest of the firm to improve the status quo of energy efficiency in their property portfolio. The debate about insufficient investments in energy efficiency in the built environment is related to several barriers that prevent investments in green buildings. The theoretical energy efficiency gap, revealed in much of the literature, is caused by a lack of information, by information asymmetry or by principal-agent problems between real estate owner and tenant. Although there are explanations of insufficient investments, the illustrated premium prices for green buildings in this paper account for a distinctive demand and willingness to pay. Moreover, study participants indicate their attitudes towards climate change issues and the abatement of greenhouse gas emissions with their responses on sustainability questions. It turns out that uncertainty about the acknowledged premium price peaks for the decision to lease a property, which corresponds to the lowest premium price on average. The most prominent industry sectors with the highest willingness to pay are the building industry, the financial service industry, and the public sector. For these industries, the benefits of green buildings appear to be higher than additional costs that are associated with green buildings. Although the survey respondents represent all industry sectors in Switzerland, one might expect that firms from the building industry are more aware of the benefits of green buildings. The financial services industry, which is very common for Switzerland,
signals a special interest in representative office space. The often proclaimed benefits of green buildings appear to be appreciated in these industries. On the hand, the findings reveal a relatively low interest in green buildings in the commerce industry. The announced premium prices range from 1.3% to 7.9% compared to conventional properties.

Surveying firms and analyzing their willingness to pay is associated with stated preferences rather than revealed preferences. It is taken into account that stated preferences are not revealed in terms of observable or transaction-based investment decisions. Signaling a certain premium price does not necessarily mean that real estate decision makers would actually pay the announced price.

Therefore, the findings might be overestimated. On the other hand, the results complement the related literature and the empirical findings of transaction-based rental and sales prices. However, the findings contribute to the related literature of green buildings in Switzerland. It provides insight into the green economy and reveals the demand for green buildings.

**Endnotes**

1 The Federal Office for Environment (Bundesamt für Umwelt, 2010) illustrates the Swiss federal strategy to reduce greenhouse gas emissions. In this context, the CO₂-enactment was revisited in late 2012. The enactment defines new elements of the Swiss Building Program supported by both, the federal state of Switzerland and cantonal municipalities. The Bundesamt für Umwelt (BAFU) and the Bundesamt für Energie (BFE) provide an overview of the current greenhouse gas strategy in Switzerland, following the Energy Strategy 2050 with a strong emphasis on the built environment.

2 Besides reducing greenhouse gas emissions, the Swiss federal energy policy tries to increase the independence of oil and gas imports, which is also part of the federal strategy for the following decades (Bundesamt für Energie, 2012).

3 The Data and Methodology section provides an introduction of stated and revealed preferences.

4 The data illustrate real market behavior and describe rather revealed preferences than stated preferences.

5 The CoStar database is a leading resource for empirical studies.

6 Diverging discount rates depend on the specification model.

7 Banfi, Farsi, Filippini, and Jakob (2008) acknowledge stated preference methods to compare household decision makers that already experienced energy efficiency investments and those who have not.

8 Gantenbein and Volonté (2012) evaluate the relation between cultural differences and corporate governance for the case of Switzerland. Although the law is equal in both, the German and French speaking part of Switzerland, substantial cultural differences appear in both regions.

9 Swiss Grand-Regions are taken from the official definition of the Federal Statistic Office Switzerland.

10 Verhoef and Franses (2002) provide an overview of revealed and stated preference methods.
Swiss Federal Statistical Office, industry and services, private businesses, and persons employed by size, 2008.

The survey provided a definition of “green buildings.” Moreover, participating contact persons were real estate professionals to ensure a proper interpretation of the question.

The vacancy rate for commercial real estate is about 1%–2%, with regard to the agglomeration (Bundesamt für Statistik, 2012).

Analyzing uncertainty using the “don’t know” answer category does not provide a clear contribution. Taking the “don’t know” variable as a dependent variable and using linear probability models, I do not find significant results for diverging uncertainty.

Amemiya (1984) provides an overview of the standard Tobit model and numerous applications of it, along with a description of the dependent variable and the most important independent variable from diverse economic fields.

Due to the lack of observations, the information and communication industries, as well as the research and development industry are not reported here.

Swiss Grand-Regions follow the definition of the Federal Statistical Office. Due to the lack of observations, Ticino is not reported.

References


I thank Paul Gans, Peter Steffen Schmidt, two anonymous reviewers, and conference participants at the European Real Estate Society for helpful comments.

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The Green Building Technology Model: An Approach to Understanding the Adoption of Green Office Buildings

Authors
Arvin Malkani and Mark Starik

Abstract
This article investigates the economic and non-economic factors that influence the willingness of building professionals to adopt green office building technology. We developed a model that analyzes the impact of four variables on the intention to adopt green building technology, as measured by the adoption of LEED and ENERGY STAR certifications. Applying our Green Building Technology Model (GBTM) to a sample of Washington, D.C.-area building professionals, we found that both economic and non-economic factors are important in the intention to adopt LEED and ENERGY STAR building technologies. The GBTM allows us to understand the factors that lead to the adoption of green office buildings, with the intended result being wider adoption of LEED and ENERGY STAR buildings.

There is a growing awareness of the need to conserve energy due to general concerns about climate change, dependence on foreign oil, and the prospect of rising energy costs. As a result, a great deal of interest in energy efficiency and social consciousness has been evidenced, as indicated by an ever-increasing number of energy-efficient buildings being constructed in the United States and most other developed nations. In fact, there are many energy efficiency, water conservation, and environmental protection efforts that are currently underway. Examples of these endeavors can be found all around the planet and include the achievement of better automobile manufacturing with increased mileage, higher use of mass transit, increased weatherization of residential units, and improvement in air quality, to name a few. The use of green building technology is another example of these efforts. With buildings estimated to account for approximately half of all annual energy and greenhouse gas emissions (U.S. Department of Energy, 2008), a contributing solution to the nation’s environmental and energy concerns is to ensure that the design, construction, operation, and maintenance of buildings are environmentally sustainable.

Although there is substantial evidence of the benefits that green building technology can provide (Yuvelson, 2008), the percentage of green buildings is low and is increasing at a very slow rate. Despite the economic value of certified green buildings is generally found to be positive in terms of rental rates and sales prices (Miller, Spivey, and Florance, 2008; Eichholtz, Kok, and Quigley, 2010, 2013;
Wiley, Benefield, and Johnson, 2010; Fuerst and McAllister, 2011). Decision makers involved in the construction of commercial office buildings continue to develop or maintain buildings with little or no green building technology. If more green technology is to be integrated into building projects, the gap between the benefits of green building technology and the low adoption of green building technology needs to be understood. This study was conducted to help researchers, practitioners, and society better understand the connection between the perceived benefits of and the intention to use green building technology.

To accomplish this goal, the study identifies the factors that influence office building professionals to adopt Leadership in Energy and Environmental Design (LEED) and ENERGY STAR certifications. Although many studies have focused on the economics of green buildings (Miller, Spivey, and Florance, 2008; Eichholtz, Kok, and Quigley, 2010, 2013; Wiley, Benefield, and Johnson, 2010; Fuerst and McAllister, 2011), the present study is unique in that it examines both economic and non-economic factors that compel office building professionals to adopt LEED and ENERGY STAR certifications. With an enhanced understanding of what motivates key decision makers in building projects, it is likely that the number of green buildings can be increased, as interventions such as awareness, education, and promotion campaigns can be developed and implemented to achieve that implementation goal.

In order to identify factors that lead to the adoption of LEED and ENERGY STAR rated buildings, we utilized an integrated theory of technology adoption, the Unified Theory of Acceptance and Use of Technology (UTAUT). Our study extends the existing literature on technology management by providing a comprehensive examination of the factors that lead to the adoption of green building technology. The UTAUT posits that four motivational factors collectively provide an assessment of an individual’s attitude toward adopting technology: (1) perceptions of performance expectation (i.e., how well the technology performs in the environment); (2) perceptions of effort expectation (i.e., how easily the technology is adopted); (3) perceptions of social influence (i.e., how people important to the individual are believed to view the adoption of the technology); and (4) perceptions of facilitating conditions (i.e., how ready the individual’s organization is to adopt the technology) (Venkatesh, Morris, Davis, and Davis, 2003). We employ and modify these factors to act as variables for research in our development of a Green Building Technology Model (GBTM). This model is used to determine the factors that lead to an individual’s willingness to adopt green building technology.

The article consists of five sections. This first section provides information about the objectives of the study and background information about green building technology. The second section provides a literature review on existing research pertaining to green buildings, the UTAUT, and its relevance and applicability to the research question. The third section contains our GBTM and its methodology, including a description of the associated survey instrument, the demographic composition of the sample and its size, and the dependent and independent variables and the moderators. The fourth section provides the results, including descriptive statistics and reliability and validity tests. The final section provides
an analysis and summary of the relevant findings and includes the implications, limitations, and conclusions of the study.

**Literature Review**

Buildings use approximately 70% of the electricity in the U.S. (U.S. Department of Energy, 2010), so a study of the factors that lead to the adoption of green building technology is potentially an important one for energy efficiency advocates. Research shows that so-called green buildings have been found to be associated with lifecycle cost savings, improvement in human performance (including productivity gains and better employee/occupant health), and an increase in prestige (Nalewaik and Venters, 2009). Although a significant amount of research has been conducted on the financial benefit of adopting green building technologies (Miller, Spivey, and Florance, 2008; Eichholtz, Kok, and Quigley, 2010, 2013; Wiley, Benefield, and Johnson, 2010; Fuerst and McAllister, 2011), little is known about the comprehensive set of factors that influence the adoption of green building technology.

We attempted to fill this research gap by gaining an understanding of building decision-makers’ attitudes toward the adoption of green building technology as measured by the intention to adopt LEED or ENERGY STAR certifications for office buildings. Traditional models of technology acceptance suggest that positive attitudes about a technology result in a positive intention toward the use of that technology (Taylor and Todd, 1995), and this same assumption underpins this study. The UTAUT, as previously described, suggests that four factors (performance expectancy, effort expectancy, social influence, and facilitating conditions) contribute to an individual’s attitude toward the use of green technology, as measured by the adoption of LEED and ENERGY STAR certifications in office buildings.

Although no single theory provides a definitive model for individual acceptance and use of technology (Halawi and McCarthy, 2006), the UTAUT currently holds the most promise due to its integration of eight competing models widely accepted by technology management researchers (Venkatesh, Morris, Davis, and Davis, 2003). Venkatesh, Morris, Davis, and Davis formulated the UTAUT based on the conceptual similarities between competing theories. These theories include the Theory of Reasoned Action (TRA), Technology Acceptance Model (TAM), the Motivational Model (MM), Theory of Planned Behavior (TPB), Combined TAM and TPB (C-TAM-TPB), Model of PC Utilization (MPCU), Innovation Diffusion Theory (IDT), and Social Cognitive Theory (SCT). The UTAUT consolidates numerous user acceptance models to create an integrated model that boasts an adjusted $R^2$ of 70% (Venkatesh, Morris, Davis, and Davis, 2003; Li and Kishore, 2006; Marchewka, Liu, and Kostiwa, 2007; Alrawashdeh, 2013), indicating that UTAUT is a dependable model for user acceptance of technology.

Generally speaking, the UTAUT has been considered a prominent and useful model in information systems adoption research and has proven to be a robust
and reliable measure of the key constructs. Validation of UTAUT in a longitudinal study found it to account for 70% of the variance in usage intention (Venkatesh, Morris, Davis, and Davis, 2003). The UTAUT has been applied to different types of technology, such as mobile services and devices (Park, Yang, and Lehto, 2007; Rao and Troshani, 2007), short message services (Baron, Patterson, and Harris, 2006), tablet PCs (Garfield, 2005; Anderson, Schwager, and Kerns, 2006), and web-based course management software (Marchewka, Liu, and Kostiwa, 2007). This study is the first to apply UTAUT to commercial real estate and green building technology. In this study, we measure the intention to adopt green building technology as the intention to adopt either of two well-known green building certifications (LEED or ENERGY STAR certifications) in the U.S.

**Methodology**

Our Green Building Technology Model (GBTM) is based on the UTAUT, with modifications to accommodate for green building technology (Exhibit 1). The UTAUT model includes four main constructs: performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC), each of which has been described above. The theory “posits that individual expectations of performance and effort, as well as influences of both social and facilitating conditions, determine behavioral intention and use behavior,” (Bray and Konsynski, 2007).

Four hypotheses derived from the research question are presented to reflect the relevant antecedents of technology adoption theoretically linked to the use of green building technology: performance expectancy, effort expectancy, social influence, and facilitating conditions. After conducting a literature review, we developed the following hypotheses:
H₁: Performance expectancy positively influences behavioral intention to adopt green building technology.

H₂: Effort expectancy positively influences behavioral intention to adopt green building technology.

H₃: Social influence positively influences behavioral intention to adopt green building technology.

H₄: Facilitating conditions positively influence behavioral intention to adopt green building technology.

The predictor variables in this study include performance expectancy, effort expectancy, social influence, and facilitating conditions. These factors are theoretically expected to affect the dependent variable: the behavioral intention to adopt green building technology. The survey items or questions used to measure the predictor and dependent variables were adapted from Venkatesh, Morris, Davis, and Davis (2003).

The four constructs are modified for the context of commercial real estate. Performance expectancy measures the decision-maker’s financial performance and company’s financial performance on the adoption of LEED or ENERGY STAR certifications. See questions 2–5 of the survey instrument in Appendix A. Effort expectancy measures the decision maker’s view of the level of ease (or difficulty) to adopt a LEED or ENERGY STAR certification. Will the adoption of LEED or ENERGY STAR certifications require a minimum (or maximum) amount of effort? See questions 6–11 of the survey instrument found in Appendix A. Social influence measures the level of support provided by peers, family, and business associates for the adoption of LEED or ENERGY STAR certifications. See questions 12–16 of the survey instrument in Appendix A. Facilitating conditions measure whether the decision maker has the components in place to make the decision to easily adopt LEED or ENERGY STAR certifications. For example, resources availability, industry group information availability, the overall condition of the building, etc. See questions 17–20 of the survey instrument in Appendix A.

The Washington, D.C. area was selected for this study because it is a large metropolitan area that allowed us to select appropriate individuals in the commercial office real estate sector. Given that Washington, D.C. (that is, the District of Columbia) at the time of the study required certain new buildings to be LEED certified, respondents from the District of Columbia were removed from the study.

Measurement

The 28-item GBTM survey design was based on the original UTAUT survey instrument (Venkatesh, Morris, Davis, and Davis, 2003) to identify participants’ perceptions of performance expectancy, effort expectancy, social influence, and facilitating conditions as they related to adopting green building technology for office buildings. Although the concept and the constructs were retained from the original UTAUT model, some changes were made to the survey to adapt to the
study’s context. The GBTM survey used a Likert-type scale to assess perceptions of the four major constructs identified in the UTAUT model. Exhibit 2 gives the coding and scaling for each question.

This survey includes one important filter question, which permitted identification of appropriate respondents. This question identifies people who make decisions for office buildings: Do you have a major influence on decisions to renovate (or develop) an office building? Only people who answered the filter question in the affirmative were included in the data analysis. In addition to the filter question, this survey instrument also included several demographic questions.

Because the original instrument was altered in this study, the reliability of the instrument was re-assessed using Cronbach alpha reliability coefficients and the scores were found to be within the ranges obtained from previous studies deemed acceptable in the relevant literature.

### Results

The respondents indicated that both economic and non-economic factors were important to the adoption of LEED and ENERGY STAR buildings. Further, social influence, a non-economic factor, was found to be a direct determinant of the adoption of green building technology.

The adapted UTAUT model, social influence, and facilitating conditions were all found to have a statistically significant correlation with the intention to adopt green building technology.

Descriptive statistics were computed for the demographic variables; then, a reliability analysis was conducted for each hypothesis and the assumptions of the multiple regression were evaluated. Finally, multiple regression was used to derive the inferential statistics from which the study’s conclusions were drawn.

The adapted UTAUT model was evaluated using the multiple R and multiple R² statistics from the multiple regression. The hypotheses corresponding to each predictor were also evaluated using non-standardized regression coefficients,
standardized regression coefficients, zero-order correlations, and semi-partial correlations.

Participants who reported that they have a major influence on the decision to renovate (or develop) an office building were included in the analysis. Of the $n = 69$ individuals who completed a survey, only $n = 40$ reported they had a major influence.

**Demographics**

It is also important to note that the respondents were knowledgeable about LEED and ENERGY STAR rated buildings. One contributing factor regarding their knowledge is that the respondents were all NAIOP conference attendees. As advertised, NAIOP “provides strong advocacy, education and business opportunities... for... commercial real estate developers, owners and investors of office, industrial, retail and mixed-use properties,” (www.naiop.com). Additionally, feedback received during the field research activity indicated that the participants were knowledgeable about the LEED and ENERGY STAR certification systems.

**Construct**

To assess reliability, Cronbach’s alpha coefficient was computed for each construct. Cronbach’s alpha is defined as a measure of the internal consistency of the items in a scale. Alpha levels above 0.70 are considered adequate (Barnett, 2002). The Cronbach’s alpha coefficients for performance expectancy, effort expectancy, and social influence were all above 0.70. Further, none of the item-total correlations were negative, indicating the scales were sufficiently reliable. The Cronbach’s alpha coefficient for the facilitating conditions scale was 0.64, which is less than the generally accepted level of 0.70. This value, however, is not so low as to be problematic, given the number of items in the scale (Huizingh, 2007). Descriptive statistics for the independent variables and the dependent variable are provided in Exhibit 3.
Assumptions

Univariate outliers were evaluated by comparing the z-scores to a criterion of ±3.29 (Huizingh, 2007). No univariate outliers were detected. Multivariate outliers were also evaluated. No multivariate outliers were detected.

Next, the assumptions of normality, linearity, and homoscedasticity and multicollinearity were evaluated using residual scatterplots. The analysis revealed that the assumptions for multiple regression were all met. Multicollinearity was also evaluated using bivariate scatterplots. None of the correlations between pairs of predictor variables exceeded 0.70; thus, multicollinearity was not an issue (Huizingh, 2007).

Hypothesis Findings

The hypotheses assert that the four variables when combined (performance expectancy, effort expectancy, social influence, and facilitating conditions) would predict the intention to adopt green building technology. The multiple regression of performance expectancy, effort expectancy, social influence, and facilitating conditions on the intention to adopt green building technology was significant (R = .623, R² = .388, F (4, 34) = 5.399, p = .002). The combined independent variables were strongly correlated with the intent to implement green building technology (R = .623) (Huizingh, 2007). Approximately 39% of the variance in intention to adopt green building technology was explained by the combined predictors (R² = .388). For illustration purposes, Exhibit 4 provides the standardized betas for each individual construct found in the sub-hypotheses. The model and construct summaries for the multiple regression are provided in Exhibits 5 and 6 in Appendix 2.
The overall UTAUT model, the social influence construct, and the facilitating conditions construct are validated. The direct constructs of performance expectancy and effort expectancy were non-significant as individual determinants.

**Conclusion**

The Green Building Technology Model (GBTM) explained over 39% of the behavioral intention to adopt LEED or ENERGY STAR office building technologies. Further, the non-economic factors of social influence and facilitating conditions appeared to be more important than the economic factors of performance expectancy and effort expectancy as independent determinants of the intention to adopt green buildings.

The population for this study consisted of commercial real estate decision makers in the Washington, D.C. area. The sample consisted of 39 qualified respondents. The small sample size was considered sufficient as the power was calculated at 0.84. The survey questions were adapted from the UTAUT survey instrument used by Venkatesh, Morris, Davis, and Davis (2003). The major changes from the original UTAUT survey were: (1) modifications to the questions to account for the context of the green technology artifact; and (2) a change of the facilitating conditions construct to measure behavioral intention in lieu of actual use.

SPSS version 20 was used for the statistical analysis. The response rate was about 14% ($N = 69$) out of an estimated population of 500 conference attendees. Multiple regression analysis was utilized to analyze the relationship between both the predictor variables with the dependent variable.

The four predictors when combined were strongly correlated with intent to implement green building technology ($R = .623$) (Huizingh, 2007). Approximately 39% of the variance in intention to adopt green building technology scores was explained by the combined predictors ($R^2 = .388$). It suggests that commercial real estate professionals can expect that these constructs, when combined, correlate with green building adoption.

The results indicate that performance expectancy was not a statistically significant unique predictor of the intention ($\beta = 0.024, t = .158, p = .875$) to adopt green building technology. This finding was not consistent with previous UTAUT studies (Marchewka, Liu, and Kostiwa, 2007; Gupte, Dasgupta, and Gupta, 2008; Alrawashdeh, 2013). It suggests that commercial real estate professionals do not expect the adoption of LEED and ENERGY STAR buildings to increase their performance; i.e., their personal compensation.

The results also indicate that effort expectancy was not a statistically significant unique predictor of the intention ($\beta = -.244, t = -1.453, p = .155$) to adopt green building technology. This finding was not consistent with previous UTAUT studies (Marchewka, Liu, and Kostiwa, 2007; Gupte, Dasgupta, and Gupta, 2008; Alrawashdeh, 2013). It suggests that real estate professionals do not expect that lower effort directly correlates with the adoption of LEED and ENERGY STAR building technologies.
We found that social influence was a statistically significant unique predictor of the intention ($\beta = .561$, $t = 3.219$, $p = .003$) to adopt green building technology. This finding was consistent with previous UTAUT studies (Marchewka, Liu, and Kostiwa, 2007; Gupte, Dasgupta, and Gupta, 2008; Alrawashdeh, 2013). It suggests that real estate professionals that receive positive social influence to adopt green building technology have a stronger intention to adopt LEED and ENERGY STAR building technologies.

We also found that the variable facilitating conditions was a statistically significant unique predictor of the intention ($\beta = .317$, $t = 2.100$, $p = .043$) to adopt green building technology. This finding was consistent with previous UTAUT studies (Marchewka, Liu, and Kostiwa, 2007; Gupte, Dasgupta, and Gupta, 2008; Alrawashdeh, 2013). It suggests that real estate professionals that experience positive facilitating conditions to adopt green building technology have a stronger intention to adopt LEED and ENERGY STAR building technologies than those who do not experience those conditions.

Of the four UTAUT independent variables, social influence provides the most significant contribution to commercial real estate professionals’ behavioral intention ($\beta = .561$, $p = .003$) to adopt green building technology, followed by facilitating conditions ($\beta = .317$, $p = .043$).

Research has shown that favorable economics drive real estate decision-makers to “go green” (Miller, Spivey, and Florance, 2008; Eichholtz, Kok, and Quigley, 2010, 2013; Wiley, Benefield, and Johnson, 2010; Fuerst and McAllister, 2011). This study suggests that real estate decision-makers are motivated by both economic and non-economic factors to adopt green office buildings. Performance expectancy, effort expectancy, social influence, and facilitating conditions collectively correlate with the intention of real estate professionals to adopt green building technology. Social influence and facilitating conditions were found to be direct and strong determinants of the intention to “go green” in the office building sector.

While neither of the constructs of performance expectancy nor effort expectancy was found to be independently correlated with the intention to adopt green building technology, the combined model explains 39% of the intention for such an adoption.

It is also important to note that the GBTM developed for this study was adapted from the UTAUT model. The specific changes to the UTAUT model may have contributed to the outcome differences between UTAUT and GBTM. Hypotheses 1 and 2 were not statistically supported, due possibly to the changes to the questions made in these constructs to accommodate for the green building context. It is noted that there were more changes to the questions for the performance expectancy and effort expectancy constructs than to the social influence and facilitating conditions constructs, so rather than the number of changes being a potential confounding factor for the first two variables, we surmise that it was the nature of the changes themselves that may have been responsible for our partial non-verifying results. Appendix 1 provides all survey questionnaire items for reference.
Given that the majority of green building research is based on real estate economics and sustainability literature, this study provides a unique perspective. It posits that real estate professionals intend to adopt green building technologies due to both economic and non-economic factors. As a result, researchers may consider using a more comprehensive approach in studying the motivations of more sustainable behaviors.

Based on the findings of this study’s analysis, we recommend that in order to increase the relative and absolute number of adoptions of green buildings, an effort should be made to increase the awareness by commercial real estate professionals of non-economic factors, particularly social influence and facilitating conditions. Specific interventions may need to be developed and used, based on the factors of social influence and facilitating conditions. For example, businesses, governments, and other organizations could include social influence factors in their marketing initiatives (i.e., websites and printed publications) that reinforce the notion that the adoption of green building technology is perceived by some stakeholders, as “the right thing to do,” or “the smart thing to do.”

The UT AUT model explained over 70% of behavioral intention of the adoption of information system technology, while the GBTM explained over 39% of the behavioral intention of LEED and ENERGY STAR rated office building adoption. The findings suggest that the combined factors of performance expectancy, effort expectancy, social influence, and facilitating conditions are important to the adoption process of green building technology in commercial office buildings. As a result, emphasis should be placed on these combined factors with added weight on the social influence and facilitating conditions in order to increase the adoption rates of green building technologies. In summary, governments, industry, and other organizations should consider interventions that can positively alter the adoption of green building technology by incorporating this new understanding of non-economic factors presented by this research.

Real estate sustainability research should go beyond its current boundaries by applying the GBTM and similar models to the green building technology artifact. Many technology theories, such as UT AUT, technology acceptance model II (TAM2), and the innovation diffusion theory (IDT) may also be applicable to green building research. The practice of applying these models to technology artifacts can be worthwhile for the real estate community in order to avoid the danger of a narrowing view of sustainable real estate research. The success of this study helps support this perspective within the commercial real estate research community. Other technology artifacts, such as green technology for retail buildings, for residential real estate, and for hotels, could be tested in the future.

There is additional demand for researchers to develop effective interventions to strengthen green building adoption intentions to increase the actual adoption of green building technology. If society better understands the problem related to green building adoption, then it can take the next natural step to develop effective interventions.

The GBTM could be extended with the use of other predictor variables or moderators. Examples of other predictor variables include personal prestige,
corporate philosophy, and keeping pace with others in the industry and relevant communities. Moderators may include building age, building size, and job satisfaction.

Moreover, alternate research designs might strengthen the understanding of the base model. While the current study focused on individuals within the commercial real estate industry, other studies might focus on organizations or on a more focused subset of users (e.g., only real estate developers) in order to better understand adoption behavior.

The GBTM is a new model that can be customized for examining the intention to adopt green building and related technologies. The green building movement could benefit from extending this perspective to include the use of models from other disciplines. Finally, the application of a technology model to a commercial real estate problem is an example of multi-disciplinary research that increases our ability to solve societal and multi-dimensional problems. The greening of buildings is an important process that this study attempts to better understand.

Sustainability research is rapidly growing and expanding. However, to our knowledge, this is the first research study on green adoption using technology acceptance as the theoretical foundation. It also underscores that green building research needs to consider both economic and non-economic factors.

Finally, this study confirms that our model’s combined independent variables (performance expectancy, effort expectancy, social influence, and facilitating conditions) strongly correlate with the intention to adopt green building technology. Governments, industry, and other organizations can use this information as a foundation for developing new interventions to increase the number of green buildings. Researchers can use this study as a basis for a new way forward in conducting green building and related technology adoption research.

Appendix 1
Survey Questionnaire

Q1: Do you have a major influence on decisions to renovate (or develop) an office building?
1. Yes
2. No

Q2: Adopting a LEED or ENERGY STAR certification for an office building in my portfolio may increase my chances of increasing my compensation.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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</table>
Q3: I would find a LEED or ENERGY STAR certification for an office building that I manage to be useful (in terms of marketing, public relations, or otherwise).

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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Q4: My company would financially gain in the short term (i.e., 1–3 years) if it obtained a LEED or ENERGY STAR certification for an office building in its portfolio.

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<th>Strongly Disagree</th>
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Q5: My company would financially gain in the medium term (i.e., 4–9 years) if it obtained a LEED or ENERGY STAR certification for an office building in its portfolio.

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Q6: My company would financially gain in the long term (i.e., 10–20 years) if it obtained a LEED or ENERGY STAR certification for an office building in its portfolio.

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<th>Strongly Disagree</th>
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Q7: LEED or ENERGY STAR certification requirements are clear and understandable.

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Q8: The process to obtain a LEED or ENERGY STAR certification for an office building is easy.

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<th>Strongly Disagree</th>
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</table>
Q9: The process to maintain a LEED or ENERGY STAR certification for an existing building is easy.

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<th>Strongly Disagree</th>
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Q10: The time it takes to obtain a LEED or ENERGY STAR certification is worthwhile.

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<th>Strongly Disagree</th>
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Q11: The effort it takes to obtain a LEED or ENERGY STAR certification for an existing building would be worthwhile.

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<th>Strongly Disagree</th>
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Q12: People that I respect (other than associates) support LEED or ENERGY STAR initiatives.

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Q13: Generally, the community at large supports LEED or ENERGY STAR initiatives.

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Q14: Professional associates (not connected to my company) that I respect support LEED or ENERGY STAR initiatives.

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Q15: The senior management of my organization supports the use of LEED or ENERGY STAR initiatives.

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Q16: People who are important to me personally think that I should adopt LEED or ENERGY STAR initiatives.

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Q17: My company has the resources necessary to obtain a LEED or ENERGY STAR certification for an existing commercial office building.

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Q18: My company has the knowledge necessary to obtain a LEED or ENERGY STAR certification for an existing office building.

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Q19: Industry groups (profit or non-profit groups) are readily available to assist with the process of obtaining a LEED or ENERGY STAR certification.

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Q20: LEED or ENERGY STAR certification is compatible with the existing office building’s condition.

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</table>
Q21: I intend to seek LEED or ENERGY STAR certifications(s) sometime in the next three years.

<table>
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<tr>
<th>Strongly Disagree</th>
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**Appendix 2**

**Results of Green Building Technology Survey**

**Exhibit 5** | Multiple Regression Model Summary

<table>
<thead>
<tr>
<th>R</th>
<th>R²</th>
<th>Adj. R²</th>
<th>Std. Error</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.623</td>
<td>0.388</td>
<td>0.317</td>
<td>0.804</td>
<td>5.399</td>
<td>0.002*</td>
</tr>
</tbody>
</table>

Note:
*Significant at p < .05.

**Exhibit 6** | Multiple Regression Construct Summary Table

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coeff.</th>
<th>Standardized Coeff.</th>
<th>Correlations</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>β</td>
<td>Std. Error</td>
<td>β</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.331 1.287</td>
<td>N/A     -0.257 0.799</td>
<td>N/A</td>
</tr>
<tr>
<td>PE</td>
<td>0.029 0.183</td>
<td>0.024 0.158 0.875</td>
<td>0.224</td>
</tr>
<tr>
<td>EE</td>
<td>-0.368 0.254</td>
<td>-0.244 -1.453 0.155</td>
<td>0.199</td>
</tr>
<tr>
<td>SI</td>
<td>0.938 0.291</td>
<td>0.561 3.219 0.003</td>
<td>0.545*</td>
</tr>
<tr>
<td>FC</td>
<td>0.468 0.223</td>
<td>0.317 2.100 0.043</td>
<td>0.396*</td>
</tr>
</tbody>
</table>

Note:
*Zero-order correlations significant at p < .05.

The relationship strength is based upon the beta value according to the following categories: $\beta \leq 0.2$ is a weak effect, $0.5 \equiv \beta > 0.2$ is a moderate effect, and $\beta > 0.5$ is a strong effect (Huizingh, 2007).

**References**


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Mark Starik, San Francisco State University, San Francisco, CA 94129 or mark.starik@gmail.com.
The Effect of Sustainability Features on Mortgage Default Prediction and Risk in Multifamily Rental Housing

Author
Gary Pivo

Abstract
This study examines the relationship between transportation-, location-, and affordability-related sustainability features and default risk in multifamily housing. It finds that sustainability features can be used to improve the prediction of mortgage default and reduce default risk. The study uses 37,385 loans in the Fannie Mae multifamily portfolio at the end of 2011:Q3. The results suggest two implications for practice. First, certain aspects of sustainability can be fostered without increasing default risk by adjusting conventional lending standards. Second, lenders could improve their risk management practices by taking stock of sustainability features when loans originate.

This study examines the relationship between sustainability features and mortgage default risk in multifamily rental housing. The borrowers are multifamily rental building owners with loans held by Fannie Mae. The sustainability features pertain to the social and environmental performance of properties including affordability, walkability, auto dependence, exposure to pollution, and proximity to protected open space.

The results show that information on the sustainability of multifamily buildings improves our ability to predict mortgage defaults. The results also show that loans on properties with sustainability features have a much lower risk of default. For example, defaults were 58% less likely for loans on properties in less auto-dependent locations, where 30% or more of the workers living there commute by subway or elevated train. Similarly impressive findings were found for each of the sustainability features examined in the study.

Mortgage Default and Multifamily Housing
Mortgage loan defaults are a risk for multifamily lenders and investors. In a study of 495 securitized multifamily mortgages originating between 1989 and 1995, Archer, Elmer, Harrison, and Ling (2002) found a default rate of nearly 12%. More recently, in the fourth quarter of 2011, the default rate for multifamily mortgages held by depository institutions in the United States was 3.7% (Chandan, 2011).
Previous studies show that the major risk factors for multifamily loan default are cash flow and property value. Default risk increases if declining cash flow prevents loan repayment or if falling property value produces negative net equity (Vandell, 1984, 1992; Titman and Torous, 1989; Kau, Keenan, Muller, and Epperson, 1990; Vandell, Barnes, Hartzell, Kraft, and Wendt, 1993; Goldberg and Capone, 1998, 2002; Archer, Elmer, Harrison, and Ling, 2002). In these studies, cash flow and equity are commonly measured in terms of debt service coverage ratio (DSCR), or the ratio of income to required loan payments, and loan-to-value ratio (LTV), or the ratio of loan amount to property value. A lower DSCR and a higher LTV, both at origination and over the life of the loan, have been linked to greater default risk.

**The Connection between Mortgage Default and Sustainability**

A growing number of econometric studies show that buildings with sustainability features generate more cash flow and value. The value premium appears to come from both the stronger cash flow and lower capitalization rates, suggesting that more sustainable properties are favored in both the space and capital markets by renters and investors. Stronger cash flow has also been tied to lower operating expenses. Specific sustainability features linked to these effects include LEED certification, ENERGY STAR labeling, historic preservation, design excellence, proximity to open space, good transit service, walkability, revitalizing urban location, and reduced exposure to pollution and natural hazards (Vandell and Lane, 1989; Harrison, Smersh, and Schwartz, 2001; McGreal, Webb, Adair, and Berry, 2006; Simons and Saginor, 2006; Miller, Spivey, and Florance, 2008; Eichholtz, Kok, and Quigley, 2009; Pivo and Fisher, 2010, 2011). Perhaps this should be unsurprising. After all, sustainability features promote qualities long associated with higher property value including health, safety, operating efficiency, occupant amenities, and accessibility.

If more sustainable buildings have better cash flow and value, then they should also exhibit lower default risk because, as noted above, default risk is inversely related to cash flow and value. However, adding information on sustainability features to the loan origination process would only be helpful if their impact on cash flow and value was not already fully accounted for in that process. If the financial benefits of sustainability were already fully reflected in the cash flow and value projections made at loan origination, then rational lenders may have already increased the size of the loans or reduced loan interest rates for the more sustainable properties (Grovenstein, Harding, Sirmans, Thebpanya, and Turnbull, 2005). The higher loan amounts or lower interest rates for the more sustainable properties would in turn have increased their LTV or lowered their DSCR, resulting in a probability of default more like that found in more conventional properties. That is to say, the effect of the sustainability variables would have already been fully endogenous to the loan origination process (Archer, Elmer, Harrison, and Ling, 2002). That would have caused the ex post default risk for the more sustainable properties to end up being similar to the risk for the
conventional ones. In that case, adding the sustainability features to a default prediction model, which already includes the original LTV and DSCR, would not improve the ability of the model to predict default because the information carried by the sustainability regressors would already be included in the LTV and DSCR.

However, if the financial benefits of sustainability had not been fully accounted for when the loans were originated, but instead future cash flows and values for more sustainable properties were expected to be closer to those of conventional properties than they actually turned out to be, then as any unrecognized financial benefits from the sustainability features materialized post-origination, the average post-origination DSCR would turn out to be higher and the average post-origination LTV would turn out to be lower for the more sustainable properties than for the conventional ones. This would produce a lower default rate for the more sustainable properties compared to the conventional ones, because there would be a lower risk of negative cash flow or a lower risk of negative equity.

This is not to say that lenders would have completely ignored sustainability features at loan origination. Indeed, some of them, such as being in a transit-oriented location, are commonly recognized by lenders as locational advantages. But even if some of the sustainability features were previously recognized as advantages by lenders, as long as their full effect on cash flow, value, and default risk were not fully reflected in the original loan terms, the more sustainable properties would have a lower post-origination default rate than the more conventional ones.

In a modeling context, if the financial benefits of sustainability were not completely reflected in the original DSCR and LTV, then adding information on sustainability features to a default prediction model could significantly improve the accuracy of that model. Put another way, if sustainability features help buffer properties from losing cash flow and value in the face of energy shocks, recessions, competition, or other events that can push cash flow and value into the default “danger zone” (Bradley, Cutts, and Follain, 2001), then knowing that a property is more or less sustainable should help lenders mitigate default risk.

These expectations led to Hypotheses 1 and 2.

**Hypothesis 1:** If certain transportation-, location-, and housing-related sustainability features are added to a model of default risk, the accuracy of the model will improve.

This is based on the expectation that most, if not all, of the impact that sustainability features have on future cash flow and value was unanticipated when multifamily loans were originated. Even though some advantages of the features may have been considered by underwriters, this hypothesis proposes that their positive effect on cash flow or value was not fully accounted for in the original loan terms.

**Hypothesis 2:** Sustainability features will be associated with a lower risk of default, ceteris paribus.
This should be the case because prior research shows that sustainability features tend to be associated with increased cash flow and value, which are in turn related to lower default risk.

**Methods**

**Logistic Regression Model**

A logistic regression model was used to test the hypotheses. This model has been used in several prior studies to estimate the effects of explanatory variables on the probability of mortgage default (Vandell, Barnes, Hartzell, Kraft, and Wendt, 1993; Goldberg and Capone, 1998, 2002; Archer, Elmer, Harrison, and Ling, 2002, Rauterkus, Thrall, and Hangen, 2010). A primer on logistic regression and its alternatives for studying default risk is given in the Appendix.

The data on individual mortgages used to build the model was provided by Fannie Mae and then combined by the author with data from other sources in order to measure sustainability and control variables. The Fannie Mae data included information on every loan in its multifamily portfolio at the end of 2011:Q3, making the study cross-sectional rather than longitudinal. The cross-sectional design raises some concern about the external validity of the findings (i.e., how far the findings can be generalized beyond the study sample) because the relationships between the regressors and default risk could change over time. For example, proximity to transit could reduce default rates by a greater amount when gas prices are peaking and demand is higher for apartments near public transit. Unfortunately, longitudinal data were unavailable for this study. It would be useful to confirm the results reported here in a follow-up study using longitudinal data. Another external validity issue comes from the fact that the Fannie Mae mortgage pool had an average default rate that was about one-fourth the rate found for mortgages held by depository institutions. It would be important to know whether the effects found in this study apply to those mortgages as well.

In the present work, each loan was treated as a separate case or observation. For each case, data were available on the loan age, type, terms, and lender, on various financial, physical, and locational attributes of the collateral property, and on the number of days the loan was delinquent, if any. More details on these variables and those from other sources are given below.

Following Archer, Elmer, Harrison, and Ling (2002), cases in the Fannie Mae database with extreme values on certain variables were excluded from the study in order to filter out possible measurement error. The extreme value filters ensured that all the cases used had an original note interest rate greater than the 10-year constant maturity risk-free rate at their origination date, an original LTV ratio of 100% or less, an original DSCR greater than 0.9 and less than 5.0, and an original note interest rate greater than 3% and less than 15%. After these filters were applied, 37,385 loans remained in the sample out of the 42,474 cases. The sample...
included mortgages with fixed and adjustable rates and with a wide variety of seasoning, originating anywhere from September, 1971 to September, 2011.

The variables evaluated in the models are described in the next section. Exhibit 1 gives their definitions and summary statistics.

**Variables**

*DEFAULT* was a binary variable indicating whether or not a loan was in default as of 2011:Q3. Loans were classified as in default if they were delinquent on their payments by 90 days or more as of 2011:Q3.

Seven sustainability variables were analyzed. Sustainability is a multi-dimensional construct with multiple distinct but related dimensions treated as a single theoretical concept. As such, the variables used in this study could not capture every dimension normally used to assess building sustainability (Pivo, 2008). Key omissions due to data limitations included operational energy and water efficiency. It would be useful to test the effect of these and other sustainability metrics on mortgage outcomes in future studies. If they affect cash flow and value, they are likely to affect default risk as well.

For some of the sustainability variables, a dummy that indicated whether their value fell above or below a cut-point produced a better result in the models than a continuous variable. This is common when a change in the dependent variable associated with a one-unit change in the independent variable is nonlinear and there is a suspected or assumed threshold effect (Williams, Mandrekar, Mandrekar, Cha, and Furth, 2006). Where nonlinearity was suspected, possible cut-points were examined by categorizing the relevant continuous sustainability variable into quantiles (e.g., quartiles or deciles) and comparing the default rates for each group. Default rates significantly higher for all mortgages above or below a certain quantile indicated a discontinuity and suggested a likely cut-point where a threshold effect may occur. The cut-point was then used to create a new dummy variable for testing in the model. This procedure was used iteratively to find the “optimal” cut-point which produced a dichotomous variable that was most useful in predicting default. In a practical setting, cut-points can be more useful than continuous indicators because they allow a simple risk classification into “high” and “low” and communicate clearly the threshold above (or below) which default risk will be consistently above (or below) average.

Three variables were used to capture the nature of the journey to work by residents living in the census tract where each property was located. These variables address the air, water, and wildlife issues linked to commuting and related social issues including traffic accidents, physical activity, and social interaction. *COMMUTE TIME* was the average commute time in minutes for people 16 years of age and older living in the tract who worked outside the home. *SUBWAY30* indicated whether a property was in a tract where at least 30% of the workers take a subway or elevated train to work. The 30% cut-point was selected using the “optimal cut-point” method described above. *PCTWALK* indicated the percentage of people in the tract who walk to work. All commuting data were from the 2000 U.S. Census.
## Exhibit 1 | Definitions and Summary Statistics for Variables in Final Models (n = 37,385)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable</td>
<td>DEFAULT</td>
<td>0</td>
<td>1</td>
<td>0.01</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>Binary variable indicating whether loan was (1) or was not (0) in default.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Default was defined as &gt;90 days delinquent as of 2011:Q3.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainability Variables</td>
<td>COMMUTE TIME</td>
<td>2.10</td>
<td>75.50</td>
<td>26.72</td>
<td>6.72</td>
</tr>
<tr>
<td></td>
<td>Mean commute time in 2000 for residents in the census tract (minutes).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SUBWAY30</td>
<td>0</td>
<td>1</td>
<td>0.08</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>In census tract where at least 30% of workers use a subway or elevated train for work (1 = yes, 0 = no).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PCTWALK</td>
<td>0</td>
<td>100</td>
<td>4.92</td>
<td>7.40</td>
</tr>
<tr>
<td></td>
<td>Percent of people in census tract that walked to work in 2000.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RETAIL16</td>
<td>0</td>
<td>1</td>
<td>0.40</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Sixteen or more retail establishments in census block group (1 = yes, 0 = no).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AFFORDABLE</td>
<td>0</td>
<td>1</td>
<td>0.10</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Meets FNMA affordable housing standards (1 = yes, 0 = no).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FREEWAY1000FT</td>
<td>0</td>
<td>1</td>
<td>0.40</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Within 1,000 feet of an interstate freeway (1 = yes, 0 = no).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PROTECTED1MILE</td>
<td>0</td>
<td>1</td>
<td>0.71</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Within 1 mile of a protected area (1 = yes, 0 = no).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Variables</td>
<td>OLTV</td>
<td>0.59</td>
<td>100</td>
<td>61.30</td>
<td>16.29</td>
</tr>
<tr>
<td></td>
<td>Loan-to-value ratio at origination.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ODSR</td>
<td>0.90</td>
<td>5.0</td>
<td>1.52</td>
<td>0.549</td>
</tr>
<tr>
<td></td>
<td>Debt service coverage ratio at origination.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LOAN_-AGE_-MONTHS</td>
<td>0.00</td>
<td>468.00</td>
<td>73.15</td>
<td>52.91</td>
</tr>
<tr>
<td></td>
<td>Number of months since loan origination.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LOAN_-SIZE_-GP</td>
<td>1</td>
<td>4</td>
<td>1.70</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>Original loan size; ordinal variable (1 ≤ $3MM, 2 = $3–5MM, 3 = $5–25MM, 4 ≥ $25MM).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ARM_FLAG</td>
<td>0</td>
<td>1</td>
<td>0.31</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Dummy for adjustable-rate mortgage (1 = yes, 0 = no).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NOCONCERNS</td>
<td>0</td>
<td>1</td>
<td>0.28</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>Dummy indicating absence (1) or presence (0) of concerns about physical condition at origination.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BUILT_YR</td>
<td>1800</td>
<td>2011</td>
<td>1967.83</td>
<td>26.25</td>
</tr>
<tr>
<td></td>
<td>The year the property was built.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TOT_UNTS_CNT</td>
<td>2</td>
<td>3284</td>
<td>94.65</td>
<td>125.05</td>
</tr>
<tr>
<td></td>
<td>Total housing units in the property.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PRINCIPAL_CITY</td>
<td>0</td>
<td>1</td>
<td>0.60</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Dummy for whether or not located in U.S. Census Principal City (1 = yes, 0 = no).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>URB_RUR</td>
<td>1</td>
<td>7</td>
<td>1.92</td>
<td>1.16</td>
</tr>
<tr>
<td></td>
<td>Ordinal variable indicating whether property is in Principal Urban Center, Metro City, Urban Outskirts, Suburban Periphery, Small Town or Rural location.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MEDHHINC000</td>
<td>0.0</td>
<td>200.00</td>
<td>42.70</td>
<td>16.94</td>
</tr>
<tr>
<td></td>
<td>Median household income in census tract in 2000 (000 dollars).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PROP_CRIME_MIL</td>
<td>0.0</td>
<td>2849.85</td>
<td>407.48</td>
<td>165.31</td>
</tr>
<tr>
<td></td>
<td>Annual number of property crimes per million persons in the city.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Newer data were unavailable at the time of the study. It is unlikely, however, that changes in commuting patterns over the past decade were sufficient to significantly alter the results.

RETAIL16 captured walkability where the apartment buildings were located or the degree to which the area within walking distance of a property encourages walking from the property to other destinations. Walkability has been linked to various social and environmental benefits and increases with the number of desired destinations within walking distance of a property (Pivo and Fisher, 2011; Federal Highway Administration, 2012). RETAIL16 was a dummy indicating whether the property was in a census block group with at least 16 retail establishments in 2011 and also was selected using the “optimal cut-point” method. The data were collected from Nielsen Claritas, which estimated the number of establishments in 2011 based on the 2007 U.S. Economic Census. The author is currently completing work on a follow-up study that examines the relationship between Walk Score—a widely available walkability metric—and multifamily mortgage risk.
AFFORDABLE indicated whether or not the loan was part of the Fannie Mae Targeted Affordable Segment, which focuses on financing properties with rent subsidies or income restrictions. Family well-being can be in jeopardy if too much of a household's budget is required for housing, leaving too little money for food, health care, childcare or other essentials (Bratt, 2002).

FREEWAY1000FT indicated whether a property was located within 1,000 feet of a freeway. There is growing evidence that living close to a freeway increases risk for autism, cancers, and respiratory disease (Gauderman et al., 2007; Volk, Hertz-Picciotto, Delwiche, Lurmann, and McConnell, 2011; Office of Health Hazard Assessment, 2012; Cakmak, Mahmud, Grgicak-Mannion, and Dales, 2012). Data on highway locations was obtained from the 2011 National Transportation Atlas Database.

PROTECTED1MILE indicated whether a property was located within a mile of a Protected Area according to the U.S. Protected Area Database. It includes public lands at all government levels held for conservation and voluntarily provided privately protected areas. Protected open space helps sustain resource-based industry, recreation, wildlife, watersheds, and other ecosystem services such as greenhouse gas absorption and heat island mitigation. Access to parks and recreation has also been linked to lower childhood obesity and other social benefits (Wolch et al., 2011).

In this study, the expectation was that if certain sustainability features were related to default risk, it is because they affect cash flow and/or value to a degree unaccounted for in the DSCR or LTV ratio at loan origination. However, it could also be true that the sustainability features are correlated with other factors that affect financial outcomes and default risk, such as other loan, property, neighborhood, or macroeconomic variables, raising questions about whether sustainability is a proxy for these other drivers of cash flow and value. Therefore, to separate the effects of sustainability features on default risk from these other factors, several control variables, suggested by prior research, were used in the models. The controls fall into four groups including loan, property, neighborhood, and economic characteristics.

OLTV and ODSCR measure the LTV and debt service coverage ratios at loan origination. Higher OLTV and lower ODSCR were expected to be associated with greater default risk. LOAN_SIZE_GP was an ordinal variable for the loan amount at origination. Esaki, L’Heureux, and Snyderman (1999) found that smaller commercial loans had lower default rates. ARM_FLAG was a dummy indicating whether the loan is adjustable or fixed. LOAN_AGE MONTHS was the number of months from the loan origination date to the observation date. Previous researchers have shown that default risk declines with age, though the pattern is nonlinear, increasing rapidly in the first few years and then declining (Snyderman, 1991; Esaki, L’Heureux, and Snyderman, 1999; Archer, Elmer, Harrison, and Ling, 2002). The same pattern was observed in this study sample. Linearity is not a requirement of the logistic regression model and it was unnecessary to transform LOAN_AGE_MONTHS to obtain significant results. However, some non-linearity
in the logit was detected for \textit{LOAN\_AGE\_MONTHS} using the Box-Tidwell transformation (Menard, 1995), so transformations of \textit{LOAN\_AGE\_MONTHS} were tried but they did not improve the results.

\textit{NO\_CONCERNS} was a dummy indicating whether there were no substantial concerns about the property condition at the time of loan origination. This should reduce default risk by decreasing the need to divert cash flow to deferred maintenance. \textit{BUILT\_YR} was the year the property was built. Archer, Elmer, Harrison, and Ling (2002) found that default rates increased with building age, so \textit{BUILT\_YR} was expected to be inversely related to default risk, although in some areas historic buildings may be prevalent, which could influence how age relates to risk.

\textit{TOT\_UNTS\_CNT} was the total number of units in the property. Smaller properties have been reported to experience more financial distress (Bradley, Cutts, and Follain, 2000). Archer, Elmer, Harrison, and Ling (2002), however, found that size was unrelated to default, although their univariate analysis showed that smaller properties had less risk, contrary to Bradley, Cutts, and Follain (2000). So the expected effect in this study was ambiguous.

Four control variables were created to control for geographical effects at the city and neighborhood level. Archer, Elmer, Harrison, and Ling (2002) found geographical effects to be one of the most important dimensions for predicting multifamily mortgage default. \textit{PRINCIPAL\_CITY} indicated whether the property was located in a Principal City, defined by the U.S. Census as the largest incorporated or census designated place in a core-based statistical area. Its purpose was to control for whether or not a property was centrally located in a metro- or micropolitan area because many central areas have outperformed suburban locations over the past decade and several sustainability features, such as walkability, are more common in central cities. Properties in Principal Cities were expected to have lower default risk. \textit{URB\_RUR} was also used to measure regional centrality. It was based on the 11 Urbanization Summary Groups defined in the ESRI Tapestry Segmentation system, which groups locations along an urban-rural continuum from “Principal Urban Centers” to “Small Towns and Rural” places. \textit{MEDHHINC000} was the median household income in the census tract from the 2000 census. Higher income was expected to be linked with lower default rates. \textit{PROP\_CRIME\_MIL} was the annual number of property crimes per million persons at the city scale, reported by the U.S. Department of Justice. Higher crime was expected to increase default risk.

Regional and national variables were used to control for differences in the economic context experienced by properties since loan origination. Dummies were created for the nine census divisions. Vandell, Barnes, Hartzell, Kraft, and Wendt (1993) used a similar variable. Other variables were tested but found to be insignificant. They included state, metropolitan area, and city location. Additional variables designed to capture regional economic effects were whether the property was in one of the 25 largest cities (\textit{TOP25CITY}), dummies for whether the property was located in New York City (\textit{NYC}) or Washington, DC (\textit{DC}), and changes in vacancy rates and prices in the metro area in the most recent six-year
period. USPRICE_CHANGE was a national indicator that captured the percentage change in the National Council of Real Estate Investment Fiduciaries (NCREIF) U.S. Apartment Index that occurred from the time the loan was originated to the observation date (2011:Q3). AVG_PRICE_6 and AVG_OCC_6 were computed using the NCREIF Apartment Index for metro areas. They described the average increase in apartment prices and the average occupancy rate in the metro area for each property over the last six years prior to the study observation date. Prior researchers have used updates of LTV and DSCR over time to predict default on the theory that negative equity or cash flow will trigger default. Both are affected by the property’s net operating income, which is in turn affected by vacancy rates and rental price indices. Therefore, changes in vacancy rates and rental price indices at the metro scale can be used to capture changes in market conditions that strengthen or weaken mortgages over time (Goldberg and Capone, 1998, 2002).

Lenders consider borrower characteristics to be crucial in predicting default rates. Relevant variables include borrower character, experience, financial strength, and credit history. In their “simple model of default probability,” Archer, Elmer, Harrison, and Ling (2002) theorized that losses from loans depend on the risk characteristics of the borrower, among other things, though such variables were not included in their models. Vandell, Barnes, Hartzell, Kraft, and Wendt (1993) used borrower type (individual, partnership, corporation, other) in their analysis of commercial mortgage defaults, as did Ciochetti, Deng, Gao, and Yao (2003), who expected individuals to represent a lower risk to lenders, although neither study found these variables to be significant. Unfortunately, due to privacy concerns, data on borrowers were unavailable for this study. It is likely, however, that lenders adjusted the original loan terms based in part on their assessment of borrower characteristics. Therefore, the LTV, DSCR, and ARM_FLAG variables may serve as proxies for borrower characteristics. It is inappropriate to make assumptions, however, about the effects of omitting variables in logistic regression.

It is known that omitting relevant variables introduces bias into linear regression, but less is known about how it may bias logistic regression (Dietrich, 2003). One study showed that omitted orthogonal variables (i.e., variables that are uncorrelated with other independent variables) can depress the estimated parameters of the remaining regressors toward zero (Cramer, 2007). That would make the findings about sustainability in this study appear to be weaker than they actually are. It would be helpful to include borrower characteristics in future work building on the present study.

Correlation among the independent variables is indicative of collinearity. Collinearity can create modeling problems including insignificant variables, unreasonably high coefficients, and incorrect coefficient signs (e.g., negatives that should be positive). Collinearity will not affect the accuracy of a model as a whole, but it can produce incorrect results for individual variables, which makes it more of a concern for Hypothesis 2 than Hypothesis 1. Tolerance statistics, which check for a relationship between each independent variable and all other independent variables, were used as an initial check and raised no concerns (Menard, 1995). A pairwise correlation matrix among the independent variables, however, did
indicate possible issues. LOAN\_AGE\_MONTHS and USPRICE\_CHANGE were moderately correlated (0.737), as were TOT\_UNTS\_CNT and LOAN\_SIZE\_GP (0.662), both of which make logical sense. SUBWAY30 was also correlated with MIDATLANTIC (0.684) and NYC (0.601). Correlations at this level do not automatically mean there will be collinearity issues, but they do raise the need for further tests, which were done and are reported below.

**Results**

Exhibit 2 gives the statistics for the three final models produced for the study. The first model predicts DEFAULT only using conventional explanatory variables unrelated to sustainability. The second model repeats the first but adds the sustainability variables. The third model is a reduced version of the second. It drops insignificant variables to produce a more parsimonious model in order to achieve the best fit with the fewest parameters. Using irrelevant variables increases the standard error of the parameter estimates and reduces significance (Menard, 1995). Insignificant variables were kept in the second model so their effect on the sustainability variables could be considered.

Some variables were excluded from the three final models due to collinearity issues. LOAN\_AGE was insignificant and had the wrong sign when it was included in the models with USPRICE\_CHANGE. This was corrected when LOAN\_AGE was used without USPRICE\_CHANGE. LOAN\_AGE was kept instead of US\_PRICE CHANGE because it captured the information included in USPRICE\_CHANGE (since they were correlated), and because it captured the effect of other forces that may have affected DEFAULT due to the seasoning of the loan and the market conditions when and since the loan entered the market.

TOT\_UNTS\_CNT was insignificant when included with LOAN\_SIZE\_GP; however both were significant on their own. TOT\_UNTS\_CNT was used in the final models because it had more informational content than LOAN\_SIZE\_GP, which was only ordinal rather than continuous.

The coefficient for SUBWAY30 was inflated when MIDATLANTIC and NYC were in the model, so both were excluded, which produced more conservative results (smaller effects) for SUBWAY30 in both cases. NYC was reintroduced in a robustness check, which is discussed below.

Since collinearity tends to produce unreasonably high regression coefficients, a rough indication of remaining collinearity in the models would be if any of the unstandardized coefficients ($\beta$) were greater than 2 (Menard, 1995). This was not the case, indicating the steps taken to reduce collinearity were sufficiently effective.

In the final models, all the variables had the expected signs except for URB\_RUR; however its results were insignificant. Also, larger properties had smaller default rates, supporting the findings by Bradley, Cutts, and Follain (2000).
The first hypothesis was that if certain sustainability features are added to a model of default risk, the accuracy of the model will improve. This hypothesis was tested by comparing the goodness-of-fit of models with and without sustainability features.

**Goodness-of-Fit with and without Sustainability**

The Effect of Sustainability Features | 163

**Exhibit 2** | Logistic Regression Results for DEFAULT

<table>
<thead>
<tr>
<th>Model 1: Without Sustainability</th>
<th>Model 2: With Sustainability</th>
<th>Model 3: Significant Variables Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loan</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLTV</td>
<td>0.041 (.000) 1.042</td>
<td>0.044 (.000) 1.045</td>
</tr>
<tr>
<td>ODSR</td>
<td>−0.868 (.003) 0.420</td>
<td>−1.037 (.001) 0.355</td>
</tr>
<tr>
<td>LOAN_AGE_MONTHS</td>
<td>−0.005 (.002) 0.995</td>
<td>−0.004 (.019) 0.996</td>
</tr>
<tr>
<td>ARM_FLAG</td>
<td>0.578 (.000) 1.782</td>
<td>0.468 (.001) 1.596</td>
</tr>
<tr>
<td>Property</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOCONCERNS</td>
<td>−0.902 (.000) 0.406</td>
<td>−0.820 (.000) 0.440</td>
</tr>
<tr>
<td>BUILT_YR</td>
<td>−0.015 (.000) 0.985</td>
<td>−0.016 (.000) 0.985</td>
</tr>
<tr>
<td>TOT_UNITS_CNT</td>
<td>−0.004 (.000) 0.996</td>
<td>−0.004 (.000) 0.996</td>
</tr>
<tr>
<td>Neighborhood</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRINCIPAL_CITY</td>
<td>0.145 (.297) 1.156</td>
<td>0.285 (.057) 1.330</td>
</tr>
<tr>
<td>URB_RUR</td>
<td>0.041 (.481) 0.960</td>
<td>0.020 (.745) 0.980</td>
</tr>
<tr>
<td>MEDHHINC000</td>
<td>−0.028 (.000) 0.973</td>
<td>−0.033 (.000) 0.968</td>
</tr>
<tr>
<td>PROP_CRIME_MIL</td>
<td>0.001 (.001) 1.001</td>
<td>0.001 (.000) 1.001</td>
</tr>
<tr>
<td>Economy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOP25CITY</td>
<td>−0.358 (.032) 0.699</td>
<td>−0.564 (.002) 0.569</td>
</tr>
<tr>
<td>DC</td>
<td>−1.158 (.115) 0.314</td>
<td>−1.420 (.056) 0.242</td>
</tr>
<tr>
<td>REGION</td>
<td>unreported reported unreported reported unreported</td>
<td></td>
</tr>
<tr>
<td>AVG_PRICE_6</td>
<td>0.004 (.790) 1.004</td>
<td>0.005 (.742) 1.005</td>
</tr>
<tr>
<td>Sustainability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMMUTE TIME</td>
<td>0.041 (.000) 1.042</td>
<td>0.037 (.000) 1.037</td>
</tr>
<tr>
<td>SUBWAY30</td>
<td>−0.821 (.014) 0.440</td>
<td>−0.878 (.008) 0.416</td>
</tr>
<tr>
<td>PCTWALK</td>
<td>−0.031 (.008) 0.969</td>
<td>−0.031 (.009) 0.969</td>
</tr>
<tr>
<td>RETAIL16</td>
<td>−0.417 (.002) 0.659</td>
<td>−0.421 (.002) 0.656</td>
</tr>
<tr>
<td>AFFORDABLE</td>
<td>−0.959 (.000) 0.383</td>
<td>−0.964 (.000) 0.381</td>
</tr>
<tr>
<td>FREeway1000FT</td>
<td>0.455 (.044) 1.576</td>
<td>0.464 (.040) 1.590</td>
</tr>
<tr>
<td>PROTECTED1MILE</td>
<td>−0.401 (.009) 0.669</td>
<td>−0.393 (.010) 0.675</td>
</tr>
<tr>
<td>Constant</td>
<td>24.620 (.000) 4.926E10</td>
<td>25.841 (.000) 1.670E11</td>
</tr>
</tbody>
</table>

Notes: In all models, n = 37,385. In Model 1, chi-square = 549.54 (.000), −2 log-likelihood = 3,097.149, Nagelkerke $R^2 = .157$, and under ROC curve = 0.829. In Model 2, chi-square = 625.55 (.000), −2 log-likelihood = 3,019.951, Nagelkerke $R^2 = .179$, and under ROC curve = 0.841. In Model 3, chi-square = 621.54 (.000), −2 log-likelihood = 3,023.967, Nagelkerke $R^2 = .178$, and under ROC curve = 0.841.
features included. Goodness-of-fit refers to how well all the explanatory variables in a logistic regression model, taken together, predict the dependent variable.

Goodness-of-fit statistics are reported in the notes for Exhibit 2. For all of the statistics except $-2 \log$-likelihood, a higher value indicates a better fitting model. All four statistics show there was less discrepancy between the observed values for DEF AULT and the values produced by the model when sustainability features were included. That supports the acceptance of Hypothesis 1.

The model chi-square measures the total reduction for all the cases in default prediction errors that occurs when the independent variables are in the model, compared to when they are not. Comparing the model chi-squares across the models in Exhibit 2 indicates that the models with the sustainability features predicted default more accurately than the model without them. This is indicated by a chi-square of 550 for Model 1 versus 626 and 622 for Models 2 and 3, respectively.

The $-2 \log$-likelihood statistic is similar to the model chi-square since it is based on the total error made by the model in predicting default for all the cases combined. But $-2 \log$-likelihood measures the total error made by the model with the independent variables included rather than the difference between the error with and without the independent variables. That is, it measures how poorly a model fits the data with all the independent variables in the equation. That is why a better model has a smaller $-2 \log$-likelihood. Here again, comparing across the models in Exhibit 2, the results show that the models with sustainability variables more accurately predicted default than the model without them, as indicated by $-2 \log$-likelihood values of 3,020 for Model 1 versus 3,024 and 3,097 for Models 2 and 3.

The Nagelkerke R-Square is a “pseudo R-square” that can be computed in logistic regression analysis. Pseudo R-squares are not analogous to the R-square in linear regression and are easily misinterpreted by readers familiar with linear regression models, according to Hosmer and Lemeshow (2000). For that reason, they recommend against reporting them. The Nagelkerke R-square is a measure of improvement from the null model to the fitted model (i.e., the improvement in each model produced by adding the independent variables). It is most useful for comparing multiple models predicting the same outcome with the same dataset, as in the present case. When used that way, the models with the higher R-squares are the ones that better predict the outcome. As Exhibit 2 shows, the models with sustainability features included had higher Nagelkerke R-squares (.178 and .179 vs .157).

Goodness-of-fit was also tested using the area under the receiver operating characteristic (ROC) curve. This test measures the model’s ability to discriminate between loans that do and do not default and is the likelihood that a loan that defaults will have a higher predicted probability than a loan that does not. If the result is equal to 0.5, the model is no better than flipping a coin. In the present study, ROCs exceeded 0.8. Values at this level indicate excellent discrimination according to Hosmer and Lemeshow (2000). In other words, the models did an
excellent job distinguishing between loans that will and will not default. Here again, the models with sustainability features did a better job than the model without (0.841 for both models with sustainability vs. 0.829 for the model without).

The Hosmer–Lemeshow test is another commonly recommended statistical test for goodness-of-fit in logistic regression models. However, its assumption that the expected frequencies are large was violated because default was a relatively rare event in this study, so its results would be invalid in the present case (Hosmer and Lemeshow, 2000).

According to all four goodness-of-fit measures, the results support the first hypothesis that if certain sustainability features are added to a model of default risk, the accuracy of the model improves.

**Interpretation of Sustainability Coefficients**

The second hypothesis was that sustainability features will be associated with a lower risk of default. This hypothesis was tested by examining and interpreting the regression coefficients in the reduced model (Model 3). According to the significance tests ("sig." in Exhibit 2), all of the sustainability features were significantly related to default risk. This means it is highly improbable that the sustainability features would be so strongly related to default in a model with this sample size if there actually were no relationships.

The size and direction of the relationships are indicated by the unstandardized coefficients ($\beta$). In Models 2 and 3, $\beta$ gives the change in the risk of default associated with a one-unit change in the sustainability variables, while the control variables are held constant. If $\beta$ is positive, then default risk increases with each one-unit increase in the sustainability variable. For example, in Model 3, a $\beta$ of 0.041 for COMMUTE TIME indicates that the risk of default increases as the average commute time increases in the area where the property is located. If $\beta$ is negative, then default risk decreases with each one-unit increase in the sustainability variable. For example, in Model 3, a $\beta$ of $-0.878$ for SUBWAY30 indicates that the risk of default decreases when a property is located where 30% or more of the people commute to work by subway or elevated train. And since these findings were estimated when the control variables were also in the model, we can say they are true regardless of neighborhood income ($MEDHHINC000$), whether or not the loan is adjustable ($ARM_FLAG$), the debt service coverage ratio at origination ($ODSCR$), etc.

Together, the significance tests and unstandardized coefficients in Models 2 and 3 indicate that when the sustainability features studied here are present, there is less risk of default, all else being equal. Note, however, that for some of the sustainability variables, a larger raw score indicates the property is less sustainable. That is the case for COMMUTE TIME and FREEWAY1000FT. For these variables, a positive $\beta$ means that a lower value (which indicates less sustainability), such as a longer commute time, is associated with less default risk. For the other variables, a negative $\beta$ means that a higher value (which indicates more sustainability), such as more walking to work, is associated with less default risk.
The unstandardized coefficients can be used to obtain estimated odds ratios by exponentiating the coefficients (i.e., computing its base e anti-log). An odds ratio is the odds of an outcome in one group (e.g., the default rate for properties near a protected area) divided by the odds of an outcome in another group (e.g., the default rate for properties not near a protected area). It is analogous to relative risk (Grimes and Schulz, 2008). The odds ratio associated with each independent variable is given as \( \text{Exp}(\beta) \) in Exhibit 2. As explained by Menard (1995), the odds ratio is the number by which we would multiply the odds of default for each one-unit increase in the independent variable. An \( \text{Exp}(\beta) \) greater than 1 indicates that the odds of default increase when the independent variable increases and an \( \text{Exp}(\beta) \) less than 1 indicates that the odds of default decrease when the independent variable increases. For example, a one-unit increase in \textit{COMMUTE TIME} (i.e., a one-minute increase, according to the definition column in Exhibit 1) results in a 3.7% increase in the odds of default (the odds of default are multiplied by 1.037). Similarly, a one-unit increase in \textit{SUBWAY30} results in a 58.4% decrease in the odds of default (the odds of \textit{DEFAULT} are multiplied by 0.584, which is 0.416 less than 1). For a dummy variable that can only be scored as 0 or 1, a one-unit increase is equivalent to referring to all cases where the dummy variable has a score of 1 or Yes. So, for example, for \textit{SUBWAY30}, if we say that a one-unit increase decreases the odds of default by 58.4%, we are saying that when \textit{SUBWAY30} is scored 1 (i.e., when a property is located in a location where 30% or more of the people commute by subway or elevated to work), the odds of default are 58.4% lower than in cases where the property is not located in such a location and \textit{SUBWAY30} is scored 0.

Odd ratios can also be interpreted as relative risk when the outcome occurs less than 10% of the time, which is the case for \textit{DEFAULT} in the study sample (Hosmer and Lemeshow, 2000). Relative risk is the ratio of the probability of an event occurring in a group with and without a certain characteristic. We can say, for example, that in locations where commute time is 28 minutes (or about one minute above average), multifamily mortgages are 3.7% more likely to default than in locations with a 27-minute commute time. Similarly, in locations where 30% or more residents take a subway or elevated train to work, owners are 58% less likely to default in comparison to locations where fewer than 30% commute by subway or elevated. And, as noted above, the reductions in risk associated with each of the sustainability features are unrelated to differences in regional location, neighborhood income, and the other control variables included in the models.

Exhibit 3 summarizes the effects of a one-unit change in the sustainability variables on default risk in relative risk terms. In every case, the effects are large, indicating that these sustainability features have a very significant effect on default risk, independent of other factors commonly used to predict default. In addition, the direction of each relationship indicates that in all cases more sustainability is related to less default risk. These findings confirm Hypothesis 2 that sustainability features are associated with a lower risk of default.

When dealing with continuous variables, such as \textit{COMMUTE TIME} and \textit{PCTWALK}, a one-unit change is not always interesting. For example, a one-minute
Exhibit 3 | Summary of Sustainability Effects on Default Risk in Multifamily Mortgages

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Effect on Relative Risk of Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMUTE TIME</td>
<td>Per 1 minute increase in the commute time to work.</td>
<td>3.7% more</td>
</tr>
<tr>
<td>SUBWAY30</td>
<td>Where ≥ 30% commute by subway or elevated.</td>
<td>58.4% less</td>
</tr>
<tr>
<td>PCTWALK</td>
<td>Per 1-unit increase in the percent who walk to work.</td>
<td>3.1% less</td>
</tr>
<tr>
<td>RETAIL16</td>
<td>Where there are 16 or more retail establishments in the block group.</td>
<td>34.4% less</td>
</tr>
<tr>
<td>AFFORDABLE</td>
<td>When property meets FNMA definition for affordable housing.</td>
<td>61.9% less</td>
</tr>
<tr>
<td>FREEWAY1000FT</td>
<td>Where property is located within 1,000 feet of a freeway corridor.</td>
<td>59.0% more</td>
</tr>
<tr>
<td>PROTECTED1MILE</td>
<td>Where property is located with 1 mile of protected open space.</td>
<td>32.5% less</td>
</tr>
</tbody>
</table>

increase in commuting or a 1% increase in the percentage of people who walk to work may be too small to be considered important. Hosmer and Lemeshow (2000, p. 63) show that as in the case of a one-unit increase, the effect from a multi-unit change in an independent variable on the odds of default can be determined from an estimated odds ratio. In the case of a multi-unit change, the odds ratio is estimated by exponentiating the product of the unstandardized coefficient (β) for a given variable times the number of units of change. If, for example, one were interested in how a 10-minute increase in COMMUTE TIME affected the odds of default, the odds ratio would be computed by exponentiating the product of 10 × β for COMMUTE TIME. Applying this method using the coefficients from Model 3 (Exhibit 2), we find that for every 10-minute increase in the mean commute time for residents in a census tract, the risk of default increases by 45%. Similarly, for every five-unit increase in the percentage of people in a tract who walk to work, the risk of default decreases by 15%.

As discussed above, NYC was excluded from the models. This was because SUBWAY30 was inflated with NYC in the model due to collinearity issues. However, it was important to know if the effects of SUBWAY30 were due to its association with NYC. To answer that question, Model 3 was rerun using the 33,733 cases that were not located in NYC. The unstandardized coefficient for SUBWAY30 (β) was −1.062 (0.003) and the Exp(β) was 0.356. Compared to the results in Exhibit 2, this indicates that the effect of SUBWAY30 outside of NYC was even stronger. When cases in New York City were excluded from the sample, the relative risk of default was 64.4% less for properties located where at least 30% of the tract residents commuted by subway or elevated, compared to 58.4% less when cases in New York City were included in the sample. This indicates that the effects of SUBWAY30 on default were not because a disproportionate share of the cases in subway-oriented locations were in New York City.

Discussion

The findings support the hypotheses. When certain transportation-, location-, and affordability-related sustainability features are included in a default probability
model for multifamily housing, the model predicts default more accurately. Also, properties with the sustainable features studied are much less likely to default. These findings suggest two important implications for practice: one pertaining to sustainability and the other to risk management.

First, certain aspects of sustainability can be fostered without increasing default risk by adjusting conventional lending standards for properties with the sustainability features studied here to achieve the same risk of default associated with less sustainable properties. For example, in the study sample, the mean $OLTV$ and $ODSCR$ were 0.61 and 1.52, respectively. However, according to Model 3, if a property is located in a subway-oriented census tract (where at least 30% of the people commute by subway or elevated train), then the $OLTV$ could have been raised to nearly 0.75 and the $ODSCR$ could have been lowered to 1.28 (which maintains the normal ratio between the two found in the sample) and the probability of default would have remained virtually equal to that found for properties not located near subway stations, all else being equal. According to the model, the extra risk produced by a higher $OLTV$ and lower $ODSCR$ would be offset by the lower risk produced by locating in a more sustainable location, leaving the total risk unchanged. Similar results can be produced with various other combinations of the studied sustainability features and conventional lending standards. Of course, lenders have programmatic constraints that set maximums for the $OLTV$ and minimums for the $ODSCR$. Those constraints establish practical limits on how far lenders could go in adjusting for sustainability features unless they are willing to make exceptions to the programmatic constraints for that purpose.

If higher LTV ratios at origination could be obtained by borrowers for more sustainable properties, the borrowers would achieve a higher return on equity as long as positive leverage is possible (i.e., when the cost of debt financing is lower than the overall return generated by the property return on asset). Ceteris paribus, this should cause investors to prefer more sustainable investments, increase capital flow to more sustainable buildings, and foster a transition to more sustainable cities.

The second implication of the findings is that lenders could improve their risk management practices by taking stock of whether a property has certain sustainability features when loans are originated. All the features studied here are based on existing federal datasets provided by the Census Bureau and other agencies. So it would be relatively easy to build an online address-based lookup tool that any lender can use to obtain certain sustainability information on a given property. In addition, recommended adjustments to $OLTV$ and $ODSCR$ ratios could be made available through a second online tool based on coefficients found in this study and confirmed by additional research. The results clearly show that traditional lending ratios have not fully recognized the presence or absence of certain sustainability features (by recognizing their effect on capitalization rates, values, or cash flows). The most common result is that these ratios have been based on an underestimation of the actual risk of default for properties without those sustainability features. This is because the “normal” rate of default expected for all properties is derived from the experience with more and less sustainable
properties combined, without the effect of sustainability being recognized. In this situation, less sustainable properties, according to the findings in this study, should have a rate of risk higher than the norm. There is more risk associated with less sustainable properties (and less risk with more sustainable properties) than is being accounted for in traditional lending ratios. If better information could be made available on the size of these effects and on how lending ratios could be adjusted to offset the effects produced by the presence or absence of sustainability features, the risk of portfolios could be more effectively managed.

Unfortunately, this study is limited to those sustainability features for which data could be obtained. It is likely, however, that other sustainability features that were not studied here also have beneficial effects on default risk. The most likely examples pertain to energy efficiency and green building certification because prior studies show they affect cash flow and value. Other sustainability features that could reduce default risk include rental unit flexibility, urban centrality, noise mitigation, water efficiency, childcare services, and school quality. This is expected because of their likely “materiality” to financial performance, rather than their positive effect on the public good (Pivo, 2008). Further work on whether these features do or do not affect default risk would be most useful, but it will have to await the development of better databases to account for them.

Other fruitful avenues for further research include repeating this study using other modeling methods (e.g., longitudinal hazard models) and data sets on higher risk mortgages. It would also be useful to conduct similar studies on other property types, including single-family homes and other commercial property types. And work should begin on a practical tool that helps lenders adjust conventional lending ratios based on sustainability information without increasing normal risk levels.

**Conclusion**

Perhaps the most important point of this study is that sustainability is just as much an issue with material consequence for investors as for those interested in social and environmental well-being. Pivo and McNamara (2005) wrote about the common ground emerging between real estate investing and sustainability stating: “It is probably apparent to anyone who thoughtfully considers real estate that it can both contribute to and be affected by many of the social and environmental issues that face the world’s societies. Until recently, however, most real estate investors would likely have said that while they are sympathetic, such issues are...not of direct concern to their investment practices. But today, a new view is emerging...that various social and environmental issues can have significant material consequences for their investment portfolios.”

Sustainability is financially consequential for property investors. Multifamily lenders can mitigate risk by gearing their portfolios toward more sustainable properties. Moreover, and for society this may be even more important, lenders can offer more favorable terms to more sustainable properties without increasing default risk, or as Benjamin Franklin once said, they can “do well by doing good.”
Appendix

Logistic Regression and Alternatives

Logistic regression is a statistical method for predicting the value of a bivariate dependent variable (Menard, 1995). A bivariate variable is one with two possible values, such as pass/fail, or in the present study, default/no default. The value of the dependent variable predicted by a logistic regression model is the probability that a case will fall into the higher of the two categories of the dependent variable, which normally indicates the event occurred, given the values for the case on the independent variables. In other words, it is the probability that an event will occur under various conditions characterized by the independent variables. The predicted value of the dependent variable is based on observed relationships between it and the independent variable or variables used in the study.

Logistic regression models are typically used to determine whether the classification of cases into one of the two categories of the dependent variable can be predicted better from information on the independent variables than if the cases were randomly classified into the categories. “Goodness-of-fit” refers to how well all the explanatory variables in a logistic regression model, taken together, predict the dependent variable. So, in terms of logistic regression, the first hypothesis in this paper is that a logistic regression model for default will have a better goodness-of-fit if sustainability features are included along with other more conventional explanatory variables in the regression equation.

The estimated parameters of a logistic regression equation can be interpreted as the change in the dependent variable that can be expected from a one-unit change in the dependent variable, holding other dependent variables constant. So again, looking at the second hypothesis in this paper in terms of logistic regression analysis, the expectation is that sustainability features will have estimated parameters that show they reduce the probability of default by a significant amount.

The most common alternative to the logistic regression model in mortgage default research is the proportional hazard model. Hazard models explain the time that passes before some event occurs in terms of covariates associated with that quantity of time. They have been used to estimate the probability that a mortgage with certain characteristics will default in a given period if there has been no default up until that period (Vandell, Barnes, Hartzell, Kraft, and Wendt, 1993; Ciochetti, Deng, Gao, and Yao, 2002; Teo, 2004). Other methods for predicting default also have been explored including neural networks (Episcopos, Perici, and Hu, 1998) and a maximum entropy approach (Stokes and Gloy, 2007).

A common view of the hazard model is that it is less sensitive to bias from database censuring than logistic regression. Censoring occurs when cases are removed from the database prior to observation (e.g., when a loan is paid off or foreclosed and sold prior to observation) or when the event of interest happens after observation occurs (e.g., when a loan defaults after the study observation...
However, as pointed out by Archer, Elmer, Harrison, and Ling (2002), bias is only an issue in logistic regression when the explanatory variables have a different effect on the censored and uncensored cases. In the present study, there is no reason to expect that sustainability features affected the odds of default differently in censored and uncensored cases. Hazard models also require a time series dataset that reports the occurrence of defaults over time and such a dataset was unavailable at the start of the present study. One effort to predict mortgage pre-payment using both approaches found that the logistic regression model made better predictions (Pericli, Hu, and Masri, 1996), while in another study on insolvency among insurers, the two models produced equally accurate predictions (Lee and Urrutia, 1996). So, while it would be interesting to repeat this study using a hazard model, there is no a priori reason to assume that the logistic regression method used here produced results that are inferior to those that would have come from another method.

References


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Does Greater Energy Performance have an Impact on Real Estate Revenues?

Authors Magnus Bonde and Han Suck Song

Abstract In order to further mitigate negative environmental impact, the European Union (EU) has adopted the so-called “20-20-20” goals, in which a (primary) energy reduction target is included. Subsequently, the Energy Performance Certificate (EPC) for buildings (via the Directive on the Energy Performance of Buildings) has been implemented in EU member states. In this paper, we examine the impact of EPCs on office revenues. By and large, we find that better EPC ratings have a positive and significant effect on revenues. This research area is important as improved energy efficiency in the built environment is necessary in order to reach the EU reduction target.

Within the European Union (EU) the energy usage related to building services accounts for about 41% of the total energy usage (year 2010). Out of this, around 27% can be related to the residential sector, whereas the tertiary (non-residential) sector accounts for about 14%. The energy usage in the tertiary sector has since 1990 increased about 1.5% per year (Lapillonne, Sebi, Pollier, and Mairet, 2012). In order to reverse this development, the EU member states are obliged to reduce (primary) energy usage by 20% by 2020 (as part of the “20-20-20” goals). As a consequence, the Directive on the Energy Performance of Buildings (2002/91/EC) was adopted in 2002 and recast in 2010, with a more aspiring intent. The Directive stipulates, among other things, a mutual method for scheming a building’s energy performance, as well as minimum standards of the energy performance of both new buildings and existing buildings that undergo major renovation. No specific energy performance levels are stipulated in the directive, instead each EU member country determines its own specific energy performance levels (Europa.eu, 2007, 2009; The Swedish National Board of Housing, Building and Planning, 2011a).

The Directive on the Energy Performance of Buildings targets rental, special purpose, non-residential, and tenant-owned apartment buildings exceeding 1,000 square meters (sqm). However, some building segments are excluded (e.g., historical buildings, buildings used for secret operations). This assessment, referred to as an Energy Performance Certificate (EPC), has to be issued by a registered, third party assessor (a so-called “independent expert”). An EPC is a building energy rating, which in an easy manner shows the building’s energy performance for different stakeholders (e.g., buyers and occupiers). The rating is presented as an annual, weather-corrected, energy usage figure (kWh/sqm/year).
Further, the EPC shall include recommendations on cost-effective energy efficiency investments. However, one of the main obstacles for real estate owners to invest in energy efficiency measures is the lack of sound evidence regarding the economic return (Concentrated Action—Energy Performance of Buildings, 2011; The Swedish National Board of Housing, Building and Planning, 2007, 2008; Kok and Jennen, 2012). When the energy assessment is finalized, a summary of the assessment is publicly displayed in a visible place in the building (e.g., at the entrance of the building), presenting the building energy usage (kWh/sqm/year). A low energy usage figure indicates that a building is an energy-efficient building. Other information, such as comparison values for similar buildings (location, age, and design) and present building code energy norms for new construction, is also presented. An EPC is after completion valid for ten years (The Swedish National Board of Housing, Building and Planning, 2008).

The impact of various energy/environmental certificates on the economic performance of real estate has been investigated frequently during the last few years. Most of these studies (e.g., Eichholtz, Kok, and Quigley, 2010, 2011; Fuerst and McAllister 2011a, 2011b; Kok, Miller, and Morris, 2012) focus on the American real estate market using CoStar data. However, European research within this field is emerging (e.g. Chegut, Eichholtz, and Kok, 2011; Kok and Jennen, 2012; Fuerst and McAllister, 2011c). The main objective with these studies is to empirically investigate if there is a relationship between “green”/more energy-efficient buildings and greater economic profits.

In the United Kingdom, Fuerst and McAllister (2011c) investigate the potential effect of EPCs on the capital (market) value, market rent (estimated market rent in an open-market transaction) and equivalent yield, using a dataset of 708 commercial assets provided by the Investment Property Databank (IPD). The authors did not find any relationship between EPCs and the economic variables. However, the authors acknowledge that their dataset is relatively small. Kok and Jennen (2012) conduct a similar study in the Netherlands. They construct a dataset using rental transaction data (provided by real estate agents), accessibility data (expressed via a “Walk Score,” measured as the distance to highway junction/train station and a “Rail Service Quality Index”) and EPC data (from the Ministry of Economic Affairs). In all, the dataset consists of 1,072 rental transactions for 2005–2010. Out of the dataset, two groups are formed: “green” and “non-green.” The buildings labeled A-C (the three highest marks) are categorized as “green,” whereas buildings labeled D-G (the lower marks) are categorized as “non-green.” The non-green buildings (less energy-efficient buildings) earned lower rents (about 6.5%) in comparison to green (more energy-efficient) buildings. Nappi-Choulet and Décamps (2013) investigate whether energy efficiency has an impact on asset values and rents. The authors use a dataset of 558 buildings, which included the following building segments: tertiary, industrial and “mixed-post office” (constitutes of post service plus an additional building usage). The effect of energy performance on the assets’ values or rents was in general not significant. Nevertheless, the study shows that energy performance to some extent affected the rent of tertiary assets. Leopoldsberger et al. (2011) study the impact of energy costs on office rents in Germany. Using a database that consists of 532
observations from 57 cities, the authors find that a higher heating/electricity cost has a negative impact on the rent level. However, maintenance costs and other service charges did not have an effect on the rent. Based on real estate economic data from IPD and geographical and demographic data from German Statistical Office (in all, the dataset consists of 2,630 observations), Cajias and Piazolo (2013) examine the economic impact of superior energy performance on residential multi-family buildings in Germany. They find that energy-efficient buildings (low EPC figures) earned higher rents, total returns, and market values.

Data

The basic data used in this article come from two sources: economic data from IPD and EPCs from the Swedish National Board of Housing, Building and Planning. The panel is unbalanced with gaps, ranging from 2007 to 2010. In all, the dataset consists of 269 building and 684 observations. Exhibit 1 provides the descriptive statistics.

The economic variables consist of Gross Revenue, Utility Costs, Vacancy Rate, Property Care, and Age, whereas each building’s energy performance assessment (rating) is represented by EPC (due to confidentiality the EPCs in this study are rounded off to the nearest ten). Gross Revenue consists of rental income and, if any, additional income from providing utilities such as heating, cooling, etc. As an EPC is valid for 10 years, this variable is time-invariant over the study period. Location is controlled at a regional level, as outlined by IPD: Stockholm CBD, Stockholm Central Area, Rest of Greater Stockholm, Malmö, Gothenburg, and Other Major Cities. See the Appendix for variable definitions.

As it is quite common to have both office and retail businesses in the same building, a retail dummy is provided by IPD. Buildings with less than 20% rentable office space are labeled as retail and are excluded from this study.

Exhibit 1 presents the sample means, standard deviations and min/max values of the dependent variable Gross Revenue, together with the main explanatory variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Revenue (SEK / sqm)</td>
<td>1823.25</td>
<td>961.22</td>
<td>0</td>
<td>4918</td>
</tr>
<tr>
<td>EPC (kWh / sqm)</td>
<td>158.63</td>
<td>47.15</td>
<td>60</td>
<td>340</td>
</tr>
<tr>
<td>Utility Costs (SEK / sqm)</td>
<td>145.90</td>
<td>73.28</td>
<td>0</td>
<td>522</td>
</tr>
<tr>
<td>Property Care (SEK / sqm)</td>
<td>134.53</td>
<td>86.13</td>
<td>7</td>
<td>637</td>
</tr>
<tr>
<td>Vacancy Rate (percent)</td>
<td>10.35</td>
<td>16.68</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Age (years)</td>
<td>20.82</td>
<td>18.29</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Note: Data on 269 buildings. There are 684 observations.
Exhibit 2 | Correlation Matrix

<table>
<thead>
<tr>
<th>Variable</th>
<th>Gross Revenue (SEK / sqm)</th>
<th>EPC (kWh / sqm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Revenue (SEK / sqm)</td>
<td>1.00</td>
<td>0.2851</td>
</tr>
<tr>
<td>EPC (kWh / sqm)</td>
<td>0.3690</td>
<td>0.0115</td>
</tr>
<tr>
<td>Utility Costs (SEK / sqm)</td>
<td>0.4134</td>
<td>0.6272</td>
</tr>
<tr>
<td>Property Care (SEK / sqm)</td>
<td>0.3549</td>
<td>0.02538</td>
</tr>
<tr>
<td>Vacancy Rate (percent)</td>
<td>0.0778</td>
<td>-0.2484</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0.0850</td>
<td>-0.1317</td>
</tr>
<tr>
<td>Stockholm CBD</td>
<td>0.3650</td>
<td>-0.1871</td>
</tr>
<tr>
<td>Malmö</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gothenburg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$EPC$ and the other explanatory variables. In the dataset, a majority of the buildings are located in Stockholm. This follows naturally from the fact that IPD has a better coverage in more urban areas. Furthermore, most of the buildings are observed during 2009 and 2010. Finally, it should be noted that the sample size is relatively small (269 buildings, 684 observations).

Exhibit 2 presents correlations between various variables. In all, the correlation between the different variables varies from very weak to moderate [according to Dransfield (2013) guidelines for interpreting the correlation coefficients]. As expected, the strongest correlation is between $Stockholm CBD$ and $Gross Revenue$. The main explanatory variable $EPC$ is weakly correlated with the dependent variable $Gross Revenue$, as well as with the costs for utilities ($Utility Costs$).

Exhibit 3 presents the VIF diagnostics. Two separate VIF diagnostics have been exercised: one based on OLS regression with dummy variables for each property (column (1)), and one based on OLS regression without the property dummy variables. The VIF figures in column (1) are for a majority of the variables above 10, which is the threshold limit for a high VIF figure. In contrast, the VIF figures based on the OLS regression without the property dummy variables results in considerably lower VIF figures (below 10, see column (2)). The high VIF figures in column (1) reflect that the variables are correlated with the property dummies, and above all, the very high VIF value for the $EPC$ variable reflects that it is highly correlated with the property dummy variable for each property. In other words, the large difference in obtained VIF values between the two VIF diagnostic tests indicates that there might not be any problem with a high degree of collinearity between the independent variables and most important between the $EPC$ variable and the $Utility Costs$ variable.

**The Econometric Model**

The hedonic regression technique, which stems from the works by Court (1939) and Rosen (1974) is a standard approach to examine the determinants of real estate


Exhibit 3 | VIF Diagnostics

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility Costs (log)</td>
<td>10.17</td>
<td>1.88</td>
</tr>
<tr>
<td></td>
<td>(0.098)</td>
<td>(0.531)</td>
</tr>
<tr>
<td>Property Care (log)</td>
<td>8.41</td>
<td>1.81</td>
</tr>
<tr>
<td></td>
<td>(0.119)</td>
<td>(0.551)</td>
</tr>
<tr>
<td>Vacancy Rate (%)</td>
<td>3.03</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>(0.330)</td>
<td>(0.930)</td>
</tr>
<tr>
<td>Age (log)</td>
<td>146.98</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.929)</td>
</tr>
<tr>
<td>EPC (log)</td>
<td>97.37</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.757)</td>
</tr>
<tr>
<td>2008 (Yes = 1)</td>
<td>11.66</td>
<td>7.80</td>
</tr>
<tr>
<td></td>
<td>(0.086)</td>
<td>(0.128)</td>
</tr>
<tr>
<td>2009 (Yes = 1)</td>
<td>16.97</td>
<td>9.39</td>
</tr>
<tr>
<td></td>
<td>(0.059)</td>
<td>(0.106)</td>
</tr>
<tr>
<td>2010 (Yes = 1)</td>
<td>21.27</td>
<td>9.80</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.102)</td>
</tr>
<tr>
<td>Stockholm CBD (Yes = 1)</td>
<td>369.95</td>
<td>3.26</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.307)</td>
</tr>
<tr>
<td>Stockholm Central Area (Yes = 1)</td>
<td>125.03</td>
<td>3.78</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.265)</td>
</tr>
<tr>
<td>Rest of Greater Stockholm (Yes = 1)</td>
<td>264.82</td>
<td>2.99</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.334)</td>
</tr>
<tr>
<td>Gothenburg (Yes = 1)</td>
<td>199.32</td>
<td>3.21</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.311)</td>
</tr>
<tr>
<td>Malmö (Yes = 1)</td>
<td>182.51</td>
<td>2.44</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.409)</td>
</tr>
<tr>
<td>Mean VIF</td>
<td>11.51</td>
<td>3.83</td>
</tr>
</tbody>
</table>

Note: Column (1) presents VIF figures based on OLS regression with dummy variables for each property; column (2) does not include dummy variables for each property. 1 / VIF values are in parentheses.

rents, prices, and values. A Hausman specification test (Hausman, 1978) is used to determine if a fixed effect (FE) model or random effect (RE) model should be used. The test indicates that a FE model is the most appropriate in estimating the rental equation. However, since the key explanatory variable, EPC, is valid for 10 years, this variable remains constant (time-invariant) over the study period. Therefore, a FE model with time-invariant variables needs to be estimated. As such, along the lines of Oaxaca and Geisler (2003) and Plümper and Troeger (2007, 2011), a FE model with vector decomposition is estimated. The model is as follows:
In model (1), the $K$ numbers of the $x$-variables are time-varying, while the $M$ numbers of the $z$-variables are time-invariant. Further, $u_i$ is the unobserved effect for each property, while $e_{it}$ denotes the error term. $\beta$ and $\gamma$ are the parameters for the time-varying and the time-invariant variables, respectively.

In the econometric model, the time-varying explanatory variables are: Utility Costs, Property Care, Vacancy Rate, and Age, whereas the time-invariant explanatory variables are: EPC and the location dummy variables. A Wald test on the group of time dummy variables shows that they are significant and are therefore included. The following econometric model is estimated to assess the impact of EPC on Gross Revenue (the location and time dummy variables are excluded for simplicity):

$$\ln(Gross\ Revenue) = \alpha + \beta_1 \ln(\text{Utility Costs})_i + \beta_2 \ln(\text{Property Care Costs})_i + \beta_3 \ln(Vacancy\ Rate)_i + \beta_4 \ln(Age)_i + \gamma \ln(EPC)_i + u_i + e_{it}. \quad (2)$$

**Anticipated Impact on Gross Revenue**

Since an EPC rating is weather-corrected, it illustrates a building’s annual energy usage during “normal” weather conditions. As such, it is not affected by energy prices or weather conditions. A building’s energy performance should however be related to the building’s technical standard, which in turn may not be captured by the Age variable. A high EPC figure is synonyms with a low energy-efficient building, which in turn can be a proxy for obsolete and less attractive properties. Consequently, the EPC variable should have a negative impact on the gross revenue.

The Utility Costs variable, as opposed to the weather-corrected EPC variable, co-varies with changes in energy prices and weather conditions (i.e., during a mild winter the cost for heating will be lower). Energy costs account for 30% of a normal office operating cost and in Sweden these costs are often a part of the landlords’ operating costs (Lind and Lundström, 2009; Eichholtz, Kok, and Quigley, 2010). When tenants enter a rental agreement, they negotiate with landlords regarding the size of the base rent, as well as the size of the additional charges for heating, cooling, etc. During the lease term, these costs are readjusted using a broad index, usually the CPI. Since the size of the additional charges both reflect a landlord’s bargaining power and the development of CPI, the additional
charges may not necessarily reflect a landlord’s actual cost for providing utilities during the lease term. However, under normal circumstances, the higher utility costs, the higher the compensation. Therefore, the Utility Cost variable is expected to have a positive impact on the gross revenues.

Older buildings might have a lower overall standard. Therefore, the Age variable should have a negative impact on gross revenues. Naturally, the variable Vacancy Rate is expected to have a negative impact on gross revenues too. The costs for Property Care should be positively correlated with the overall building upkeep and therefore this variable should have a positive impact on Gross Revenue. Buildings in Stockholm in general, and in Stockholm CBD in particular, should have higher revenues. Furthermore, positive effects should be observed for the second and third largest cities, Gothenburg and Malmö.

In order to analyze the impact of our key explanatory EPC variable on gross revenues, two different models are estimated. Model 1 estimates the impact of EPC without the Utility Costs variable, while model 2 includes the Utility Costs variable.

**Results**

Exhibit 4 presents the results of the two regression equations. Our primary interest is what happens to gross revenues when EPC varies. Column (1) presents the impact of EPC on gross revenues without using Utility Costs as an explanatory variable. Although the adjusted R² in this model is fairly high (0.80), the EPC variable is not significant. However, as column (2) shows, when the Utility Costs variable is added, the coefficient for the EPC variable becomes statistically significant, and shows the expected negative sign, which corresponds with our prior beliefs that a higher EPC figure will result in lower gross revenues. Furthermore, the Utility Costs variable has a statistically significant, positive effect on gross revenues, which also reflects our expectations. Column (2) also shows that the adjusted R² increases to 0.84 when the Utility Costs variable is included.

The coefficient of the EPC variable (−0.260) is the estimated elasticity of Gross Revenues with respect to EPC. The coefficient implies that a 1% increase in EPC decreases gross revenues by 0.260%. Since Exhibit 1 shows that the EPC figures for the properties included in this study vary from 60 to 340 kWh/sqm, while the mean EPC value is around 158 kWh/sqm and the standard deviation is about 47 kWh/sqm, it is more interesting to interpret larger percentage changes in EPC than just 1%. Consequently, if EPC increases by 10%, its estimated coefficient implies that gross revenues will decline by 2.6%. Similarly, a property owner who invests in energy saving measures might find that a large percentage decrease in EPC, say 20%, will result in a 5.2 percentage increase in gross revenues. Given the mean EPC value of 158 kWh/sqm, a 20% reduction corresponds to a 31.6 kWh/sqm reduction in the EPC value for a specific property (and therefore an improvement in energy efficiency), which still is much less than the sample standard deviation of 47 kWh/sqm. Our results indicate that there might be incentives for property owners to invest in energy efficiency measures.
### Exhibit 4 | Robust Estimation Results of Two Different Regression Models

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross Revenue (log)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>EPC (log)</strong></td>
<td>0.045</td>
<td>-0.260**</td>
</tr>
<tr>
<td></td>
<td>(0.091)</td>
<td>(0.101)</td>
</tr>
<tr>
<td><strong>Utility Cost (log)</strong></td>
<td></td>
<td>0.582***</td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
<td></td>
</tr>
<tr>
<td><strong>Property Care (log)</strong></td>
<td>0.542***</td>
<td>0.237***</td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
<td>(0.056)</td>
</tr>
<tr>
<td><strong>Vacancy Rate (%)</strong></td>
<td>-0.008***</td>
<td>-0.007***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td><strong>2007 (Yes = 1)</strong></td>
<td>Omitted</td>
<td>Omitted</td>
</tr>
<tr>
<td><strong>2008 (Yes = 1)</strong></td>
<td>0.225*</td>
<td>0.106</td>
</tr>
<tr>
<td></td>
<td>(0.125)</td>
<td>(0.117)</td>
</tr>
<tr>
<td><strong>2009 (Yes = 1)</strong></td>
<td>0.456***</td>
<td>0.211*</td>
</tr>
<tr>
<td></td>
<td>(0.129)</td>
<td>(0.127)</td>
</tr>
<tr>
<td><strong>2010 (Yes = 1)</strong></td>
<td>0.369***</td>
<td>0.106</td>
</tr>
<tr>
<td></td>
<td>(0.135)</td>
<td>(0.133)</td>
</tr>
<tr>
<td><strong>Age (log)</strong></td>
<td>-0.162</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>(0.163)</td>
<td>(0.176)</td>
</tr>
<tr>
<td><strong>Stockholm CBD (Yes = 1)</strong></td>
<td>0.785***</td>
<td>0.861***</td>
</tr>
<tr>
<td></td>
<td>(0.121)</td>
<td>(0.122)</td>
</tr>
<tr>
<td><strong>Stockholm Central Area (Yes = 1)</strong></td>
<td>0.497***</td>
<td>0.415***</td>
</tr>
<tr>
<td></td>
<td>(0.118)</td>
<td>(0.121)</td>
</tr>
<tr>
<td><strong>Rest of Greater Stockholm (Yes = 1)</strong></td>
<td>0.180</td>
<td>0.129</td>
</tr>
<tr>
<td></td>
<td>(0.125)</td>
<td>(0.125)</td>
</tr>
<tr>
<td><strong>Malmö (Yes = 1)</strong></td>
<td>0.188</td>
<td>0.134</td>
</tr>
<tr>
<td></td>
<td>(0.133)</td>
<td>(0.138)</td>
</tr>
<tr>
<td><strong>Gothenburg (Yes = 1)</strong></td>
<td>0.205*</td>
<td>0.162</td>
</tr>
<tr>
<td></td>
<td>(0.120)</td>
<td>(0.119)</td>
</tr>
<tr>
<td><strong>Other Major Cities (Yes = 1)</strong></td>
<td>Omitted</td>
<td>Omitted</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>4.359***</td>
<td>4.222***</td>
</tr>
<tr>
<td></td>
<td>(0.625)</td>
<td>(0.634)</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>0.884</td>
<td>0.908</td>
</tr>
<tr>
<td><strong>Adj. R²</strong></td>
<td>0.802</td>
<td>0.842</td>
</tr>
</tbody>
</table>

Notes: Gross Revenue is the independent variable and EPC is the key explanatory variable. Standard errors are in parentheses. For column (1), there are 676 observations; for column (2), there are 666 observations.

* $p < 0.1$
** $p < 0.05$
*** $p < 0.01$
Both column (1) and column (2) in Exhibit 4 show that the remaining explanatory variables that are statistically significant also have a sign that corresponds to our prior beliefs. For instance, costs for Property Care have a strong positive significant effect on gross revenues, while the coefficient for the Vacancy Rate variable has a strong negative significance. Furthermore, office buildings that are located in Stockholm CBD and Central Area earn a large gross revenue premium. The location variable Gothenburg is also positively significant, but is less statistically significant.

The regression results also show that when the Utility Costs variable is not included, the coefficients of all the yearly time dummy variables are positive and statistically significant. However, when Utility Costs are included in the regression models, only the 2009 time dummy variable becomes statistically significant. These changes in the estimated coefficients might be explained by the fact that both the time dummy variables, and the Utility Costs variable, capture the effect of changes in for instance energy prices and weather conditions.

**Summary and Conclusions**

Within the EU, as well as globally, energy efficiency has become one of the most important issues. As the built environment uses large quantities of energy, this sector has a great savings potential. To increase the public awareness regarding the energy usage of the built environment as well as energy-saving potential, the EU introduced the EPC. In addition, the EPC makes the energy usage figures visible and comparable all over the EU, reducing the information asymmetry. Still, practitioners need to gain better knowledge as to whether there is a relation between energy efficiency and economic performance, in order to evaluate energy efficiency. If an energy-efficient building can yield higher rental incomes, real estate owners will have a greater incentive to invest in energy efficiency measures in their existing buildings, as well as to evaluate energy efficiency in new construction. The impact of a superior EPC has been investigated in many parts of the EU. However, we are the first to investigate the impact of EPC on office income in Sweden. We create a unique dataset, where economic data on an asset level is matched with respective EPC. In all, the panel dataset consists of 269 building and 684 observations, covering the 2007–2010 period.

Our models incorporate the EPC as the key explanatory variable. The EPC is a measurement of a building’s energy efficiency, where a low EPC figure indicates an energy-efficient building. By and large, our results indicate that superior EPC ratings (i.e., low energy usage figures) have a positive impact on real estate revenues. However, the results are not as conclusive as one could expect. Since the process of EPC ratings has started rather recently, it may be necessary to study data for a longer time period and therefore further research is appropriate in order to estimate the effect of EPC on revenues more accurately.

This paper adds to the growing body of literature that examines the potential effect of energy performance on economic return. The results can be used as a basis for
commercial real estate owners when deciding on undertaking energy efficiency investments. In addition, this research can be used by regulatory authorities when they make evaluate measures that aim at reaching energy reduction targets in the built environment, which within the EU will be necessary in order to reach the overall energy efficiency target of a 20% (primary) energy reduction by 2020.

**Appendix**

**Variable Definitions**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Union (EU)</td>
<td>EU is a political / economic union between 28 European countries.</td>
</tr>
<tr>
<td>Energy Performance Certificate (EPC)</td>
<td>A report of a building’s energy performance, expressed as kWh / square meter (“A-temp”) / year. A low figure indicates an energy efficient building and is valid for 10 years. A summary of the EPC is displayed at a visible place in the building (e.g., in conjunction with the building entrance). Due to confidentiality, the EPCs in this study are rounded off to the nearest ten in this study.</td>
</tr>
<tr>
<td>Investment Property Databank (IPD)</td>
<td>IPD provides real estate indices and performance analysis for the real estate market. IPD is a part of MSCI Inc.</td>
</tr>
<tr>
<td>Gross Revenue</td>
<td>The rental income for the premises floor space as invoiced during the calendar year (ex. VAT and arrears / prepayments) and additional income for providing heating, water etc. In Sweden, the gross lease, in which utility costs are included, is quite common (Lind and Lundström, 2009). The Gross Revenue is normalized into Swedish Krona (SEK) per square meter (sqm).</td>
</tr>
<tr>
<td>Utility Costs</td>
<td>Costs that are incurred throughout the calendar year for heating, cooling, property electricity (normally tenant's business electricity is excluded), water and other utility costs (gross costs ex. VAT). These are normalized into Swedish Krona (SEK) per square meter (sqm).</td>
</tr>
<tr>
<td>Vacancy Rate</td>
<td>The property’s initial vacancy rate as of January 1. The definition is as follows: a percentage of a ratio between the rental income and the assumed rental income without any vacancies.</td>
</tr>
<tr>
<td>Property Care</td>
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<td>Age is the difference between time of observation and Construction Date. If the building has been redeveloped, the age is defined as the difference between time of observation and Redevelopment Date. Similar definition of age as (Leopoldsberger et al. (2011)).</td>
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<td>Construction Date</td>
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**Endnote**

1 *Atemp* = a measurement of floor area (in square meters) in temperature-controlled rooms that are designed to be heated to more than 10 degrees and limited by the building envelope.

**References**


The authors are grateful to the two anonymous reviewers, and editor Robert Simons, for constructive comments. Furthermore, the authors thank Christina Gustafsson and Erik Lagerström at IPD, as well as to Roger Antonsson at the Swedish National Board of Housing, Building and Planning, for providing data for this study. Finally, the authors wish to thank Professor Thomas Plümper for advice regarding the FEVD-model, as well as Professor Mats Wilhelmsson and Professor Hans Lind for insightful comments.

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Transpired Solar Air Collectors: An Energy Efficient Technology for Commercial Buildings

Authors
Stephen Sewalk, K. Sunny Liston, and Morteza D. Maher

Abstract
Buildings account for 41% of energy consumption in the United States. Eighty-five percent of this energy comes from non-renewable fossil fuels. There are several ways to use energy more efficiently and produce energy using renewable energy sources. In this paper, we examine three types of solar technologies—photovoltaic (PV), solar water heaters, and transpired solar air collectors (TSAC)—and then focus on TSAC. TSAC is an energy-efficient air-heating technology utilizing existing ventilation systems that is extremely efficient (60% to 80%) and has a payback period of 2–8 years based on a variety of variables. While a relatively new technology and best installations are in areas with cool weather but significant sunshine, given the relatively quick payback and the aesthetically pleasing designs, building owners should evaluate whether a TSAC system is viable option.

In 2011, the building sector (commercial and residential) accounted for 40.8% of total energy consumption in the United States, 44% and 36% more than the transportation and industrial/power sectors, respectively. Exhibit 1 illustrates the high levels of energy and power consumed by the building sector, accounting for 74% of all electricity produced and 40.8% of the total energy consumed (DOE, 2010).

Including hydropower, approximately 7% of the energy consumed by buildings in the U.S. originated from renewable sources, while over 85% of the energy and power consumed by buildings came from non-renewable fossil fuels, primarily coal and natural gas, with some oil (diesel) (EIA, 2013). The energy demands of the commercial building sector worldwide continue to increase due to more buildings and users with more computers and handheld technology. Combined with concerns for climate change (IPCC, 2013) and limits on power plant emissions (Weinhold, 2013), the increased energy demand will keep pressure on prices, particularly power in the form of electricity, as shown in Exhibit 2.

The U.S. Energy Information Administration (EIA) forecasts that energy costs will increase in the future. These increasing costs combined with the possibility of further legislation to limit greenhouse gas (GHG) emissions, which will increase energy costs, would highly encourage building owners and managers to seek energy efficiency savings, as well as alternative sources of energy. According to the EIA (2009), conversion losses from burning fossil fuels in power plants
combined with losses from carrying power over the centralized power grid, results in energy losses totaling 53%, purely due to inefficiencies. Once power arrives to a building, it is converted into heating, cooling, and light, further increasing these energy losses as HVAC, water heaters, lights, technology, refrigeration, etc. are less than 100% efficient. If buildings use power and energy more efficiently, this reduces the overall demand for energy and power, thereby reducing total system energy losses and therefore GHG emissions.

With increasing concern regarding our fossil fuel supplies combined with climate change, there is significant interest in alternative and renewable energies, in particular solar, wind, and geothermal. Solar is high on this list because of estimates showing that it has a very large potential, even after a 2013 study by Castro, Mediavilla, and Frechosso on the potential of solar electric limitations and the reduction of the potential on a scale of 4–10 times. The biggest challenge for
these renewable energy technologies is a combination of their cost and efficiency, which researchers are working hard to improve.

**Solar Technologies: Power vs. Heat**

In terms of solar technology, there are three primary alternatives: photovoltaics (PV) is best for generating power, while solar water heaters and transpired solar air collectors (TSAC) are better for heating.

**Photovoltaics (Power)**

While the concept of PV technology has been around since French physicist Edmund Becquerel (1839) discovered materials that could produce small electrical currents when exposed to light, and Albert Einstein (1905) defined the photoelectric effect, it was the aerospace industry in the 1960s that first used the technology. Since then PV has made strides in terms of efficiency with a recent record where new technology converted 44.7% of the sun’s energy into electricity (Valentine, 2013).

However, typical PV solar panels installed commercially on buildings only have an efficiency rate of 14% to 16%. In comparison, wind power achieves roughly a 30% efficiency and hydropower up to 90% efficiency (Valentine, 2013). In comparison, coal-based power plants are typically 32% to 42% efficient and natural gas power plants are 32% to 38% efficient, although some combined cycle plants can achieve efficiencies as high as 60% (Bellman et al., 2007). Exhibit 3 lists the energy conversion ratio (energy efficiency) of different forms of energy and includes transmission losses for power delivery to buildings.
Regarding PV, because of rebates offered by many utilities to meet renewable portfolio standards, state tax credits, as well as federal tax credits and incentives for residential consumers, this technology typically has a payback of 10–20 years. However, once all costs are accounted for (including subsidies), the payback period is typically beyond 20 years, outlasting the 20-year projected life of solar panels. These incentives, however, have stimulated the technology to advance and prices have continued to drop significantly and are down 99% since 1977 (Cameron, 2013). Exhibit 4 shows the effect these incentives have had, as well as the cost reductions, with the increasing number of solar PV installations in the U.S.

### Solar Water Heaters (Heat)

Solar water heaters use sunlight to heat a liquid to provide heating and hot water. Water is typically used, however, as this involves outside piping exposed to the environment, in colder climates anti-freeze is added to prevent the pipes from freezing. The Carter Administration installed this technology on the White House, using 32 panels to heat water in June of 1979 (Biello, 2010) in reaction to OPEC I/II and runaway energy prices. Conceptually easy, this requires significant installation work, making it much more costly than PV. With the advent of hybrid water heaters, which take warmth from the air to heat the water, this technology is now outdated (Holladay, 2012; Wilson, 2012) and not cost efficient.

### Transpired Solar Air Collectors (Heat)

TSAC is a passive solar technology used to pre-heat ventilation air in commercial, industrial, military, and multi-story residential structures. In comparison to PV,
TSAC systems are 60% to 80% efficient, which makes a significant difference in terms of payback. The design is straightforward. In the Northern Hemisphere, a large, dark, perforated corrugated metal (or plastic) plate is installed on a south-facing wall over the building’s ventilation intake system. The metal collector plate is passively warmed throughout the day by diffuse and direct solar radiation. Ambient air drawn through the perforated collector plate and into a plenum void space between the solar collector and the building’s exterior structural wall and as the air travels through the plenum, it is heated by up to 40°F Fahrenheit and the warmed air is then drawn into the building as fresh ventilation air. It is important to note, that collectors installed in the Southern Hemisphere are on north-facing walls. Exhibit 5 displays two different installation techniques for the transpired solar collectors: rooftop and wall.

According to Evans (2013), TSAC is the world’s best-kept secret, as it is a valuable tool to assist building and facilities managers to decrease their buildings’ net energy consumption. The technology is relatively recent. Patented in 1984, the invention uses solar radiation to heat the air in a controllable cycle (Canadian Patent CA 1179565). The first installation occurred in 1990. Although the technology is in many countries, it is under-used compared to other renewable technologies, including PV, wind, and heat pump installations. Unlike PV, TSAC does not produce energy or power, which makes it more difficult to track and compare to PV. Also TSAC installations pre-heat air, making a building more
Transpired Solar Air Collectors

Exhibit 5 | Transpired Solar Air Collector System


energy efficient. Solar Wall, the owner of the Canadian patent, claims 96 total projects to date, 42 in Canada and 30 in the U.S., with most of the remainder in France, Germany, and the United Kingdom and other companies who license the technology, claim similar numbers of TSAC installations. M&S in the U.K. added a very large SolarWall transpired solar collector measuring 46,651 ft$^2$, equal to $8/10$s the area of a football field or more than 16 tennis courts in size. This system produces 1.1 GWh of power, reducing carbon emissions by 250 tons (Evans, 2013). TSAC and PV are complimentary and proposals exist to combine them as solar co-generation.

Of the approximately 40 quadrillion BTUs of energy consumed in residential and commercial buildings, 30.7% and 14.2% respectively, or 9.27 quadrillion BTU (2005), is used to heat these buildings because people need to feel comfortable in their work, shopping, and residential spaces. According to ASHRAE Standard 55, the temperature of the air in a building should be 68°F to 74°F during the winter to create the perception the building is a comfortable place to work (TSI Inc., 2007). Transpired air collectors serve to passively pre-heat ventilation air by up to 40°F, without using electricity or gas, thereby reducing the above-stated energy demands (DOE, 1998). These devices also serve to reduce the amount of energy used for space cooling; however, cooling energy savings are minimal and therefore not examined in this paper.

TSACs work most efficiently in cold climates with lots of sunshine. Whereas geographically the U.S. has relatively strong solar radiation, the transpired solar air collector system works most efficiently in locations where it can heat a
significant portion of the air coming into the building. Exhibit 6 shows the average winter temperatures for the 50 U.S. states (Current Result Nexus, 2013).

**Materials**

The materials used to build PV systems compared to TSAC systems are quite different. The traditional PV system uses silicon materials; although they are inexpensive, these PV systems are not very energy efficient (14%–16% range). Newer technologies focus on gallium materials (with indium and copper) and it is possible to achieve 20% energy efficiency. Using a combination of arsenide (poisonous), gallium, and germanium, a record of over 44% energy efficiency has been achieved. The challenge is that silicon is widespread and easy to find (sand), while many of the other materials (minerals) come from the “rare earth” metal category. From the 1960s to 1980s, a mine in the Mojave Desert of California produced most of the world’s rare earth metals. Due to economic (China) and environmental challenges, the mine closed in 2002. As a result, today China supplies 90% to 97% of the world’s rare earth metals (Jones, 2013). In 2011, China imposed export restrictions on rare earth metals, which sparked concern about the availability of rare earth metals and led the U.S., European Union, and Japan to lodge a complaint with the World Trade Organization (WTO), as Chinese export restrictions could severely limit their abilities to manufacture advanced PV systems, among other goods (Cho, 2012). This also created concerns that lead to new energy security questions (Lydersen, 2012), particularly for the EU, since it is on a path to reduce GHG emissions and shortages of rare earth metals could prevent it from achieving its energy goals (Hall, 2013). A result of this shortage has been to promote technological innovation in an attempt to replace the rare earth metals with materials that are more commonly available (American Chemical Society, 2012), and while these technologies are still developing, TSAC can use aluminum, copper, steel, and even styrene plastic (Gawlik, Christensen, and Kutscher, 2005). However, while TSAC systems are much more efficient than PV systems (60%–80% vs. 14%–16%), they are complimentary, with TSAC providing heat and PV being best for electricity and lighting.

**Literature Review**

In order to understand how to create an energy-efficient building, it is necessary to understand the literature for building efficiency. We discovered that there are two distinct sets of literature that have not been previously combined in any journal article, and an in-depth discussion tying these together could in and of itself make for interesting reading. As our goal is to lay the foundation for TSAC systems, we provide a short in-depth review of the research that has occurred in these distinct areas.

The first set of literature examines alternative energy systems and the sustainability of buildings by examining the economics, energy efficiency, implementation, and potential tax incentives/strategies of making a building greener. The second set of literature takes a technical perspective, examining technology and challenges
### Exhibit 6 | The Best U.S. States to Install Transpired Solar Air Collectors

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The Best U.S. States to Install Transpired Solar Air Collectors

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Notes: The source is Current Result Nexus (from NOAA) Showing average winter temperatures over 30 years. In Alaska, a TSAC will not work during the winter months due to the lack of sunshine; however, transpired solar air collectors do an excellent job during the spring, fall, and even summer seasons. The states in dark gray can use solar air collectors approximately 5–8 months a year; however, during the winter the solar air collector needs to work with gas or electric heat, as the temperature difference between ASHRAE’s indoor air comfort level and the outside air is greater than 40°F. The light gray states can successfully use solar air collectors to heat the air 3–6 months a year and rarely need to rely on backup sources for additional heat. Florida and Hawaii are not good locations for TSAC, but are excellent for solar PV.

Within the real estate literature, many areas of energy efficiency, greening buildings, and sustainability have been reviewed; however, no paper has focused on transpired solar air collectors. Binkley (2007) and Naucler and Enkvist (2009) linked green real estate improvements and carbon emission reductions to commercial real estate. In another stream of research and policy, researchers identify and address energy efficiency potential, examining building performance and possible energy conversion in the commercial building sector (Ashford, 1999; Houvila, Ala-Juusela, Melchert, and Pouffary, 2007; Llewellyn and Chaix, 2007; Nelson, 2007; DiBona, 2008; Fuerst and McAllister, 2008; Miller, Jay, and Florance, 2008; Eichholz, Kok, and Quigley, 2009). Commercial buildings and their related emissions and potential improvements have also been studied by international organizations such as the United Nations Foundation, in 2007, and
the World Business Council on Sustainable Development, in 2009, and support of energy-efficient investments through policy has been also discussed (Reed, Johnson, Riggert, and Oh, 2004). Binkley and Ciochetti (2010) evaluated the value added of potential carbon markets to investments in commercial building energy efficiency from the perspective of monetizing reductions in carbon emissions. The value-added potential when applied to TSACs shows that they tend to have a rapid payback period.

Warren-Myers (2012) conceptually assessed the green efforts of the leaders in the Australian industry to find the best name for the concept of green, resulting in the best practices of the management of sustainability. Warren-Myers has also found that 65% of the Australian Leadership in Energy and Environmental Design (LEED) practices focused on energy conservation methods. Some authors discussed the driving forces and policies affecting LEED buildings (Choi, 2010), while others evaluated the investors’ willingness to invest in LEED methods (Harison and Seiler, 2011). Harrison and Seiler found that investors in LEED projects believe that it is an uncertain investment with a relatively high capital requirement (US$100,000) and depreciation rates of 25% to 30%; however, investing in LEED programs depends on market conditions. Research by Addae-Dappah, Way, Dollah, and Foo (2010) revealed that the indoor air quality resulting from LEED solutions increased the value of the property by up to 3.85%, leading to an increase in the return on investments of up to 78.56%.

The second, more technical set of literature includes an examination of solar panel technical improvements (Biwole, Eclache, and Kuznik, 2013), as well as an analysis of the technological advancements in construction materials (Scrivener and Van Damme, 2004) and energy-saving devices, among them occupancy sensors and photocells (Fleck, 2009) to improve the technical energy efficiency of buildings. Researchers have examined the TSAC optimum ambient air velocity (Li, Karava, Savory, and Lin, 2013), the optimum hole dimensions, and arrangement, as well as the materials used to build these (Leon and Kumar, 2007). The National Renewable Energy Laboratory (NREL) has promoted technological advances and implementations, encouraging the adoption of the technology, especially on government buildings (Kozubal, Deru, Slayzak, and Norton, 2008). Hollick (1998) examined TSAC and PV technologies and the production of solar co-generation panels.

To make a more energy efficient, it is necessary that (1) the technology improve (and develop) to create equipment and materials to make energy-efficient technologies economical and easier to install in a building and (2) for governmental policies to encourage building owners to adopt and install these technologies in their buildings. This is very relevant to TSAC systems as the technology has become very user-friendly and can now enhance the architecture of a building. We also compare the economics of TSAC systems with PV systems to explain the advantages and benefits of this technology with a goal to increase adoption within the built environment.

TSAC, developed in the 1980s and first installed in 1990 in Canada, has been slow to be adopted outside of the U.S. and Canada. During the 1990s the
technology was installed in 24 commercial projects in Canada, six in the U.S., five in the EU, and one in India and Malaysia (DOE, 1998). This was a combination of new technology with unappealing visuals. It worked, but did not look good initially. While the technology continued to be incorporated into commercial projects in the U.S. and Canada, it wasn’t until 2002 when the EU adopted new energy performance standards to reduce the energy consumption of buildings that the technology began being adopted more readily in Europe (Brown, 2013). In 2006, a TSAC system was installed on the first industrial building in the U.K., and within six years, 16 more TSACs were installed (Brown, 2013).

Alfarra, Stevenson, and Jones (2013) conducted a survey to examine the architectural integration of TSAC systems. The survey focused on experts in the design and construction fields—the architects, engineers, and academics in over 73 countries. They found that respondents from Canada had a higher awareness of the technology, while those from the U.S., U.K., and European regions had a 50% lower awareness of the technology. Further, while 48.6% of the respondents were aware of the technology, only 1.7% considered themselves as “experts” or “knowledgeable” concerning how the technology worked. The study also showed that the clients were the most important stakeholder in the decision-making process.

The Federal Technology Alert, which is a publication designed to facilitate the adoption of energy efficiency, identifies user acceptance as the biggest hurdle to the adoption of TSAC technology; in particular, they state that the main issue with the adoption has been the stigmatization of poorly designed solar systems from the 1970s and 1980s. Early designs of TSAC systems were cumbersome, limited to installations on south-facing walls, and had poor aesthetic characteristics, all of which contributed to the slow adoption of the technology (DOE, 1998). As the technology evolved, applications that allow for a roof installation instead of a south-facing wall installation have addressed the aesthetic concerns of architects and their clients; with a strong preference for the roof installation over the façade installation for domestic buildings.

The EU adoption of the energy performance of buildings directive has a goal of reducing the dependency on energy and the emission of GHGs through a reduction in the energy consumption of buildings (Ekins and Lees, 2008). As part of this directive, buildings in Europe are required to employ renewable energy systems to offset the use of fossil fuels in space heating, and by 2020, the EU will require that a building built within its region be a “nearly zero energy consumption” building (Kalogirou, 2013). This directive, in part, has led to an increase in adaptation of TSAC systems in Europe and combined with improving aesthetics and efficiency, implementation of the technology in the EU is increasing.

**Benefits**

To be comfortable, people need a warm space to work and live, which requires heating, and by pre-heating ambient air before it enters a building, this results in reduced consumption of electricity and fossil fuels to heat air. Reduced energy
Different studies have provided ranges for estimated payback periods and NREL estimated a payback period of 3 to 12 years in its 1998 report (DOE, 1998). In a study by Brown (2009), using U.S. Air Force installations, demonstrated a payback range of 4 to 14 years, and Hall, Wang, Ogden, and Elghali (2011) in a U.K. based study calculated the payback range to be 2 to 12 years. At the time of the NREL study, the cost of installation of TSACs was $10 to $12 per square foot for retrofitting and $5 to $7 per square foot for new installations. The study further showed that the TSAC’s costs could be broken down to 60% for materials and 40% for labor and overhead costs (DOE, 1998). A TSAC system’s costs are highly susceptible to the costs of raw materials, particularly aluminum, as the system relies heavily on aluminum forms; however, with innovations the materials used to produce TSAC units has changed. This innovation has come about because of rising aluminum prices, as seen in Exhibit 7.

While U.S. labor costs have increased around 20% from 1998 to 2013, the recent recession has held wages down. Exhibit 8 shows U.S. labor market costs.

These same wages apply to other alternative energy sources and while labor installation is a large factor, TSAC systems are cost-competitive. We contacted SolarWall Inc., the patent owner of the transpired solar air collector, to get updated installation costs and per their recent RFI, a retrofitted installation now costs approximately $25 to $30 per square foot, while a new installation costs $20 per square foot for existing customers (M. Maher, personal communication, April 30, 2013).

Although material and labor costs have increased resulting in rising prices for these systems, and consequently, longer payback periods, other parameters have
helped to shorten the payback period. Over the past two decades, significant research and development has occurred, leading to increasing the efficiency and workability of TSACs. It is now possible to install these systems on rooftops, whereas originally there were solely designed for wall installations. Research has also progressed concerning air velocity in the plenum space, porosity of the metal sheet, optimum solar radiation, and thermal emissivity and optimization (Leon, 2007). Further metallurgical research has occurred to make the transpired air collectors lighter, adding to the aesthetics of these systems (Chan, Riffat, and Zhu, 2010).

As energy costs increased (especially in the 2000s) and as TSAC systems are an energy conservation technology, cost savings from reduced energy consumption have increased. The EIA conducts independent research on the use of, and forecasted use of, energy for the U.S. government, the public, and the environment. The 2013 energy price projection is based on forecasts of energy prices for 2014 to 2040. We include 2010 energy prices as a guide. The cost of energy is anticipated to increase in real terms by 14.32% (4.13% from 2010) for electricity to 76.08% (105.53% from 2010) for residual fuel, and by 52.47% (58.03%, 2010) for fuel oil, and 41.79% (7.63%, 2010) for propane (EIA, 2013), as shown in Exhibit 9. Natural gas, which is a main source of space heating fuel for the commercial sector, could experience a price increase of 60.21% (40.53%, 2010) over this period. Note, these are delivered costs to commercial enterprises, which includes transmission and distribution costs, these are not the costs of the raw materials traded on the commodity exchanges. Increasing energy costs (or costs applied to emissions) shortens the payback period for energy-efficient technology, such as TSAC.
### Exhibit 9 | EIA Energy Prices, Actual and Projections for the U.S. (2010–2040)

<table>
<thead>
<tr>
<th>Year</th>
<th>Propane</th>
<th>Distillate Fuel Oil</th>
<th>Residual Fuel</th>
<th>Natural Gas</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>17.537</td>
<td>22.197</td>
<td>13.277</td>
<td>8.104</td>
<td>27.734</td>
</tr>
<tr>
<td>2040</td>
<td>25.943</td>
<td>33.738</td>
<td>23.411</td>
<td>13.213</td>
<td>31.747</td>
</tr>
</tbody>
</table>

Projected % Increase

<table>
<thead>
<tr>
<th>Year</th>
<th>Propane</th>
<th>Distillate Fuel Oil</th>
<th>Residual Fuel</th>
<th>Natural Gas</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014–2040</td>
<td>41.79%</td>
<td>52.47%</td>
<td>76.08%</td>
<td>60.21%</td>
<td>14.32%</td>
</tr>
<tr>
<td>2010–2040</td>
<td>7.63%</td>
<td>58.03%</td>
<td>105.53%</td>
<td>40.53%</td>
<td>4.13%</td>
</tr>
</tbody>
</table>


While increasing energy costs (or costs applied to emissions) shortens the payback period, note that even if costs do not rise as the EIA is predicting, TSAC systems provide rapid payback as illustrated in the examples that follow.

The TSAC payback period is directly dependent on the number of heating degree-days where the system is used and the actual payback period will vary. For instance, a manufacturing facility located in Allentown, Pennsylvania installed a 3,600 square foot retrofitted system in 2006, resulting in annual energy savings of $22,086. The payback period was less than 3.5 years. Greenwood Elementary School, also in Pennsylvania, installed a 730 square foot system on its façade in 2008, saving $2,553 per year, resulting in a 5-year payback period on investment. The payback period is dependent on three key parameters: (1) the number of hours the system operates, (2) energy prices (Riegger, n.d.), and (3) the availability of state and federal tax credits. For example, the state of Oregon calculates that based on available tax credits and accelerated depreciation, the payback period for a TSAC system is less than 4 years.

In addition, environmental regulations aiming to decrease the carbon footprint of buildings and facilities would also play a significant role in the economics of TSACs. Both the federal and state governments provide different incentives to support the greening of buildings and policies such as tax incentives. Further, if the U.S. adopts a carbon tax or cap-and-trade system, this would incentivize investment by shortening the payback period. The Pennsylvanian projects, the
manufacturing facility and the school, reduced their GHG emissions by 49 tons of \( \text{CO}_2 \) and 9.5 tons of \( \text{CO}_2 \) annually, respectively (Riegger, n.d.). As in Binkley and Ciochetti (2010), if we were to apply a price of $50 per ton of \( \text{CO}_2 \), this would result in a gain (if traded) or savings (if payment were required) of $2,450 and $475, respectively, per year. This would translate into an additional 11.1\% and 18.6\% savings, respectively, reducing the payback periods to 3.1 and 4.1 years, respectively (from the original 3.5 and 5 years). Increasing environmental regulations promoted by the EPA combined with concerns about global warming will make TSACs even more profitable for building owners. The rate of return on unglazed solar collectors has been shown to have an inverse correlation with the cost per square foot of the absorber collector place, as the cost of the collector drops, the IRR increases exponentially (Kozubal, Deru, Slayzak, and Norton, 2008).

One of the biggest challenges for building efficiency is the building envelope. During the course of a cold day, a building loses its heat due to the conductive transfer through the walls. A properly installed TSAC improves a building’s energy efficiency by capturing this lost heat in the plenum void space between the collector and the structural wall (Christensen, Hancock, Barker, and Kutcher, 1990). This lost heat helps the collector plate to preheat the ventilation air drawn into the building. This transfer requires no additional supplied energy and generates no harmful byproducts. Effectively the TSAC in combination with the walls results in an increased R-value, which is the measure of thermal resistance that is used in the building industry to measure the insulation efficiency of building materials; a higher R-value signifies a more energy-efficient building. Where the R-value measures the overall heat transfer coefficient, this is used to describe the rate at which heat transfers through one square meter of a structure to the outside; the higher the value, the higher the level of insulation, equating to higher energy efficiency. The U-value is the inverse of R, where \( U = \frac{1}{R} \); U is most typically used for windows and R is used for all other building materials.

A TSAC system uses the heat from the sun, as well as heat transferring through the walls, to heat the building, thereby creating a very energy-efficient building. In essence, this system takes the R-value of the wall or roof (wherever it is installed) close to infinity or the U-value equivalent close to zero, as heat is recycled into the building through the TSACs during heating seasons. A TSAC system designed into a building would allow a building to achieve a higher energy efficiency rating. The International Energy Conservation Codes, updated every three years, are illustrated in more detail in Sewalk and Throupe (2013). Different states have adopted different versions of the International Energy Conservation Codes that codify the level of insulation required in walls, ceilings, and other building components. These Codes dictate the energy efficiency a building needs to incorporate when being built. Exhibit 10 is a display of a TSAC system.

TSAC systems are virtually maintenance-free as the only moving components consist of the fan to draw the ambient air through the collector plate. Once installed, they replace one of the most significant energy uses in buildings, that of space heating, reducing both energy usage and the release of \( \text{CO}_2 \) emissions.
More significantly, research shows that worker performance and efficiency is impacted by the building’s ventilation rates. In a study conducted in a commercial telephone call center, workers performed most efficiently when ventilation rates were at their highest (Federspiel et al., 2002). As TSACs have proven to deliver increased ventilation rates, they also improve worker performance; this further increases the return and reduces the payback period. In addition, this improvement in performance leads to higher worker retention, as better-ventilated buildings tend to be healthier buildings. Higher worker retention reduces the cost of hiring and training new people; while outside the scope of this paper, we propose that additional research be undertaken to quantify the exact relationship between the addition of a TSAC system and overall worker performance and how that affects the bottom line.

Kozubal, Deru, Slayzak, and Norton (2008) noted that because of the preheated ventilation air that a properly designed and installed TSAC provides, building designers might be able to reduce the size of HVAC equipment. Reducing equipment sizing provides added cost savings during the building’s construction and savings in facility maintenance costs. However, this needs careful examination because while it is enticing to building owners and managers, it is important to note that decreasing HVAC equipment size could have a negative effect on the benefits of the increased ventilation rate they afford. If building designers downsize HVAC equipment, they need to do so without losing the previously defined benefit of increased productivity of workers, suggesting prudence when making the decision of whether or not to downsize HVAC equipment.

**Challenges**

Surprisingly there are few challenges and many benefits to installing TSACs. Originally, the technology had significant room for improvement both schematically and aesthetically. Visually speaking, many building owners and tenants may find that having a large, dark corrugated metal apparatus on their
Building designers have worked effectively to make this technology architecturally appealing, as seen at http://solarwall.com/en/home.php, with additional photos of several installations. The technology is elegant and surprisingly energy efficient.

From a design standpoint, the TSAC is most efficient installed vertically on a south-facing wall. Research modeling has shown that under normal operating conditions, approximately 62% of the final temperature rise of the air occurs on the front surface, 28% in the hole, and 10% on the back of the plate (Van Decker, Hollands, and Brungren, 2001). Potentially this means that the plenum, which is the area behind the plate, could be minimized or even eliminated, allowing for better design configurations. Solar plate collectors’ efficiency can be increased if their tilt is no longer limited to a 90° angle. The collector plate’s efficiency increases if designers can decrease the vertical angle, allowing the device to tilt more towards the sun. The challenge is that this minimizes their potential...
installation on vertical walls. However, as a test of a possible solution to this efficiency obstacle, researchers developed a prototype and then installed it on a Walmart rooftop in Aurora, Colorado (Kozubal, Deru, Slayzak, and Norton, 2008), decreasing its vertical angle to approximately 60°, allowed for solar radiation collection optimization. Further studies are needed on this design concept to address factors including wind effects and the loss of the heat recapture benefit from the walls; however, as heat also escapes through the roof, this loss might be offset.

Current Additional Uses

There are many uses for TSACs, including using them for agricultural purposes with large passive solar collector plates used for crop drying efforts (Njomo, 2000) and more recently, to increase ventilation rates using unglazed solar air collectors in buildings where livestock are held (Conserval Engineering Inc.). An additional potential untapped market for unglazed solar collectors is the preheating of ventilation air for theaters and other structures with high ceilings. Building with high ceilings, for example, present an unusual problem caused by air stratification. This problem requires an HVAC system to use more power to heat the lower levels, as the high levels are losing the heat energy through structural convection. Although this issue has been solved in commercial structures such as General Motors’ battery plant (DOE, 1998) and Boeing’s industrial plant (Conserval Engineering, Inc.) in Canada, this required foresight in the planning and construction of the facilities. Further research and development efforts are needed to determine how best to address existing structures built without incorporating this technology in their planning when retrofitting them.

Further Research

Research is currently being conducted at NREL regarding the use of low-conductivity materials such as styrene and polyethylene to construct collection plate absorbers. These low-cost materials may be used in lieu of high-conductivity metals that are prone to corrosion (Gawlik, Christensen, and Kutscher, 2005). If lightweight, flexible collector plates can be manufactured, this could increase their use in a variety of mobile functions including manned space exploration, frontline military applications, and anywhere that portable space and ventilation heating are required. As the architectural designs become more appealing, this technology could potentially be installed en masse on many buildings, leading to efficient applications for residential buildings where smaller footprints are appreciated and better rooftop applications for commercial buildings with limited footprints in cities.

Hybrid versions of transpired air collectors are also in development where PV cells are installed on the collector plate for PV/TSAC systems (Joshi and Tiwari, 2007), which seems to further increase PV efficiency as the TSAC removes heat from the PV system. The opportunity to combine technologies, such as PV, with a TSAC and potentially small wind turbines should be examined to increase the
overall energy efficiency of buildings by using smaller spaces such as roofs to more efficiently collect energy for a building.

**Conclusion**

The transpired solar air collector is a simple technology that can significantly increase building energy efficiency and therefore needs to be considered in designing and retrofitting buildings. With plenty of potential applications for agriculture, military, and commercial use, the system is very cost effective; it requires low capital investment with a rapid payback typically measured in 2–4 years with tax credits and up to eight years without tax credits. TSAC can provide 50%+ of a building’s heating while making the building more energy efficient, reducing total electrical and heating demand, with the potential to also save money on HVAC systems if installation is planned prior to construction. TSAC systems have solid returns on investment, especially compared with PV and wind. They last as long as the building and are an environmentally-friendly technology that decreases dependency on fossil and non-renewable fuels. If all buildings in the U.S. incorporated TSAC, energy use would decline by approximately five quadrillion BTUs (5% of total U.S. consumption). Building owners, designers, and managers would be remiss in not considering the incorporation of a TSAC to decrease building operating costs and carbon footprint, with rapid payback periods in the 2–8 year range. With multiple materials in use to make TSAC systems today, these systems can enhance the aesthetic design and fit nicely with a building (commercial, residential or industrial), making it both energy efficient and elegant.

**Endnotes**

2. Id.

**References**


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Investigating Deep Retrofits for Toronto’s Financial District Office Towers

Author Alita Jones

Abstract In response to a perceived shift towards green building practices and an increased focus on energy efficiency in commercial office facilities management, in this report I examine the barriers and drivers related to deep retrofits for the purpose of developing recommendations for increasing the energy efficiency goals of future retrofit projects. Centered on the Financial District in Toronto, Ontario, I integrate the existing literature, interviews, and local case studies to indicate the current environment for whole building energy efficiency reductions. Recognizing deep retrofits as relatively new to the commercial real estate market, my ideas and recommendations include: corporate social responsibility reporting to build tenant demand; an easily accessible national energy labelling system; improving tools for benchmarking and industry knowledge; and providing innovative financial incentives.

In this paper, I investigate and assess the current business environment for commercial office tower deep retrofits in Toronto’s Financial District. The decision to research this topic stems from a perceived shift in the built environment towards green building practices, and an increased focus on energy efficiency in commercial office facilities management. Although there are many instances of sustainable practices and commercial retrofits around the world, this study was restricted to Toronto’s Financial District as a means to provide research specifically relevant to the Canadian building market.

By looking at deep retrofits, I examine the factors related to tower renewal, and explore the drivers and barriers for retrofit projects that have an articulated and substantial energy use reduction goal. In addition, three retrofit projects from Toronto’s Financial District have been examined to illustrate the current direction of retrofit projects and how they fit within the criteria for energy use reduction as defined here Trends were gathered from literary sources, personal interviews, and case studies, then analyzed with the goal of forming an integrated assessment of the primary drivers and barriers for deep retrofits. The data related to the case studies are focused on the aspects of the retrofit, without providing specific financial details related to payback.

The objective of the paper is to analyze trends and expert opinions regarding energy reduction drivers and barriers related to retrofits in the commercial real estate market, and to understand what the current environment is for pursuing
deep retrofits for commercial towers in Toronto’s Financial District. From this analysis, the goal of the research is to identify best practices or recommendations for increasing energy efficiency goals for future tower retrofit projects.

**Literature Review**

In reviewing the literature, the initial purpose was to establish a definition for a “deep” retrofit, and secondly to examine the current range of opinions on the drivers and barriers to whole building energy use reductions. As this is a relatively new topic of research, the majority of the literature is associated with government and independent research groups who have published white papers and conference proceedings. A secondary source of information comes from case studies of recent Toronto commercial tower retrofits, originating from the property owners and associated consultants. Finally, information from the City of Toronto and real estate management companies with a strong presence in Toronto were reviewed to get a broader sense of the current commercial property environment in Toronto’s Financial District.

Four sources in particular proved to be excellent resources of information on the topic of deep retrofits for commercial towers: Sustainable Development Technology Canada (2009), Smith and Lane (2011), B+H Architects (2012), and GRESB Report (2012). All four papers were developed by highly reputable organizations, and contain substantial content regarding specific data for Canada. Presenting a broad overview on energy efficiency and the Canadian commercial real estate market, these papers provided the literary baseline for this paper. The findings build on the existing literature by introducing current professional opinions from a broad base of practice, together with location-specific case studies, to indicate the current environment for deep retrofits in Toronto’s commercial market.

**Methodology**

The methods of research for this paper are literature review, semi-structured interviews with regional experts, and case studies. These methods are used to present a “holistic” picture of the retrofit practices in the Toronto’s financial commercial tower market.

Much of the current research and analysis involves a diverse range of specialties. The primary sources of information include the green building councils in the United States and Canada, the Tower Renewal Office of Toronto, and related North American government energy sites. These articles, presentations, and case studies establish the academic background for the study and a broader assessment of retrofit trends.

The majority of white papers and research presentations are based on data from the U.S. While some reports included data for Canada, the best source of regional information for Toronto was local professional organizations including the
Building Owners and Managers Association (BOMA) and REALpac. It should be noted that the literature review was focused on energy reduction through the retrofit of existing buildings, and not on the use of or outcomes related specifically to sustainable certification programs.

To provide specific regional data, 11 local experts from various building-related professions were interviewed. Prospective interview candidates were primarily identified through the Greater Toronto Area chapters of the International Facility Management Association and the Canadian Green Building Council, or through their connection to the case study properties. The interviews were semi-structured. Each interviewee was informed of the research objective and asked for their opinion on the primary drivers and barriers for deep retrofits for commercial towers. By interviewing experts from a variety of backgrounds, the research aims to encompass a broad perspective permitting the identification and assessment of trends or conflicts in the interview data.

To add a third dimension to the analysis, three Toronto Financial District commercial tower retrofit case studies have been reviewed, using both property specific interviews and publicly available data. Both the TD Centre and First Canadian Place represent large commercial properties that have undergone high profile and substantial retrofit projects completed (or near completion) in 2013. The State Street Financial building demonstrates a unique retrofit project which indicates the potential for deep retrofits on property revitalization. These case studies provide a snap shot of current retrofit practices and highlight the impacts of deep retrofit drivers and barriers in real application.

**Discussion and Analysis**

**Defining a Deep Retrofit**

Many facilities undergo substantial retrofit projects at some point. While every building is different, and there are many reasons for undertaking a retrofit, most retrofits are undertaken for one or more of the following reasons: property renewal for tenant retention, upgrading or replacement of failing systems, or increasing the facility’s asset value (Neate, 2013). A reduction in energy use is a common result of modernization retrofits, and new equipment and systems may be selected with energy efficiency as a key consideration. A deep retrofit is characterized by the inclusion of energy reduction as a primary goal for the project and is measured by the level of verified whole building energy savings achieved compared to the pre-retrofit baseline (Liu, et al., 2011).

The U.S. Department of Energy (DOE) estimates that buildings are responsible for 40% of national energy use and 38% of greenhouse gas emissions (Vanderpool, 2010). Furthermore, of the 40% of energy use from buildings, 17%–18% of that amount is specifically attributed to commercial buildings. Canadian statistics demonstrate similar trends: Sustainable Development Technology Canada (SDTC, 2009) reported that energy consumption in Canada increased by 27% between 1990 and 2005. It has also been estimated that commercial buildings account for...
14% of end-use energy consumption in Canada. As a result, the SDTC, along with a number of reports for the U.S., target energy reduction in commercial buildings as a key strategy for reducing overall energy consumption over the next two decades. In response, deep retrofits have been explored by a number of agencies as an important strategy for reducing end-use energy consumption in existing commercial buildings.

There is currently no universally or even broadly accepted definition of a deep retrofit. Liu, et al. (2011) define a deep retrofit as one achieving a 45% energy savings, Smith and Bell (2011) describe a deep retrofit as a retrofit that results in a 30%–50% energy savings, and Vanderpool (2010) uses a 25%–50% energy reduction as the deep retrofit goal. While overall definitions for deep retrofits ranged from 25% to 75% reductions, the majority of literary sources focus on the 30%–50% range for energy reductions. For the purposes of this paper, a deep retrofit is defined as a project that uses integrated building strategies to achieve a 30% or greater reduction in whole building energy use reduction compared to the pre-retrofit baseline. The overall retrofit project should include defined goals, the benchmarking of baseline energy use, and verified measurement of the energy use reduction on completion.

One of the defining aspects of a deep retrofit is the consideration of the whole building during project planning to maximize energy savings. Whole building retrofits generate the best overall results, potentially allowing increases in insulation, upgrades to windows and façade materials, and new control systems to reduce the loads on HVAC systems and decrease lighting needs (Liu, et al., 2011). The combination of strategies and the ability to leverage benefits between systems is the primary benefit of proceeding with an integrated energy reduction plan. Relatively easy changes with fast paybacks can be used to offset the higher costs associated with replacing critical equipment or upgrading major assemblies (Lockwood, 2009).

A deep retrofit is considered to work best when planned in tandem with a critical replacement point in a building’s lifecycle. At this point the building owner can take advantage of planned capital upgrades or major system replacements to get the best value from the retrofit (Liu, et al., 2011). Opportunities for deep retrofits should also be considered in the event of major occupancy changes, regulatory required upgrades, or sustainable certification. However, the focus of a deep retrofit may differ from that of a certification strategy, where some reduction of energy use is typically required, but the whole building energy reduction may be much lower than 30% from the baseline. Kok, Miller, and Morris (2012) noted that most respondents to a survey on LEED Existing Building retrofit projects indicated that they implemented “low hanging fruit,” such as lighting, HVAC, and water fixtures, with less than 10% addressing insulation or windows. Though this type of strategy addresses the needs of the certification program, it does not use the whole building approach to achieve the more substantial energy reductions associated with deep retrofits.

**Commercial Office Towers in the Toronto Financial District**

Commercial buildings have been identified as substantial contributors to end-use energy consumption; it follows that cities with a significant inventory of
commercial office tower properties could play a substantial role in the reduction of greenhouse gases and energy use. B+H Architects (2012) identified over 20,000 commercial office buildings above 12 stories in Hong Kong, New York City, and Toronto. They reported that the majority of these buildings were built in the 1960s and 1970s, and many are now approaching a critical component replacement point in their lifecycle. This is supported by data from the SDTC that shows 52% of commercial buildings in Canada were constructed between 1960 and 1989 (SDTC, 2009), with the highest energy use intensity being found in buildings constructed between 1960 and 1969, as shown in Exhibit 1.

A sample of 60 commercial office properties from the downtown Financial District of Toronto gives a targeted picture of construction dates, as shown in Exhibit 2 (A full listing of the buildings sampled is in Appendix A.) As was seen with the national numbers shown in Exhibit 1, the majority of the Financial District towers in the sample were built after 1970.

REALpac (2010) reported similar energy consumption results to those of the STDC. Their results are from a survey of 261 office buildings, with 46% of the sample being located in the Greater Toronto Area. REALpac researched and published commercial office building energy intensity benchmarks as part of their initiative “20x15,” a joint project with the CaGBC promoting a 20% reduction in energy use (against 2010 as a benchmark) by the year 2015. When the project was being developed in 2009, the feedback from property owners and managers was that 20% reduction was an unrealistic target (St. Michael, 2013). The 2010 benchmarking information included area, occupancy, operating hours, and vacancy rates and provided a basis for comparison because the actual regional energy use was normalized for energy intensity and weather (REALpac, 2010). As shown in Exhibit 3 the normalized energy intensity was found to be highest for buildings
Exhibit 2 | Toronto Financial District Building Sample by Construction Date

Exhibit 3 | Average Actual & Normalized Energy Use by Building Age

The source is REALpac (2010).
constructed between 1960 and 1979. The same data set determined the Canadian current national annual normalized energy intensity to be 28.7 ekWh/ft²/yr, which is 13% lower than the average normalized energy intensity for 1970s buildings.

The growing number of commercial office tower properties in the Greater Toronto Area that are reaching a typical major renewal age makes the region a potential Canadian hub for achieving energy reductions through deep retrofits. Commercial office buildings in the Toronto region are responsible for consuming 37% of the region’s electricity, 17% of the natural gas, and generate approximately 20% of the total carbon emissions (Geller, 2011). The greatest density of these buildings is located in the downtown Financial District (Exhibit 4).

The “Toronto Skyline” represents the downtown prime commercial real estate market, with many of the office towers defined as Class AAA (Johansson, 2012). These Class AAA towers provide high material quality common spaces and access to transit or services, and command a rental rate threshold of $25 per square foot, with many charging $30+ per square foot. As reported by real estate specialist
company Jones Lang LaSalle, the Skyline market in 2012 consisted of 18 buildings, including landmark properties such as First Canadian Place, TD Centre, Scotia Plaza, and Royal Bank Plaza. The recent construction of new commercial towers has added competition to the Skyline market, with 2.2 million square feet of commercial space completed between 2009 and 2011, and another 1.6 million square feet to be completed by 2015.

On average, the new Toronto commercial towers have a 15% lower operating and maintenance cost compared to a Financial District benchmark (Johansson, 2012). In addition, sustainable certification has become standard for new construction, with many of the buildings featuring LEED or BOMA BESc certification, state-of-the-art technology, and enhanced occupant comforts such as increased daylighting. Aging assemblies and systems, along with competition from new Class AAA tower construction, are generating pressure on mature commercial towers in the Financial District to undergo facility revitalization for tenant retention and maintenance of property value.

**Drivers for Deep Retrofits**

Significant research and analysis have been devoted to the identification of the drivers most likely to result in energy use reduction. While there is no consensus on the key driver(s), a commercial properties survey report by Smith and Lane (2011) indicated that 80% of Canadian respondents considered cost savings to be the primary driver to reduce energy use. Respondents also placed a high value on enhanced public image and existing legislation when deciding to implement energy reduction projects. The key Canadian influences on company decisions resulting in energy efficiency decisions from the IBE survey are shown in Exhibit 5.

Other research has indicated that many Canadian commercial property managers consider reduced operational cost savings and increased asset value through reduced operational costs to be primary drivers for deep retrofits (Smith and Lane, 2011). Other primary drivers such as brand equity and tenant retention are not items that directly translate into accounting statements, although they do impact the overall financial value of a project.

When asked to give their thoughts on drivers for deep retrofits, the first response from research interviewees trended to two key considerations: tenant retention (meeting tenant demands and decreasing competition from new construction) and organizational values (particularly senior leadership on sustainability strategies). Tenants with strong corporate social responsibility (CSR) requirements, such as the Royal Bank of Canada (RBC), are demanding green building office space (Ouellette, 2013).

The 2009 survey from CoreNet Global and Jones Lang LaSalle, as referenced in a study for REALpac by Jantzi Sustainalytics, indicated that 70% of 231 commercial facility executives considered sustainability to be a “critical business issue today” (MacMahon, 2010). The Jantzi study noted that although 18
Canadian real estate companies participated in the benchmarking for the study, only four had published sustainability reports: Brookfield Properties, Oxford Properties, First Capital Realty, and SITQ.

Enhanced public image or brand equity as a primary driver was also recognized by a number of the interviewed experts, who noted that property management companies and real estate investment trusts (REITs) not only have recognized the value of sustainability to their brand marketing, but tend to be competitors in their operational strategies. Demonstrating industry leadership or operational firsts adds value to the brand and differentiates a company from its competition.

The fourth driver trend that emerged from the expert interviews is the increase in asset value through reduced operational costs. Love (2012) on behalf of the Energy Services Association of Canada indicated that major energy efficiency retrofits have an annual average return on investment (ROI) of approximately 22%, with a less than 10% rating on the risk index. Retrofits also have the potential to increase profits by 35% from reductions in operating costs, reduced recruiting costs, increased productivity, and brand equity benefits. Some of the potential for increased asset value comes from capital rate gains, while other financial benefits may be less directly linked. As an example, the retrofit project at First Canadian Place allowed the building management to hold the rent rate at under $30/square foot (McQueen, 2013). A number of studies from the United States and Canada support the potential financial benefits for deep retrofits, although the financial benefits are often placed on hold or passed over due to project barriers, such as project size or complexity (Katz, 2013).
The combination of aging facilities and increased competition from new construction is potentially creating an ideal environment in the Toronto Financial District for the implementation of deep retrofits. The conditions of the commercial real estate market in this district correspond to three categories of drivers for retrofit projects: (1) physical drivers including lifecycle replacement, reduced risks associated with failing assemblies or systems, and the need for increased energy efficiency (B+H Architects, 2012); (2) financial drivers including tenant retention, property value, office classification, and brand equity; and (3) environmental drivers such as tenant demands, CSR reporting, and investment, occupant productivity, or regulatory changes. These three categories of drivers do not specifically lend themselves to pursuing energy use reductions of 30% or greater from the baseline as a target goal of the retrofit project, although they can contribute during the initial evaluation and decision-making process to the inclusion of projects in the retrofit that may result in significant energy use reductions.

Given the importance of environmental drivers, strategies to enhance their effectiveness are crucial in exploiting the potential of Toronto’s Financial District to become a leader in commercial tower energy use reduction. Currently, CSR reporting and investment are key drivers in energy reduction programs, and the research indicates that CSR programs run by managers and major tenants of the towers are having an impact on energy conservation programs. As well, CSR requirements are a driver for tenants, who are demanding sustainable office space. For example, the Toronto Dominion (TD) Bank has a commitment to become carbon neutral and, while their current strategy includes using carbon offsets to achieve this goal, there is a shifting focus towards increased use of reduction strategies (Love, 2013). At the TD Centre (a Cadillac Fairview property) building management has incentivized goals at a corporate level, which are annualized per property, including energy use targets, energy reduction planning, and energy management programs (Hoffman, 2013a).

Similarly, Oxford Properties is working to align its sustainability objectives to support the increasing CSR requirements of their tenants (Oxford Properties, 2013). In addition to annual energy reduction targets and internal sustainability strategies, Oxford is working towards the implementation of green leases for all new office or retail tenants and establishing joint landlord-tenant engagement teams across their portfolio by the end of 2013.

Civic programs can also promote energy reduction. The “Race to Reduce” was started by CivicAction in 2011 as a challenge to reduce total building energy use by 10% over four years (Geller, 2011). It is a program that capitalizes on public image as a driver that reaches both landlords and tenants.

The literature and interviewees acknowledge the importance of regulatory or voluntary schemes that require or encourage standardized energy usage and CSR information to be made available to tenants, building owners, and the public. In Canada, CSR and energy reporting are relatively new activities within the real estate industry (Neate, 2013). Management companies are evolving in their integration of sustainable practices in the real estate investment market. In the
In the GRESB (2012) report, the majority of respondents who were collecting and reporting energy use data reported on less than 50% of their portfolio, and only 8% of respondents were able to obtain data on tenant energy use. Furthermore, only 32% had developed a sustainability performance plan with defined energy use reduction targets. These statistics indicate that CSR reporting may not be fully capturing energy reduction strategies, but note a promising trend as sustainability reporting on energy use numbers for 2012 had increased from previous years.

The GRESB (2012) report also recognized the importance of organizational values, noting that 70% of respondents surveyed considered sustainability to be the responsibility of senior management. According to the report, regular and frequent updates to the executives are an essential aid to accurate and timely decision making on sustainability. However, 12% of respondents only provided annual updates and another 17% provided no updates at all. For a property company or REIT to fully realize performance and operational financial benefits, there needs to be a sustainability vision and corporate strategy with targets and performance goals.

There is support in the literature, and among a number of the interviewees, for standardized commercial building energy use labelling. Five of the interviewees felt that building labelling of energy use could capitalize on concerns about brand equity and public image. In addition, the creation of a publicly accessible benchmarking and labelling standard would allow for office property comparison, increase transparency, and permit facility managers to see how their buildings perform against a defined benchmark or other neighboring properties (Theaker, 2013). This strategy could also act as a driver by giving tenants a metric by which to assess office lease options or apply to internal CSR goals and potentially become part of the standard due diligence when considering lease contracts.

An easily accessible national database for commercial buildings would represent significant movement towards the goal of increased transparency and benchmarking and would give building owners an opportunity to self-manage (Stoate, 2013). Currently, a number of individual professional organizations have started their own databases, with various levels of participation and accessibility. Cooperation between these professional groups to create a single body of knowledge would encourage and support the commercial real estate industry to pursue national benchmarking. Increased access to case studies, best practices, and lessons learned from all sectors of the industry would also improve peer-to-peer networking while building knowledge for owners and tenants. Finally, the introduction of a federal program of mandatory labelling would allow for consistency and equality across national real estate portfolios, making it easier for all stakeholders to evaluate properties.

Barriers to Deep Retrofits

As discussed in the previous section, the barriers to deep retrofits can be classified as financial, physical (including operations), and environmental. Although each retrofit project is unique with specific concerns and restraints, an analysis of the Toronto commercial property market indicates that competition for capital funds
and expectations for ROI, operational challenges, and executive buy-in are the four primary barriers associated with deep retrofits. These barriers must be addressed in order to meet the business needs of the occupants, management, and investors and to promote the goal of a 30% energy use reduction through whole building retrofits.

The low cost of energy was noted by a number of interviewees as being a fundamental issue in creating a weak fiscal connection with energy reductions. Government subsidies and the pricing model for energy in Canada makes energy relatively cheap (Theaker, 2013), and, with a typical lease structure in the commercial market, the energy use for common spaces and base systems only represents 15% of the overall operating costs (Hoffman, 2013a). The effect of the low cost of energy was clearly seen in the U.S. when, in 2008, an energy price spike increased the appeal of energy reduction to the U.S. commercial market (White, 2010). Uncertainty in the energy market also makes it difficult to produce accurate cost analysis over a longer period of time. Without a stable model for energy pricing, and increases to the overall cost of energy, energy will continue to be a secondary consideration for building retrofits (Lockwood, 2009).

Finances currently present one of the most significant barriers to deep retrofits. The traditional business model, which evaluates project viability on simple payback and competitive ROI calculations, does not readily support the slower returns and large initial costs associated with deep retrofits. Love (2012) reports that the key indicators for decision making on energy reduction retrofits shows capital availability, payback or ROI, project ownership, and split incentives as the top four barriers to deep retrofits. Smith and Lane (2011) report that key findings specific to Canada in 2010 survey indicate that “20% of respondents identified uncertainty around the savings or economics of projects as the top barriers limited by difficulty in finding projects with reliable results and acceptable levels of risk,” and 18% indicated a lack of buy in or internal champions for more energy efficiency projects. As illustrated in Exhibit 6, 30% of Canadian companies surveyed list the lack of capital budget as the primary barrier to deep retrofits (Smith and Lane, 2011). B+H Architects (2012) found that fewer than 20% of building owners used banks to finance retrofits, with most green retrofits funded by operational revenues. In another study evaluating the financial value of deep retrofits, competition for capital funds and low ROI were determined to be primary barriers to pursuing 30% or greater whole building energy use reduction as a key goal (Smith and Lane, 2011). These latter studies confirm the interviewees’ experience, which is that the key financial barriers for deep retrofits in the current environment are competition for capital and low ROI, not lack of capital.

Although the lowest cost way to borrow is to re-mortgage and use the equity, the traditional business case may not support using borrowed equity for retrofits when it could be invested in a higher value project, such as buying a new building. Specific to Canadian real estate investment market, there is a new trend since the 2008 recession for REITs to focus on acquiring U.S. properties for investment or resale purposes as a way to maximize on investment (Theaker, 2013).

Other financial barriers such as split incentives, uncertainty in returns, leasing terms, and low energy costs act as disincentives when assessing the business case
The source is Smith and Lane (2011).

for deep retrofits. Commercial office towers function as a valuable asset for the owner or management company. Their first obligation in decision making is to generate value for invested shareholders (Katz, 2013). The effect of split incentive was also noted by Kok, Miller, and Morris (2012), who observed that LEED-certified buildings that were energy efficient may have more energy savings than reported, but did not count those savings as they were accrued by the tenants.

Competition for capital is directly linked to the second key financial barrier: lack of ROI or payback. Expectations for ROI are determined internally to meet the requirements of the individual companies. Although these values can vary substantially, Lockwood (2009) found that 50% of commercial buildings require a simple payback of three years or better. A 10%–15% energy use reduction is more common for typical retrofit projects, and such an investment is more likely to achieve a payback in less than five years (Love, 2013). Therefore, capital projects or acquisitions that offer higher and faster ROI will often be cherry-picked over more complicated deep retrofits with a slower return (Sweatman and Managan, 2010). How the value of a deep retrofit project is assessed and the parameters for the business case are strongly related to the corporate vision and values of the management company (Smith and Lane, 2011).

Real estate investment is a business equation with the balance resting on how business wants to spend its capital resources. Preference is usually given to projects with a high ROI (Ouellette, 2013). Most deep retrofit projects have a 5–10 year payback, making capital investments in a new building more attractive for REITs and other investors. As well, investing in a new building is more
familiar for property management companies, and there is less uncertainty about planning and outcomes. Because financial drivers and barriers are so integral to the decision-making process for deep retrofits, it is necessary to examine in greater detail the market conditions and business factors that impact the financial viability of deep retrofits for commercial office towers in Toronto’s Financial District.

Michael Barker, President of Hope Beckwith Group, suggested that one must look at the asset class of the building, assess the options of borrowing versus equity, and then determine the impact on obtaining rents (Barker, 2013). If the property is older, with a high vacancy rate, and is located in a desirable urban area, a deep retrofit project makes sense as an option to raise the asset class and attract new tenants. As the common gross effective rent is usually a combination of the lease cost and the cost of use, reducing operating cost while maintaining gross rent will provide an increased profit for the building owner.

In the current economic climate there is a high level of debt capital loans available from banks and lending institutions. However, as much as 50%–75% of the loan rate may be based on the lease values, making it more difficult for a building with high vacancy to obtain favorable external financing (Barker, 2013). Upgrades to the building classification favor larger retrofit projects: an average urban district Class A tower is approximately $400–$500 per square foot in construction (hard), soft, and land costs or $250–$300 per square foot in hard costs. In comparison, deep retrofits are estimated to cost $50–$100 less than a new build. A successful financial case can be made for a deep retrofit in this scenario, particularly if there are no tenants or a low tenancy rate. If the building has tenants they must be relocated, or the cost of retrofit will increase due to such factors as premiums for late night work, and possible rent reductions or concessions for the duration of the project.

Another consideration when looking at the commercial office tower market is the nature of the ownership (Stoate, 2013). Common legal ownership arrangements include owner/operator, REITs, and property management companies. Each arrangement has its own specific economics, and usually an obligation to provide a reasonable return on investment to shareholders. However, all ownership arrangements benefit from a reduction of net operating costs: the reduction fundamentally increases the asset cap rate (which is expressed as a percentage of net operating income divided by the purchase price), and therefore increases the profitability of the building asset for the owner. A better cap rate translates into better loan terms and tends to extend the simple payback period that will still meet lender terms (Wisdom, 2012). A successful deep retrofit, where the estimated operating cost savings are achieved, will increase the owner’s equity and improve the value of the building for refinance or sale.

The potential to increase property class, tenant attraction, and equity value are all additional financial benefits to deep retrofits. Not only are these potential outcomes beneficial to assessing the value of targeting energy cost reductions, but they also assist in addressing competition for capital and lower ROI. While most retrofits maintain or add to the physical value of the building, a deep retrofit adds to the value of the building and reduces the gross operating costs, leading to an improved
stabilized baseline value (Wisdom, 2012). When assessing the cost of a deep retrofit against competing projects with a faster payback, the doubled value associated with energy use cost reductions may assist in presenting the financial case to executive management. The move from simple payback and discounted cash flow to a total value model of analysis can provide the needed motivation for decision makers (New Buildings Institute, 2013).

While deep retrofits can show a positive ROI, it is often difficult to attain the commitment to the funding levels needed for whole building renewal and increased energy reduction goals (Tower Renewal Office, 2011). To maintain cash flow and reduce the burden on capital or operating budgets, external funding can assist in a building owner’s ability to manage the initial costs of a deep retrofit. In examining financial models for deep retrofits, the Clinton Climate Initiative found that many financiers were uncertain of how to approach energy efficiency projects as an investment (Henderson, 2011). Lenders need security of repayment, standardization, and scalable investment opportunities. Uncertainty related to retrofit outcomes and future energy prices increase the risk associated with funding these types of projects.

In both the literature and interviews, two financing models are promoted as the means for funding deep retrofit projects, managing risk, and ensuring security of repayment: Property-Assessed Clean Energy (PACE) bonds and energy performance contracting. PACE funding is based on a municipality (or potentially a utility) providing the loan for retrofit projects with an energy reduction target above a specific level (Henderson, 2011). The loans are repaid over a longer term, typically 20 years, via an assessment on the building property tax or the utility bill. Under the terms of this kind of contract, the energy use cost savings pay for the loan and the payments transfer with the sale of the asset. As a condition of this type of financing, the PACE loan becomes senior to all other existing liens.

Under the pilot projects in the U.S., the benefits of PACE funding include providing security for the investments by removing the initial cost barriers (Henderson, 2011). As well, where the property tax assessments qualify as a pass-through expense, concerns about split incentives were reduced. Split incentive refers to the circumstance where the building owner bears the cost of the retrofit but the tenant gains the majority of the benefit associated with lower operating costs. By qualifying the tax assessment as a pass-through expense, the building owner can regain the costs through the common gross effective rent and the tenant still gains from reduced space metered utility charges.

In the U.S., PACE funding models have been piloted by utilities in Connecticut and California (Smith and Bell, 2011). The Tower Renewal Corporation (TRC) in Toronto is looking at this option for deep retrofits for residential tower properties as it would allow building owners to invest in their buildings without borrowing against their mortgages or reducing equity (Tower Renewal Office, 2011).

However, for this model to be used in Toronto, changes would be required to Ontario Regulation 594/06, which governs the creation of priority liens and property tax bill additions, and assigns the municipal assessment tax with priority...
lien status (Tower Renewal Office, 2011). The bank or mortgage holder has priority charge on the asset and will not welcome external encumbrances of relatively low value that could jeopardize the value of the building asset (Barker, 2013).

The second financial model, energy performance contract, centers on an energy service company (ESCO) or private contracting company carrying the design, financing, and implementation of the deep retrofit (White, 2010). The performance contract is repaid over a set period of time (typically 10 years) from energy use cost savings. The company that implements the improvements guarantees the savings on energy consumption and operations performance, which greatly reduces the risk for the building owner. ESCO acts as the team manager who collaborates with the owner, carries the most majority of risk, and provides capital and resources (Love, 2013). ESCO also provides the expertise and processes to deliver successful project outcomes. An additional advantage is that the model gives the building owner a single point of contact; if something goes wrong, the building owner does not have to chase after multiple contractors or spend time trying to identify the source of concerns. In Canada, energy performance contracts have primarily been implemented for MUSH (municipal/university/school/hospital) projects (Love, 2013). The contract model transfers the financial burden, the risk, and the technical expertise requirements to ESCO, which has been very attractive for institutional and government clients.

In buildings that operate on a triple net lease contract model, long-term anchor tenants could be the contracting agent to ESCO, using the guaranteed savings to lower lease costs and obtain additional financial gains (White, 2010). In an anchor tenant financing scenario, the building owner also benefits from building upgrades, which modernizes the facility and improves the asset value. The contract term can also be extended, so that guaranteed energy savings can be used to finance non-energy deferred priority maintenance projects.

Energy performance contracts have been in Canadian use since 1993, with over 90% of the market being represented by the eight founding ESCOs, which make up the Energy Services Association of Canada (Love, 2012). To date, very few commercial office projects in Canada have been completed with energy performance contracts, although the Toronto Atmospheric Fund (TAF) is now providing energy performance contracts for the smaller commercial market (Stoate, 2013). Tim Stoate, the Vice President of Impact Investing at TAF, emphasizes the high level of expertise that is required to successfully enter into this type of contract, which is usually detailed and extensive due to the transfer of risk to the contracting party. TAF only contracts with clients who have a very strong financial position. As a result, TAF does not place a lien against the property mortgage, which negates the issue of encumbrance on the primary mortgage holder.

Although the literature review on barriers for deep retrofits does not indicate that physical or operational barriers are primary disincentives, interview responses often referenced them as the primary limiting factor to retrofit activities. In particular, disruption to tenants becomes a key consideration when assessing the
Investigating Deep Retrofits

financial and environmental barriers. Simply put, according to the interviewees, the primary barrier to a deep retrofit is operational in nature.

A comprehensive whole building retrofit will not happen if the project requires vacancy because it is too difficult to move tenants and the risk of losing a tenant is too high. As retrofits usually occur while the building is occupied, there is a need for minimal tenant disruption. Activities deemed too disruptive to tenants, either due to noise or reduced access, cannot be pursued without strategies for tenant cooperation. In the case of the First Canadian Place retrofit, the glazing was not replaced as it was deemed too disruptive to the tenants, thereby limiting the opportunity for increased daylighting (McQueen, 2013). The TD Centre retrofit had labor crews removing perimeter office furniture and replacing it exactly each night as part of their glazing replacement plan (Knifton, 2011).

Both the interviews and the literature acknowledge the effect of physical barriers on a retrofit project. In addition to size, each building is uniquely structured and clad and presents new challenges for each retrofit project (B+H Architects, 2012). However, the physical concerns are not the primary barriers to deep retrofits, possibly because most retrofit projects are initiated in response to a need to replace or revitalize building systems and assemblies. Most envelop retrofits are driven by end of lifecycle, system failure, and tenant loss (Theaker, 2013). The owner is looking at the potential for lost revenue as a reason to initiate the retrofit and energy savings are a secondary bonus.

There are also post-retrofit challenges: the tenants need to understand the “how and why” of new operations, while building operators need training to use new technologies correctly (Lockwood, 2009). Many buildings with advanced technology have poor energy performance because the operators often use overrides to make the systems manageable.

Lockwood (2009) reports that lack of corporate or executive buy-in is the fourth largest barrier referenced by Canadian respondents. To overcome many of the perceived financial barriers, the executive management must fully recognize the potential benefits of significant operational savings. Business environmental issues related to low awareness, lack of knowledge on financing options, and traditional short-term investment criteria are contributing factors to reduced management support (Sweatman and Managan, 2010). Having strong policies and strategies for corporate sustainability, with clear reporting and assessment tools, is vital to driving energy efficiency performance (GRESB, 2012).

The impact of corporate buy-in is addressed by many of the interviewees, with 60% identifying corporate culture or executive support as the largest barrier (and potential driver) after competition for capital funds. The current executive inclination is to pursue projects with the fastest completion time and highest returns, with limited interest in pursuing energy reductions (Stoate, 2013). The reasons to pursue a retrofit are often not based on technical considerations but rather on the values of the company, where the value of a project is related to financial projections, social status, and competition (Theaker, 2013). In addition, the building manager may not be allocated extra time and resources for major
retrofits, if facility management is under-resourced then a deep retrofit means additional work and stress.

A building management company looking at a whole building retrofit must have the whole company behind the project and corporate commitment and executive buy-in is an essential component to the project’s success (St. Michael, 2013). There is a difference between belief and commitment, with a full building retrofit requiring a leap-of-faith and an analysis of the full project in light of the corporate vision and goals. If the executive management fully supports the goals of a deep retrofit, then the primary drivers for deep retrofits will be more likely to bridge the operational, financial, and environmental barriers.

Toronto Financial District Retrofit Case Studies

Case Study 1: TD Centre

The Toronto-Dominion (TD) Centre is a Class AAA collection of six striking modern black office towers. Gathered on a seven-acre site, the TD Centre also includes the TD Pavilion, multiple courtyards, and an extensive underground retail concourse, which is part of the Toronto PATH system (Cadillac Fairview, 2012). The original three towers were designed by architect Mies van der Rohe, including the 56 story TD Bank Tower (66 Wellington St. West), which opened in 1967, 46 story Royal Trust Tower (77 King St. West Tower), which opened in 1969, and the(Canadian Pacific Building (100 Wellington St. West), which opened in 1973. The other buildings were added over the next two decades, ending with the 95 Wellington Street tower, which was constructed in 1986 but purchased as part of TD Centre in 1997. The original towers are defined by sleek black steel and glass façades and clean modern interior common areas (Exhibit 7). They are unique structures that were designated as heritage buildings under the Ontario Heritage Act in 2003 (B+H Architects, 2012). This designation not only recognizes the importance of the buildings to the architectural fabric of Toronto’s Financial District, but also restricts changes that would impact the historical preservation of the towers.

In 2010, a $110,000,000 capital revitalization project was initiated by owner Cadillac Fairview Corporation for the Royal Trust Tower and TD Bank Tower (Cadillac Fairview, 2010). An envelope and systems retrofit project is part of an overall revitalization plan, designed to refresh the original architecture, enhance the public spaces, and provide upgrades to the retail levels. Physical aspects (B+H Architects, 2012) of the project include: (1) replacement of 5,676 windows (now double-paned with low e-glazing); (2) repainting of the steel façade; (3) elevator replacement; (4) new waterproofing under the plaza; (5) upgrades to controls; (6) improved fan efficiency; (7) full renewal of the lobby areas; (8) replacement of the lighting systems, (9) installation of roller blinds; and (10) changes to the perimeter induction units. Energy management consultants, Duke Solutions Inc., forecasts savings of $5,000,000 annually through energy cost reductions garnered from the upgrades to elevators, HVAC systems, and lighting systems (TowerWise,
The Duke energy management section of the project has a project cost of $33,000,000, with a payback period of 6.5 years.

In tandem with the physical changes, both buildings have been LEED Existing Building (LEED EB) Gold Certified and BOMA BEST Level 3 certifications.
Further sustainable strategies are addressed by the TD Centre’s “Green at Work” program, which targets annual reductions of energy consumption for a total of 15% by 2014 from the 2008 baseline, enrollment in the “Race to Reduce” challenge, and a custom occupant engagement program developed by HOK to help the tenants partake in energy reduction programs. The central component of the engagement program is the TDC Green Portal, which allows tenants to see how the buildings are performing in real time, learn about annual energy and cost savings, and access data specific to their own office space. The overall revitalization plan follows upon previous Cadillac Fairview initiatives, such as the early adoption of deep lake cooling in 2004, the largest project of its kind when implemented, which allowed for a 90% reduction in the energy required for running chiller systems. In their public documentation on sustainability, Cadillac Fairview cites the drivers for the 2010 retrofits as tenant expectations, community responsibility, and current industry practices, with the results building on the TD Centre brand for uncompromising success.

David Hoffman, TD Centre’s Building Manager, described the primary drivers for the 2010 retrofit project as tenant demand and tenant retention planning, in part due to competition from the new Class AAA properties opening in the Financial District (Hoffman, 2013a). Energy reduction was not a primary decision driver for the project but it was one of the considerations. With the loss of a major tenant, opening up 17 floors in the Royal Trust Tower, there was an additional opportunity to replace existing perimeter floor level induction heating systems with more efficient ceiling-based systems. However, the induction replacement is only being completed on floors that are completely vacant, otherwise it would be too disruptive to the tenants and major space upgrades are not performed mid-lease.

Hoffman (2013b) notes that over the past 3–4 years, sustainability has become part of the corporate culture, both internally and for tenants. As part of this trend, the management policy for TD Centre drives sustainable initiatives by mandating that environmental considerations must be part of all business cases, setting annual energy reduction targets, and implementing sustainability targets as part of the management’s incentive program. Using 2008 operations as the benchmark, there is a mandate to reduce energy use by 3% every year, with an expected 20% reduction overall by 2015. TD Centre is on target to meet the mandate and is currently exceeding its targets year to year.

The first TDC Sustainability Report (2013) indicates that energy was reduced from the 2008 baseline by 14% in 2011, with energy savings close to $1.8 million; the TDC Green Portal shows an 18% reduction was achieved by early 2013 (Race To Reduce, 2012). A key initiative for TD Centre to reduce energy consumption is the tenant engagement program. Every tenant space now has its own submeter providing tenants with a tool to monitor their specific energy use through the TDC Green Portal dashboard. This allows the tenants to better understand the impacts of turning off lights or installing more energy efficient-equipment within individual offices. The program also helps tenants meet their internal CSR requirements and increases tenant buy-in for ongoing building initiatives.

With regard to barriers, Hoffman (2013a) indicates that energy reduction goals have to meet the needs of the business. For example, the recharge rate for
operational costs (including utilities) is generated from metered loads and a portion of the common areas. If the building management paid for energy reduction projects, the tenant would benefit through reduced operations charges, and the building management would have to recoup the costs through additional charge-backs to the tenants. As noted earlier, the split incentive created by the operator/tenant lease contracts can make it difficult to justify increased energy reduction targets. Another potential issue is the inherent difficulty with implementing a clean energy management plan, which requires extensive long-term planning and a highly dedicated interdisciplinary team. In the TD Centre retrofit project, the facility management team was able to engage the assistance of the corporate development team due to the size of the project; however, not every management team would have that level of project support.

While the TD Centre retrofit does not meet the 30% energy use reduction criteria of a deep retrofit, it is likely to be close to 25% less than the 2008 baseline by the end of 2014 (Hoffman, 2013a). As one of the largest retrofit projects of its kind in Canada, the TD Centre leads by example in tenant engagement and the inclusion of energy efficiency targets for management. Going forward, Hoffman suggests that increased reporting could be a beneficial driver for encouraging both owners and landlords, potentially mandating CRS by property instead of aggregated at the corporate portfolio level. Increased visibility and data sharing through a public forum such as real-time sustainability dashboards will help tenants drive the demand for energy-efficient office space.

**Case Study 2: First Canadian Place**

First Canadian Place (FCP), owned by Brookfield Properties Corporation, is the tallest standing office tower in Canada (B+H Architects, 2012). Established in 1975, the 3,468,610 square foot Class AAA building stands 72 stories. It is a modern white clad landmark in Toronto’s Financial District. The original construction was one of the first to include structural tube steel and advanced HVAC systems. In 2009, Brookfield initiated a retrofit project for FCP with the primary purpose of replacing the 45,000 marble façade panels with 5,600 fritted glass panels (Exhibit 8). The goal of the retrofit was to rejuvenate and reinforce the status of the iconic building, redefining it as a premier business location in Canada (B+H Architects, 2012).

Starting from the top, a uniquely designed elevated exterior platform system was used to remove and replace the façade panels. With 80 workers, it averaged 3 days per floor to replace the panels using an elevated platform to work their way down each side of the building. It is estimated that 1.3 million man hours were saved by using advanced building technologies, allowing the complete retrofit to be completed in 1.5 years from initial construction. Along with the enormous task of replacing the facade panels (B+H Architects, 2012), the retrofit project included: (1) new heat recovery chillers; (2) recovery of heat from existing cooling systems and domestic hot water; (3) washroom exhaust heat recovery and low flow fixtures; (4) new high efficiency condensing boilers; (5) retrofit and recalibration of the perimeter induction systems; (6) improved systems controls;
As part of their sustainable initiatives for the retrofit, FCP targeted LEED EB Gold, receiving certification in 2012, and Honorable Mention for Innovative Technology in the Zerofootprint Awards (B+H Architects, 2012). The new glass panels were locally sourced and all of the original marble was either reused in other areas of the building or recycled through local construction projects.
Mechanical and electrical upgrades had a $17,000,000 project cost and estimated annual savings of $113,000 with a 9.7 year payback (TowerWise, 2012). In addition to the energy savings estimated from systems upgrades, Brookfield enrolled the property in a demand response charge reduction program with the Ontario Power Generation (OPG), which allows the energy provider to increase the office floor temperature from 24°C to 26°C and reduce lighting when peak energy demands are too high (B+H Architects, 2012). It is estimated that Brookfield will save an overall 20% in annual energy consumption or $1,800,000 per year through the retrofit, commissioning, and tenant energy management initiatives (Geller, 2011).

Along with their anchor tenant, BMO Financial Group, Brookfield has committed FCP to the “Race to Reduce,” targeting a 10% reduction in whole building energy use by 2014. Key benefits expected to arise from the retrofit project and subsequent initiatives include increased productivity, renewed brand equity, and reduced operational costs.

As a director on the leasing side of Brookfield Corporate Real Estate, interviewee Rosalind McQueen was not part of the decision-making team for the FCP retrofit but she confirms that the successful results of the retrofit project impacts the relationship with existing and perspective tenants (McQueen, 2013).

One of the primary drivers for the façade replacement was the deteriorating condition of the existing marble panels (McQueen, 2013). Two marble panels had come loose from the building and fallen to the ground, creating a substantial risk for the property. Following this occurrence, a very high operational cost was associated for assessing weakness in the façade. Of the 45,000 panels, 1 in 8 was found to be in need of replacement. Where older panels had been replaced with new marble it created a “patchwork” appearance and the associated costs of testing and replacement were not being charged back to the tenants. The retrofit costs were financed internally through the operational budget, in part from savings on annual panel testing and replacement, and these costs were not passed on to tenants.

At the time the decision was made to replace the façade, there were 10 vacant floors, which allowed for additional retrofit activities such as washroom and controls upgrades in those spaces (McQueen, 2013). The decision to pursue LEED certification and some of the retrofit goals were related to the new standards for Class AAA buildings, driven by tenant CSR requirements and competition from new office towers. McQueen confirms that tenants now have an expectation that office space of this rating have LEED certification and have documented sustainable initiatives. One of the immediate benefits of the operational cost reductions was the ability for Brookfield to hold the additional rent rate at just $29.40 per square foot from 2012. Having a rent under $30 for a bank tower has very beneficial optics for tenants, and indicates a commitment for creating the best value in the “newest” new building in the Financial District.

The noise and disruption from the façade replacement was challenging for the tenants (McQueen, 2013). As the retrofit was implemented from the top down,
the vacant 58th floor was placed into service as a designated “quiet floor” that all tenants could use as a guaranteed quiet work or meeting space at no additional charge. Operational disruption was a barrier to more comprehensive retrofit activities; for example, the vision glazing was not replaced as that was deemed too difficult for the tenants. Similar to the TD Centre project, intrusive changes were not made to occupied office spaces both to minimize disruption and because upgrades are not typically implemented mid-lease.

While reduced energy consumption was a consideration as part of the retrofit planning, McQueen did not think it was a major driver. From a lease management perspective most tenants do not ask about energy use (McQueen, 2013). In her experience, price, views, and durability are the key decision-making properties that determine office space selection, with tenants taking a checklist from new building stock to compare against existing office space.

As a single whole building project, the projected 20% reduction in energy consumption does not meet the deep retrofit criteria. Additional energy savings from ongoing tenant engagement programs may eventually bring the energy use down 30% from the 2009 baseline and office renovations will continue as spaces turnover occupancy. However, the project was primarily intended to address structural safety, revitalize the building, and promote tenant retention. The project did excel at many sustainable strategies, particularly related to innovative construction practices, and clearly demonstrates the growing importance of sustainability to tenant retention and attraction.

**Case Study 3: State Street Financial**

Originally constructed in 1959 as the headquarters for Revenue Canada, the 30 Adelaide Street East building was innovative for its time with a full curtain wall façade, an open access atrium, and two tower connection bridges (Curtner, 2013). After sitting vacant for two years, Dundee Realty and ING Realty Partners purchased the building in the 1999 at $30 per square foot for redevelopment (DREAM, 2011). The complete renovation of the building, including replacement of the façade and mechanical systems, was completed in 28 months from purchase. The now Class A commercial office building was fully leased by completion of the renovation, and the building showed a gross internal rate of return of return of 30% or 1.8 times the original investment value. The redesign of the 17 story commercial tower was designed by Quadrangle Architects Ltd, and the retrofit was awarded the NAIOP Office Project of the Year.

In discussion of the State Street Financial retrofit, Brian Curtner, Quadrangle Principal and Co-founder, characterized the original building as needing replacement for all mechanical and electrical systems (Curtner, 2013), the once innovative curtain wall façade was thermally broken, and the floor plates were narrow with odd connections (not appropriate for commercial office layouts). Given a limited budget, the best option at the time was to strip the building back to structural elements and renew it as commercial office space. By removing the constant volume/constant temperature induction systems, the design team was able to reduce the HVAC footprint, gaining a whole extra floor and additional
parking space. New heat pump systems allowed for the reclamation of valuable core space while modernizing the heating systems.

Had there been tenants in the building it would have been difficult to implement the depth of changes they achieved, particularly replacing the electrical systems (Curtner, 2013). The combination of reclaimed floor space, high-efficiency operating systems, low purchase price, and early sign-on of a strong anchor tenant provided the elements for a good financial case on the retrofit.

The project was completed before LEED and other sustainable programs were adopted in Canada, but the owner and tenant worked with the design team to make decisions that supported energy efficiency, resulting in recognition and a grant from Natural Resources Canada (Curtner, 2013). Although the property was vacant for an extended period prior to retrofit and there is no baseline to use for measuring the operation energy use change, it appears likely that a 30% reduction was achieved with this project. Decisions were based on total value analysis to provide the best financial case from multiple perspectives. By considering the whole building, the design team was able to gain valuable leasable space while modernizing the operational systems and minimizing future operating costs.

**Conclusion**

Studies from government agencies in both Canada and the U.S. identify energy reduction in commercial buildings as a key strategy regarding overall energy consumption during the next two decades. With energy consumption rising 27% between 1990, and commercial buildings accounting for 14% of end-use energy consumption in Canada, deep retrofits present an opportunity to maximize energy savings in the built environment. Characterized by the inclusion of energy reduction as a primary goal for the project, measured by the level of verified whole building energy savings achieved compared to the pre-retrofit baseline, a deep retrofit uses whole building consideration to achieve 30% or greater reductions in gross building energy use. As the best retrofit energy and cost savings are achieved when combined with major system replacement projects, or critical upgrades, the aging Toronto Financial District office towers present an opportunity for deep retrofits to be integrated with future revitalization planning.

In addition to the large number of buildings reaching a lifecycle renewal point, a boom in commercial office tower construction has placed new pressure on existing towers. With over 3.5 million square feet of new office space opened or in development (between 2009 and 2015), mature properties are beginning to use revitalization retrofits to maintain property value and retain tenants. Indicators from the literature show that physical drivers such as aging systems and an increased need for energy efficiency do not inherently lend themselves to pursuing energy use reduction targets of 30% or greater, but they do contribute to the initial decision-making process during retrofit planning. The State Street Financial case study illustrates how integrated energy efficiency decisions can benefit both the operations and the financial outcomes of a commercial office tower retrofit.
However, the TD Centre and First Canadian Place case studies confirm the views of interviewees that, in a low energy cost environment, energy use reductions are a secondary consideration when initiating a commercial tower retrofit project. The low cost of energy makes it difficult to make a financial connection specific to energy reductions. Until energy prices increase, it is likely that energy use reduction will remain a secondary consideration during retrofit decision making.

Although the literature review and interviewees analysis shows that even in the current low energy cost environment, deep retrofit projects can generate a positive financial case and increased asset value, the risk of disrupting existing tenants, competition for capital funds, and business expectations for high ROI keep energy use reduction targets from becoming a primary decision-making factor during retrofit planning. Building executive buy-in, through education and tenant demand, will make it more likely for deep retrofit drivers to overcome the operational, financial, and environmental barriers.

The research indicates that in Canada, the drivers that most likely influence energy use reduction decisions are tenant retention, organizational values, public image, and increased asset value. The increasing importance of CSR reporting to both building management and tenants is driving awareness of sustainability and energy efficiency. Although CSR reporting is a relatively new in practice, increases in corporate engagement and evolving sustainability policies are having a strong impact on the industry, with real estate management companies, such as Oxford Properties and Cadillac Fairview, integrating sustainability planning and energy reduction with annual targets and incentive programs.

By combining competition between commercial tower owners with increased CSR demands, programs such as “Race to Reduce” are showing positive results in bringing whole building energy use reduction to the forefront of retrofit and operational planning. The focus of Race to Reduce is on bringing tenants and owners together to reduce overall building energy consumption. This model of cooperation may offer the best results for deep retrofits as well. The importance of tenant engagement is demonstrated in the strategies being developed by the TD Centre as part of their revitalization program, where working with the tenants of the building is a key part of the ongoing efforts to reduce energy consumption against a 2008 baseline.

Another tool that could build on CSR and corporate image to drive deep retrofits is the establishment of publicly accessible energy use labelling for a building. By increasing transparency, and giving both tenants and facility managers a method of evaluating buildings against a benchmark, a national labelling program would provide a metric that could be used for assessing lease options or supporting CSR goals. Professional organizations could further support benchmarking efforts by cooperating to create a national database for commercial buildings. An easily accessible single body of knowledge would help building owners and managers increase their knowledge through case studies, best practices, and improved networking.

Innovative financing for deep retrofits, including PACE financing and energy performance contracts, can offer potential solutions to the issue of raising capital
funds, and create a framework for ensuring guaranteed energy reduction results. While neither model offers a panacea for all financial barriers, they do offer property management companies tools for minimizing the risk and internal expertise requirements associated with deep retrofits. Similarly, the relatively new field of project planning for integrated whole building energy reductions will likely lead to greater energy reduction at a lower cost in the commercial real estate industry as experience and expertise in this area develops.

Finally, both the literature and the interviewees agree that it is not sufficient to just make physical changes to a commercial building. Even buildings that are built or retrofitted to be energy efficient will not achieve expected energy reductions unless tenants and building managers use and maintain buildings properly. The need for extensive tenant and building management education and ongoing resources points to the importance of facility management as a component in an integrated whole building energy reduction strategy.

Toronto’s Financial District is an ideal setting to assess the current business environment for deep retrofits. Aging assemblies and systems, along with competition from new Class AAA tower construction, are generating pressure on mature commercial towers in the Financial District to undergo facility revitalization for tenant retention and maintenance of property value. In the current low cost energy environment, energy reduction alone does not generate a sufficient financial incentive to support implementing deep retrofits. So long as energy costs remain low, factors such as growing tenant demand, accessible benchmarking data, and increased transparency through CSR reporting will help build executive support for pursuing greater energy use reduction targets, while revitalizing the Financial District’s commercial towers.

Appendix A
Sample Building Inventory

The included list is a sample of 60 commercial towers in Toronto’s Financial District, generated from real estate listings and Toronto’s public library archives. The list is not inclusive of every commercial tower in the area, but provides a fair representation of the district building population.
<table>
<thead>
<tr>
<th>Building Name</th>
<th>Address</th>
<th>Street Name</th>
<th>Construction Date/ Major Renovation Date</th>
<th>Number of Storeys</th>
<th>Original Date</th>
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<tr>
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<td>Bay</td>
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<td>Bay</td>
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<td>Richmond</td>
<td>1920</td>
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<td>18</td>
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<td>York</td>
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<td>King</td>
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<td>York</td>
<td>2013</td>
<td>.30</td>
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</table>

Case Study Buildings
Appendix B

Glossary

Actual Net Effective Rent: Common net effective rent together with the present value of lease takeover costs, mandatory tenant space take-up costs, early termination and space put costs, the cost of limits on recoverable costs, the costs of holding space for expansion, moving, or other tenant relocation costs. (REALpac/AIC, 2001, pp. -ANER-1-101-2001).

BOMA: Building Owners and Managers Association.

Building Class A: Top class of building that competes for premier office tenants at rents above average for the area. The buildings have a very high standard of finishes, systems, and exceptional accessibility. Buildings have a prominent market presence (BOMA, 2011).

Building Class AAA (bank): Another term for Building Class A commercial space, defined in Toronto as buildings that command a rental rate of over $25 per net square foot (Johansson, 2012).

CaGBC: Canada Green Building Council.

Capital Cost Pass-Through: A lease provision that allows owners to pass on to tenants the cost of capital improvements that lower total operating costs. Lease terms should ensure that pass-through costs comply with a sustainable certification or rating program (White, 2010).

Capitalization (Cap) Rate: The capitalization rate is the value of a commercial building based on the expected earnings expressed as a percentage value. An investment in equipment that improves energy efficiency and increases the building’s cash flow will both pay back the original investment and increase the value of the building (TowerWise).

Common Gross Effective Rent: Calculated by combining the common net effective rent with the building’s quoted realty taxes and operating costs, but excludes direct billed or separately metered hydro consumption (REALpac/AIC, 2001, pp. -CGER-1.01-2001).

Common Net Effective Rent: The true rent related to a certain lease transaction, based on the present value using the common discount rate, of all rent receivable by a landlord over the initial fixed term, less the present value of all tenant inducements, free rent periods and commissions payable, with such remainder present value amortized over the fixed initial lease term (REALpac/AIC, 2001, pp. -CNER-1.01-2001).

Corporate Social Responsibility (CSR): Voluntary activities undertaken by a company to operate in an economic, social, and environmentally responsible manner (Government of Canada, 2013).

ekWh: The combined energy consumption of natural gas, oil, and electricity expressed in kWh (Enermodal Engineering, 2011).

Energy Services Company (ESCO): Energy Service Company finances an energy efficiency retrofit and recovers invested capital based on retrofit performance and energy savings (Sweatman and Managan, 2010).
ENERGY STAR: A national energy performance rating system (ENERGY STAR, 2013).

HVAC: Heating, ventilation, and air conditioning.

Increased Building Value Using Net Operating Income (NOI): An investment in capital equipment that improves the NOI improves the value of the building. Divide NOI/Cap Rate to see increased value (TowerWise).

Internal Rate of Return (IRR): The interest rate that brings the value of the investment back to zero; rate of return greater than the value indicates a positive return on investment (TowerWise).

LEED: Leadership in Energy and Environmental Design is a third party certification program for the measurement of building performance through design, construction, and operations (Canada Green Building Council, 2013).

Lifecycle Costing: Comprehensive measure of the expected cost and expected repair and replacement costs over an extended period of time (TowerWise).

Net Present Value (NPV): The value of an organization will increase by the amount equal to the present value today of future cash flows. A positive NPV indicates an increase in the value of the organization (TowerWise).

Net Rent: The rent, excluding a tenant’s share of real estate taxes, operating cost, and other costs directly related to the tenant’s occupancy of the space (REALpac/AIC, 2001, pp. -NR-1.01-2001).

REIT: Real estate investment trust.

Simple Payback: The time it takes to return back to the organization the funds invested through the savings generated (ignores time value of money and therefore biased against investments where the highest returns are in 8–10 year time frame) (TowerWise).

Triple Net Lease: A lease contract where the tenant is required to pay all taxes, insurance, maintenance, and utility costs on top of a monthly rent rate (White, 2010).

Appendix C

List of Interviewees


McQueen, Roslind. Brookfield Properties: Director, Office Leasing. Interview Feb 15, 2013.


St. Michael, Julia. REALpac: Manager, Research & Environmental Programs. Interview February 4, 2012.


References


Curtner, B. Principal, Quadrangle Architects Ltd. (A. Jones, interviewer). February 20, 2013.


———. (A. Jones, interviewer). February 27, 2013.


Alita Jones, Conestoga College, Kitchener, ON, CAN, N2G 4M4 or swampjones@gmail.com.
2013 AMERICAN REAL ESTATE SOCIETY
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Is Value-Added and Opportunistic Real Estate Investing Beneficial? If So, Why?
James D. Shilling and Charles H. Wurtzebach
34:4, 429–61

Journal of Real Estate Portfolio Management

Winner of the PREA Manuscript Prize ($1,000) for the best research paper published in JREPM in 2012.

Decomposing Underwriting Spreads for GSEs and Frequent Issuer Financial Firms
David M. Harrison, Andrea J. Heuson, and Michael J. Seiler
18:2, 135–53

Congratulations to all the authors.
2013 ARES MANUSCRIPT PRIZE WINNERS

The American Real Estate Society proudly announces the following manuscript prize winners for research papers presented at the American Real Estate Society’s 29th Annual Meeting.

**Apartments**, sponsored by the National Multi Housing Council (NMHC): Luis Mejia and Kyle Potter for “Value Beyond the Value-Add: Multifamily Rent Growth After Renovations.”


**Housing**, sponsored by the Lucas Institute for Real Estate Development and Finance at Florida Gulf Coast University: Jing Zhang, Robert De Jong, and Donald R. Haurin for “Are Real House Prices Stationary?” Evidence from New Panel and Univariate Data.

**Industrial Real Estate**, sponsored by the NAIOP Research Foundation: David M. Harrison for “Further Evidence on Political Risk in Industrial Property Markets.”

**Innovative Thinking “Thinking Out of the Box,”** sponsored by the Maury Seldin Advanced Studies Institute (MSASI): Scott Wentland, Xun Bian, and Raymond Brastow for “Neighborhood Tipping and Sorting Dynamics in Real Estate: Evidence from the Virginia Sex Offender Registry.”

**Marc Louargand Best Research Paper by a Practicing Real Estate Professional**, sponsored by the James R. Webb ARES Foundation: Grant I. Thrall for “Who Buys for Cash, and Where.”


**Real Estate Brokerage/Agency**, sponsored by the National Association of Realtors (NAR): Ping Cheng, Zhengu (Len) Lin, Yingchun Liu, and Michael J. Seiler for “The Benefit of Search in Real Estate Market.”


**Real Estate Education**, sponsored by Dearborn Real Estate Education: Annette Kaempf-Dern, Andreas Pführ, and Stephen E. Roulac for “Real Estate Perspectives as Major Cluster Attributes for the Analysis of the Last Decades’ Real Estate Research.”


**Real Estate Investment Trusts** (NAREIT): Desmond Tsang and Crocker Liu for “CEO Bonus: Alternative Performance Versus Gamesmanship.”

**Real Estate Market Analysis**, sponsored by CBRE Econometric Advisors: Patrick Smith for “The Impact of Consumer Sentiment on Single Family Home Prices.”


**Real Estate Valuation**, sponsored by the Appraisal Institute (AI): Joseph T.L. Ooi, Thao T.T. Le, and Lee Nai Jia for “Construction Quality and House Prices.”


**Seniors Housing**, sponsored by the National Investment Center for the Seniors Housing and Care Industry (NIC): Donald R. Haurin, Chao Ma, Stephanie Moulton, and Jason Seligman for “Reverse Mortgages: Consumer Selection.”

**Sustainable Real Estate**, sponsored by the NAIOP Research Foundation: Spenser J. Robinson for “Managing Well by Managing Good—The True Story of Sustainable Real Estate Premiums.”
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**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.

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**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)).
ARES MONOGRAPHS
PAST, PRESENT AND FUTURE

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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).


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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.

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Journal of Real Estate Research
Special Issue on Asian Real Estate Markets

The American Real Estate Society announces a call for papers for a special issue of the *Journal of Real Estate Research*. Authors are encouraged to submit original research on topics related to the Asian Real Estate Markets. Areas of interest include, but are not limited to, the following:

- **Property Rights**: Their relationships with development strategies, property valuation, and market structure.
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All papers will be subject to double-blind anonymous review. Empirical and theoretical oriented manuscripts are welcome. Style and submission guidelines can be found at the back of *JREER* and on the ARES website. Electronic submissions are encouraged in Word or PDF formats. Authors should submit their manuscripts **no later than October 1, 2014** to Ko Wang at: ko.wang@baruch.cuny.edu.

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JOSRE Call for Papers

Property Values and Environmental Factors

The American Real Estate Society and the Land Economics Foundation announce a call for papers for the sixth volume of the Journal of Sustainable Real Estate (JOSRE). The volume will focus on property values and environmental factors. Some examples of negative environmental factors include leaking underground storage tanks, superfund sites, landfills, water and air pollution, power lines, pipeline ruptures, nuclear power plants, and animal feedlots. Positive environmental factors include beach access, views, park area proximity, and new housing construction.

Authors should submit original research papers that can help investors, developers, appraisers, lenders, asset managers, government officials, and land use regulators improve their strategies, decision-making, and understanding of the impact of property values and environmental factors, and how these relate to sustainable real estate practices. Topics and questions of interest include, but are not limited to:

- What are “environmental factors” as they pertain to property values?
- How and what are the observable and unobservable value effects of environmental factors?
- What is the scope of positive or negative environmental factors and their impact on property values?
- How does stigma impact contaminated and adjacent property values before and after decontamination?
- What is the effect of proximity to the source of environmental contamination?
- How do prices change over time as a result of environmental factors? What control variables should be included in a pricing model? What can we learn from others outside North America?
- Nearly every major city and several U.S. states and Canadian provinces have codes for environmental factors for certain types or sizes of buildings. How do these requirements compare and how do these regulations affect valuation?
- What are the effects of subsidies, taxes or other incentives on the ROI for properties that incur additional costs to cope with environmental factors?
- Are there additional financing costs for properties affected by environmental factors? What is their effect on property value?
- How do you value a building with features designed to address environmental factors? Are benefits imbedded in rents and occupancy or expenses, or is there an impact on risk that should affect valuation and required returns? How do lenders view the costs and benefits of these features?
- What are the implications of environmental factors for appraisers and the appraisal process?
- Are there conflicts with state/province and local building codes and municipal subdivision and site conditions that make implementation difficult, as they relate to environmental factors?
- What is the impact of buildings designed for environmental factors on worker productivity and morale? Can these be valued? Do or will they eventually translate into rent and property value?
- What is the state of the art for controlling various types of contamination, what regulations impede or assist in this effort, and how do they affect valuation?
- What are the new technologies and strategies affecting various types of contamination? Are they cost effective and to what extent do they affect valuation?

All papers are subject to anonymous double-blind peer review. Papers must 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 at www.aresnet.org, www.lai-lef.org, and www.josre.org. Submissions must be in MS Word or PDF format. Submissions are due by June 1, 2014 to Myla Lorenzo Wilson at JOSRE, mlwilson@san diego.edu. Please copy the following Guest Editors on your submission: Frank A. Clayton, Urban and Real Estate Economist (frankclayton@bells.net), Daniel T. Winkler, University of North Carolina at Greensboro (dt_winkler@uncg.edu), and Norm Miller, University of San Diego (nmiller@sandiego.edu).
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JOURNAL OF HOUSING RESEARCH

The American Real Estate Society announces a call for papers for the Journal of Housing Research (JHR). The objective of the JHR is to serve as an outlet for theoretical and empirical research on a broad range of housing related topics, including but not limited to, the economics of housing markets, residential brokerage, home mortgage finance and mortgage markets, and international housing issues.

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Manuscripts should be original, unpublished works not under publication consideration anywhere else. Interested authors should contact or submit manuscripts to:

Justin D. Benefield
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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.

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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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The Editor reads each submitted manuscript to decide if its topic and content of the paper fit the objectives of JOSRE. Manuscripts that are appropriate are assigned anonymously by the Editor to one member of the Editorial Board and at least one other reviewer. The Editor makes the final decision regarding re-submissions. Upon receiving a re-submission, the Editor determines whether or not the manuscript should re-enter the reviewing process, be accepted or simply be returned.

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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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