# PROPERTY TAX APPRAISAL FOR GREEN BUILDINGS:

# ENERGY STAR CERTIFICATION IN TEXAS

by

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Abstract

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This study investigates whether tax appraised values of commercial office buildings in major Texas cities are influenced by ENERGY STAR (ES) rating. Per square foot (PSF) tax appraised value of property improvements and certification ratings are used to determine whether higher levels ES rating (a numerical grade from 75 to 100) increase tax appraised values in the five most populated Texas cities – Austin, Dallas, Fort Worth, Houston, and San Antonio.

Quantitative data on ES buildings in each selected city is obtained through the EPA and county tax assessor online resources. Data on 723 ES properties is collected and cleaned for the purpose of selecting properties that have accurate land areas, gross square footages, net square footages, land market values and improvement values. A total 370 ES office buildings with average improved tax appraised values of $42,654,608 are included in the cleaned dataset.

Linear regressions are utilized to determine whether ES ratings effect tax appraised values of property improvements of 76 commercial office buildings built since 1995. A model that utilizes Year Built and city variables suggests that for every one-unit increase in ES rating, improved property value increases by $1.56 PSF. A second model

that utilizes the more precise locational characteristic of zip codes similarly concludes that for every one-unit increase in ES rating, improved property value increases by $1.58 PSF. These models suggest that properties with higher levels of ES certification have higher PSF tax appraised value of property improvements.

The research results allow conclusions about the extent to which ES certification is reflected in commercial real estate tax appraised values in Texas. This body of green building appraisal research provides taxing authorities with a more comprehensive understanding of how green building certification influences property values. This study is intended to serve as a foundational document to aid in the development of a best practice methodology for tax professionals to accurately appraise the market value of ES properties prior to comparable market transactions.

Table of Contents

List of Illustrations

List of Tables

# Chapter 1

# Introduction

## 1.1 Context

There is a general consensus among green building professionals that ES certification adds value to the subject properties, yet the researcher remains unaware of any tax appraisal districts that consider certification when appraising real estate for property tax purposes. Even though some of the financial benefits to owning ES certified buildings may be offset by higher construction costs, taxing jurisdictions often fail to consider energy efficiency characteristics in favor of comparing these high-performance buildings to those which are built to specifications that satisfy only minimum building code requirements. The question that this study examines is – do properties with higher levels of ES certification have higher tax appraised values?

Developing and administrating accurate, financially feasible taxation policies and methodologies for green buildings is a primary concern for every taxing jurisdiction within the United States. The majority of economic transactions at the local level require the continued provision of at least the most basic public goods, such as roads, which assist in connecting individual economic actors and facilitate agglomeration economies. Local services are predominantly funded by property taxes which are collected according to the market value of real estate as determined by the local taxing jurisdiction. In fact, “in virtually every aspect of the real estate industry and its regulation at the local, state, and federal levels, market value considerations are essential to economic stability” (The Appraisal Institute 2008) because the certainty of service delivery drives both public and private investment.

One of the main issues regarding property tax policy for green buildings is that determining market value — the definition is of great contention among the literature — for ES properties often remains subjective because each structure utilizes a unique blend of green materials, methods, and technology (MMT) in its construction, each of which has costs and benefits unique to the individual property. It is possible that some of these structural features generally increase operating efficiency, add value, and improve investment returns, while others have the opposite effect. The imperfect information which results from the heterogeneity of real commercial property has stirred an ongoing debate over how to accurately determine the value of these structures. Developing appraisal methodologies which allow property tax professional to determine the market value of these incomparable parcels has become essential due to their widespread emergence in recent years.

Three common methodologies exist to determine the market value of real estate — the sales comparable approach, the cost approach, and the income approach (Ling and Archer 2008). Each of these three appraisal methodologies and their applicability to the subject assets are explored extensively in Appendix A. The sales comparable approach — commonly used for residential properties for which ample comparable sales usually exist — often cannot be effectively utilized for the subject properties because few transactions take place and comparison is often unfeasible with the complex deal structures that high-value, investment grade properties command. The cost approach would seemingly be the most accurate way to determine the value of these structures, but most rational property owners would not share the actual cost of construction with their taxing jurisdiction if the result would be that their taxes would be raised.

The difficulties involved in obtaining information to conduct appraisals using the sales comparable and cost approaches makes the income approach the best and most commonly used method for determining the current market value of these structures. Most industry professionals agree that the income approach, which utilizes discounted cash flow (DCF) financial modeling, is the most well-suited appraisal tool for sustainable properties (Muldalvin 2010), using DCF analysis to forecast the financial costs and benefits of green buildings remains difficult as a result of their relatively short history. Although the income approach will always be inhibited by imperfect information, comparable leases of like-kind space are usually available as the majority of ES office buildings are located in central business districts (CBD) where a vast amount of office space is leased. However, obtaining commercial lease information from properties that collect similar rents does not provide insight regarding one of the main financial cash flow benefits that green buildings have: reduced operating expenses.

The primary advantage to green structures have over conventional structures is they are far less expensive to operate (Fuerst and McAllister 2008). The usefulness of the income approach for analyzing operating expense savings is similarly limited by the lack of data on the true costs of operating these structures. Most owners and managers of these properties are keen about this strategic advantage. Leases are often negotiated as a gross lease wherein the tenant pays a flat rate instead of paying their own operating costs. In this fashion, the owner of the property is able to effectively charge higher rental rates to cover the costs of operation — power, water, etc. — all of which are less than they would be in conventional structure. For example, not passing through operating expenses further reduces the availability of operating expense data available to property appraisers. Perceived and actual operating expense savings are a primary concern for this study because these benefits have a profound effect on the value of the subject properties.

This study explores whether ES certification influences tax appraised values. The ultimate objective of this research design is to develop foundational methodologies for creating models which more accurately appraise these assets. The potential policy implications for utilizing such a model at the municipal and county levels are then explored.

### *1.1.1 Statement of the Problem*

Imperfect information in the commercial property market in major Texas cities may result in ES certified buildings being inaccurately appraised for property tax purposes, which shift the tax burden from the stakeholders of these properties to all of the other property owners in the taxing jurisdiction.

### *1.1.2 Purpose*

This study serves as foundational research for developing a best practice methodology for tax professionals to accurately appraise the market value of ES properties in the selected metropolitan areas of Texas.

## 1.2 Research Design Overview

Data from 723 ES certified properties in Austin, Dallas, Fort Worth, Houston and San Antonio are obtained from the USGBC and EPA. The data is mined and cleaned for the purpose of selecting properties with adequate information that does not deviate by more than 20% from tax appraisal directories. ES property profiles are obtained from the five selected county tax appraisal district websites. After cleaning the data according to the previously mentioned requirements, a total of 370 ES properties with average tax appraised values of $42,654,608 have adequate information.

Five variables are pulled for each property. Land area, the square footage of the property, is identified for the purpose of determining the size of the property. Gross square footage, the entire area of each floor of a structure including interior and exterior walls, is identified to determine the size of each structure. Net square footage, the entire leasable area of the property excluding common areas, is identified because it is commonly used to determine the value of properties when using the income approach – how most commercial property is valued. The appraised value of the land is identified to understand how the parcel itself is valued PSF. The value of the land improvements, the structures on the property, is identified to understand how much the structures are worth when removing the value of the land.

The variables on each ES office building include: property identification number, building name, building type, building owner, manager, address, city, state, zip, year(s) certified, rating(s), square footage, and year constructed. Using these variables, PSF tax appraised value of property improvements are determined for each property. The net square footage from the EPA master list of ES properties is used.

Linear regressions are run to determine whether ES certification influences tax appraised values of property improvements. Preliminary results, suggest that if cities and years since 1995 are included in the model, every one-unit increase in ES rating increases improved property value by $1.56 PSF.

### *1.2.1 Assumptions*

This research assumes that the vast majority of taxing jurisdictions within the United States do not currently take ES certification into consideration when appraising property for tax purposes; however, they are interested in knowing more about the potential for improving appraisal methodology by incorporating green certifications. These taxing jurisdictions primarily use the income approach to appraise commercial buildings. The researcher has been in contact with many tax appraisers, each whom expressed interest in this topic and agreed with these assumptions.

Data gathered from the EPA and county appraisal districts are assumed to be accurate. Data inconsistencies are addressed according to the relevant literature. Although all efforts are made to gather accurate inputs, extensive data cleaning is required given that, in some circumstances, the three sources used may contain inconsistencies.

### *1.2.2 Research Questions*

1. Do properties with higher ES ratings have higher PSF tax appraised value of property improvements?
2. Does the city affect the PSF tax appraised value of property improvements in the observed data?
3. Does the zip code affect the tax appraised value of property improvements in the observed data?

### *1.2.3 Significance*

Accurate tax appraisals are of great importance to all taxing jurisdictions because property taxes serve as one of the main revenue streams for local governments. In many states, the ongoing provision of local government services is heavily contingent on a tax base which predominately determined by real estate appraisals. Perhaps the most complex, consequential, and contested form of taxation is that which is levied against land and its improvements: real estate. Real estate is one of the most heterogeneous forms of private property that exists, yet its taxation serves as one of the main revenue sources for local governments since it is the single largest tangible and taxable asset class within most taxing jurisdictions.

The vast majority of appraisals are conducted for single family homes which are relatively homogenous with frequent sales occurring. Conversely, the sale of commercial office properties, which are often more valuable and income producing, are far less common and the properties much more unique. In today's market, some of the most uncommon real estate transactions involve the subject properties of this study: commercial office buildings with ES certification. A wealth of new data gathered from recent ownership transfers of these assets merits further taxation research. This study explores the propensity for local governments to develop policies which improve tax appraisers' ability to uniformly commercial buildings with green certification by helping to understand how current appraisals are influenced by ES certifications. This body of knowledge aides the development of methodologies capable of determining the market value of ES certified buildings prior to comparable market transactions.

### 1.3 Sustainability

The words *sustainability*, *sustainable development*, and *green building* are used interchangeably throughout this study. Although a myriad of interpretations and applications of the word sustainability and its epistemology exist, the most widely accepted definition of sustainability, and that which this study employs, is "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Commision 1987). It should be noted that this original definition was intended to describe sustainable development, but is now the generally accepted definition for sustainability (Ball 2011). This seemingly broad description is often broken down into what are commonly referred to as the three pillars of sustainability: economic, social, and environmental. Lorenz and Lutzkendorf (2011) further break these categories down into monetary and non-monetary elements (tangible and non-tangible are interchangeable in this study).

The monetary elements —considered the economic pillar — of sustainability are market value/exchange value and worth/value in use, while the non-monetary elements — the social and environmental pillars — are physical, social, cultural, emotional, image/sign, and environmental. Although the economic pillar is the focus of this study, it must be noted that both social and environmental aspects of ES structures add to their economic value. These qualitative benefits each affect the market value of buildings; however, this study is strictly focused on monetary, market value/exchange value and, therefore, does not consider any benefits outside those which are incorporated in the transaction prices of the subject assets. In other words, this research focuses on only the internalized benefits or detriments that owners receive from property ownership and does not consider any negative or positive externalities that their assets have on any other entities.

## 1.4 ENERGY STAR

ES is a much less comprehensive, easier to understand, and more standardized than other green building rating systems such as the United States Green Building Councils' (USGBC) Leadership in Energy and Environmental Design (LEED). It "is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy" utilized throughout the world (U.S. Environmental Protection Agency 2012). ES is primarily concerned with "energy efficient products and practices" in order to improve energy performance rather than specifically geared toward rating the efficiency of the built environment (U.S. Environmental Protection Agency 2012).

ES is most commonly known as a certification for consumer products but it is also a form of benchmarking for buildings. Unlike consumer products, ES commercial and industrial facilities are not usually labeled with the blue ES label. Properties earn the ES label by applying and having their properties inspected by “a professional engineer or registered architect must verify that the information contained within the certification application is accurate” (Environmental Protection Agency n.d.). Certification is then annually verified by a third party who gathers data on all certified properties. There are 30 types of property certification categories, each of which has ratings of 75 to 100. The rating of each property is the percentile on how much energy it consumes PSF. Therefore, if a building achieves a score of 80, it is more energy efficient than 80% of buildings in its class. In this way, the system is self-adjusting over the years as more different – often more efficient – buildings are built and/or energy consumption in that class changes. This encourages building owners to continue to make efficiency improvements and use less energy as both of these actions improve ES ratings relative to other structures. In some ways, this makes ES a more competitive system than LEED. In 2012, there were more than 20,000 ES certified buildings (Environmental Protection Agency n.d.).

## 1.5 Market Value

Although there are many ways to define “market value” in the context of real estate appraisal – monetary or economic value – and an even wider array in terms of sustainability – market value/exchange value, worth/value in use, physical, social, cultural, emotional, image/sign, and environmental – this study necessitates a very specific, quantifiable definition which leaves no margin for error (Lorenz and Lutzkendorf 2011). This may seem counterintuitive given that this exploratory study involves green buildings, which, according to growing body of literature, have significantly less negative economic, social, and environmental qualitative externalities (Tatari and Kucukvar 2011).

It is necessary to explicitly reiterate that even though each of the subject properties provides qualitative benefits in each pillar of sustainability; this investigation is designed to explore solely the financial methodologies used to appraise green buildings in different municipalities within the United States of America. For these reasons, *The Appraisal Institute's* definition of "market value" is utilized: "The most probable price, as of a specified date, in cash, or in terms equivalent to cash, or in other precisely revealed terms, for which the specified property rights should sell after reasonable exposure in a competitive market under all conditions requisite to a fair sale, with the buyer and seller each acting prudently, knowledgeably, and for self-interest, and assuming that neither is under undue duress" (The Appraisal Institute 2008, 23). This definition from *The Appraisal Institute* is the industry standard and the crux of this research. It contains all of the elements that should be considered when qualifying whether a transaction price was truly market value. In general, this research utilizes tax appraised value which is not adjusted for externalities as market value can often be. Tax appraised value is the value to the property owner or potential owner. It does not include any other external benefits or detriments – qualitative or quantitative – as defined by Tatari and Kucukvar, 20011.

Information regarding the market value of subject properties is scarce compared to more common assets which limit the accuracy of appraisals. Sales of the subject properties are limited by several factors. Demand for these properties is limited by their higher values. Even if buyers are using financial leverage, large amounts of equity are often required for properties to be purchases. This limits the pool of potential buyers. Allowing for "reasonable exposure in a competitive market under all conditions requisite to a fair sale" sale to these types of individuals and firms is complex in itself (The

Appraisal Institute 2008). Potential buyers are often sought after by owners which increases the potential for transaction that are not “arm’s length” because of a previously established connection between the two parties. The terms of many transactions and relationships between the parties involved can lead to suggestions that the buyer and seller were not “each acting prudently, knowledgeably, and for self-interest, and assuming that neither is under undue duress” (The Appraisal Institute 2008). Similarly, the terms of a sale can be limited by time horizons or other circumstances unique to that individual property transfer. As a result, a major challenge for property appraisers is make adjustments to appraised values when one element or more of the elements of market value is negated. This becomes increasingly complex as their scope is limited by the multitude factors which can deem a transaction not to be considered market value.

## Chapter 2

## Literature Review

The literature on price premiums of the subject assets can be divided into three main categories – each broken down chronologically.  The first category explores a wide variety of benefits attributed to green buildings from a normative perspective. When green buildings were in their infancy, many academics and professionals (practitioners) began to theorize that there should be tangible and intangible benefits to building green. At first, social, economic and environmental benefits could only be measured on a small scale; much of the research was based on theory and case studies of individual properties. According to Myers (2007), “a lack of empirical evidence on the sustainable property market” made a meaningful quantitative study “impossible to undertake”. Since 2008, much of the qualitative research from last decade has been confirmed by quantitative studies discussed in the next section. This qualitative research served to encourage further exploration of the topic and shape the trajectory of further research.

The second category of literature reviewed is empirical research that began to emerge as viable datasets of green office buildings became available. Although the pool of subject assets remains small in comparison to conventional structures, the increasing green building stock has allowed many studies to identify and quantify specific aspects of green buildings that increase market value. In recent years, studies with cross sections of tens of thousands of non-certified and thousands of certified buildings have begun to emerge – the findings of all studies with over 500 observations are also presented in Appendix B.

The third category focuses on the literature that presents policy recommendations with a particular emphasis on the increasing number of studies that recommend utilizing DCF and cost-benefit analysis (CBA) for green building valuations and investment decisions. There are two very comprehensive studies that provide specific recommendations for those involved in the valuation and policy-making process. Although there is a broad spectrum of policy recommendations, the common theme is that CBA and DCF are the most accurate way of valuing these assets. Property investors are increasingly utilizing these tools to determine the value of the benefits that they will receive through ownership.

## 2.1 Benefits Ascribed to Green Buildings

Before empirical research began, it was theorized that green buildings provide tangible and intangible “benefits (that) range from being fairly predictable (energy, waste and water saving) to relatively uncertain” (Kats, et al. 2003). Benefits carry differing weights for each pillar of sustainability. Although the majority of the applicable literature from this study comes from analysis that would be considered based upon the economic sphere and is predominantly quantitative, a variety of qualitative studies that guided the debate merit review. This section explores the benefits ascribed to green buildings absent of quantitative justification. These studies started the conversation about green building valuation and were the impetus for empirical research.

In 2004, German researchers Lutzkendorf and Lorenz (2004) presented a paper to the CIB World Building Congress that suggested green buildings needed fundamentally different valuation methodologies because current valuation practices could not determine the value to the user of the property. These assets have “particular building characteristics and associated performance” that necessitated “valuation theory and practice” that considers social and environmental benefits (Lorenz and Lutzkendorf 2004). These benefits were seen to be bestowed upon the users of these properties. Lorenz and Lutzkendorf (2004) believed that the combined use of Life Cycle Costing

(LCC) and Life Cycle Assessment (LCA) could overcome assessment issues if researchers “strive towards standarisation of terminology and towards more exchange of ideas.” Similar to most studies that were conduct in the next five years, Lorenz and Lutzkendorf (2004) agreed that “it is very difficult to empirically prove the benefits of green buildings due to the lack of detailed information on different building characteristics and associated performance.” Lorenz and Lutzkendorf (2004) not only began a conversation about the need for LCC in valuation, they identified a growing perception that current valuation methodologies were incapable of valuing green commercial assets.

A 2005 Canada Green Building Council (CGBC) study from Canadian engineering firm Morrison Hershfield theorized that economic gains of green buildings are associated with life cycle operating costs, insurance rates, churn rates, productivity gains, as well as property value and absorption rates (Hershfield, et al. 2005). With hopes to encourage additional green building construction in Canada, this CGBC report generalized that green building benefits include:

- superior occupant comfort and health
- ecological benefits and reduced climate change impact
- reduced operating costs, productivity gains
- property value and absorption rate gains
- increased retail sales
- improved image
- risk reduction

Even though this document serves mostly as a review of literature, a section on lifecycle costing and DCF analysis set the tone for future studies by validating research by Kats, et al. (2003) – a publication at the time that is explored in the next two sections.

With constrained data, a number of studies began to theorize how benefits from each pillar of sustainability would influence market values. Because there was “still little evidence of the impact of environmental and social factors on the return of an investment property” Kimmet and Boyd (2005) put forth the suggestions that all properties should be valued according to how each pillar of sustainability influences their performance, an approach that he called *The Triple Bottom Line Approach to Property Performance Evaluation*. In this study, Kimmet and Boyd (2005) utilizes a hypothetical example to demonstrate how IRR’s could be affected by incorporating building features that were socially good, environmentally good, or a combination of both with those based solely on financial improvement. In this study, the internal rate of return IRR for “property with high ratings in both environmental and social factors is estimated at 10.4%, while a similar property without the social and environmental features would have a return of 9.8%” (Kimmet and Boyd 2005). The study concluded that the most effective means of measuring building performance was CBA. CBA was necessary in order to “emphatically demonstrate to property investors and managers that such efforts are not just affordable, but have significant performance benefits and contribute to higher returns and premium value that the Triple Bottom Line will have meaning and become an integral part of the valuation approach for investment-type buildings” (Kimmet and Boyd 2005). This study pioneered the use of performance measurements by promoting what it championed as the Triple Bottom Line approach for operational performance of green assets.

The Kimmet and Boyd (2005) Triple Bottom Line approach was taken in to a much broader context when Pivo and Fisher transformed their message in to what they coined Responsible Property Investment (RPI) and Socially Responsible Investment (SRI). Although Kimmet and Boyd (2009) were initially fond of what they saw as a progression in the literature and terminology, they later became critical — as they were with other studies — of the way that these broader categories because it drew the focus away from the fact that “commercial property investment is fundamentally focused on profit-making.” They suggested that the lack of focus compounded difficulties with property performance reporting and subsequent process towards sustainability. Kimmet and Boyd (2009) believed that separating the pillars of sustainability with the term *sustainability* had a negative effect on commercial property investment.

Pivo and McNamara (2005) begin their exploration of RPI for the United Nations Environment Program Finance Initiative (UNEP FI) —they also started a broader program with similar goals for financial institutions called Principles of Responsible Investment—in their paper entitled *Responsible Property Investing*. RPI is defined as “maximizing the positive effects and minimizing the negative effects of property ownership, management and development on society and the natural environment in a way that is consistent with investor goals and fiduciary responsibilities” (Pivo and McNamara 2005). Similar to preceding literature, they also suggest there is a lack of empirical data to prove their findings. This is exemplified by citing ES as the best indication of increasing investment returns. Although energy consumption remains to be one of the main operating expense savings today, ES is not a good metric for measuring sustainability or investor commitment —what they seek to measure in later studies utilizing CBA and matrices.

In a study published later in 2005, *Is There a Future for Responsible Property Investments*, Pivo further promotes the need for RPI. He hopes that by encouraging institutional investors — including pension funds that “now hold about 19% of all U.S. commercial real estate equity”— to engage in Socially Responsible Property Investing (SRPI) they can create a corporate climate where organizations whose values align with green properties push each other to go green (Pivo 2005). Pivo (2005) sees a large and quickly growing corporate market for green office buildings and “opportunities to create new products designed for the SRPI market which perform even better on the Triple Bottom Line – socially, environmentally, and financially". Reiterating much of his previous writing, he stresses the need to analyze and share the performance of these assets going forward.

The Triple Bottom Line discussion became prevalent in the literature in 2005 while the confidence of emerging, viable datasets began to grow. Boyd (2005) and others began to ask "whether the impact of sustainability on investment property can be quantified" with "very little evidence of market rent differentials." With the Triple Bottom Line, Boyd (2005) became more optimistic. The approach had the ability to incorporate cash flow measurements with adjustments for social and environmental benefits as identified by Key Performance Indicators (KPI). KPI are quantifiable measurements that can be used as inputs into the Triple Bottom Line. Boyd (2005) suggested that "the environmental and social indicators of sustainability can be evaluated using investment cash flow studies and the appropriateness of this methodology" which is later demonstrated in empirical case studies once data becomes available.

Similarly, Kimmet (2006) suggests that a growing body of research confirms "that sustainable construction has net-positive cost-benefits. However, this is not flowing through to real estate valuation practices." Kimmet (2006) makes the case for a more transparent and integrated approach to property appraisal by reviewing applicable literature. He aims "to advance [the] theoretical platform, explaining how and why sustainability initiatives impact on the value of assets generally and buildings in particular" by exploring the topic from a property rights perspective with a transaction cost lens. This new-institutional economic approach yields the realization that the "sale and use of sustainable buildings is largely a function of relational contracting in which information is knowledge that provides the building blocks for a whole new architecture charaterised by effective and efficient governance" (Kimmet 2006). In other words, Kimmet (2006) expects that rationally acting investors will identify the value of being sustainable which will encourage them to shift toward sustainable investments. Over time, developers will identify this demand and increase the production of buildings with sustainable attributes because of increased returns due to this increased demand. This theoretical approach derived from Coasean and new-institutional economics is a step back to the economic framework that provides a basis for all of the literature on this topic. It is suggested that the market will identify the value of being economic, environmental, and socially sustainable and increase the value of being sustainable on the Triple Bottom Line.

In 2007 and 2008, Pivo published two additional studies on RPI using the Delphi method and a survey approach. A survey administered to senior American executives questioned their organizations progress towards RPI, which he redefined as being "efforts by property investors that go beyond compliance with minimum legal requirements to better manage environmental, social and governance issues associated with property investing" (Pivo 2007). This survey of 1169 CEOs had a total of 189 respondents for a response rate of 15%. The target population was (Pivo 2007):

- Pension funds, foundations and endowments with property assets.
- Real estate investment trusts (REITs).
- Real estate operating companies (REOCs).
- Property fund managers.
- Property development companies.

The results indicated that 82% of respondents stated that their organization went beyond the legal requirements for RPI while 88% stated that "this activity will be more important in the future" (Pivo 2007). 74-82% of organizations reported that they engage in some of the 15 strategies and investments studied with most reporting that these "actions are being driven by business considerations" (Pivo 2007). Pivo (2007) concludes that "further studies of the economic costs and benefits of RPI, perhaps more than anything else, will do the most to support further development of the field."

Pivo's (2008) Delphi method approach takes an international panel of experts from the "real estate and social investing sectors" to evaluate and reach a consensus for ranking 66 criteria for their "materiality and importance to the public interest". The article suggests that LEED does not do a very good job of measuring social dimensions of property investments. Energy efficiency and conservation are found to be the two most important criteria while "high level of public transport services, transit-oriented development, daylight and natural ventilation, and contributes to higher density, mixed-use walkable places" are also very important to RPI (Pivo 2008). LEED is very good with the first two criteria, which are more important to the environmental pillar of sustainability; it does not do well with the social pillar. Pivo (2008) uses the identified criteria, their rankings and existing RPI studies to produce a regression analysis explored in the next section.

Recognizing the RPI and Triple Bottom Line shift in the literature, Sayce, Ellison, and Philip (2006) present findings from a UK survey they conducted in 2005 addressing attitudes towards sustainable property. Sayce, Ellison, and Phillip (2006) believed — similar to Pivo and McNamara — that respondents simply fail to recognize the case for RPI and the Triple Bottom Line. Although awareness had grown significantly since studies administered in 1995 and 2000 (research conducted on this topic for the last ten years, but never published), deciding to invest in sustainable property "requires a means of quantifying that assessment in terms of property worth; only if this is possible can the investor understand the financial implications of taking action and the risk attached to taking no action" (Sayce, Ellison and Philip 2006). Similarly, Sayce and Ellison (2007) discuss the "need to understand the range of ways building occupation and ownership can be affected by perceptions of sustainability, both in relation to their worth and their physical characteristics." By focusing on specific criteria similar to what Pivo (2008) would expand on later, Sayce and Ellison (2007) identify a information gap which they suggest causes rational investors to underestimate the value of green property due to their lack of information. Sayce, Ellison, and Philip (2006) and Sayce and Ellison (2007) continue the push toward RPI and the Triple Bottom Line approach by calling for a "transactional market" that "explicitly recognize(s) the impact of sustainability factors within its pricing structure." However, they still lack the data to effectively make the appeal.

Myers (2007) and Myers, Reed and Robinson (2007) provide a review of the preceding studies along with surveys of investors and developers. With a macro level analysis, these two studies serve as a turning point in the literature (and in this review) by shifting the focus toward the appraisal of green office buildings. Although "the immaturity of the property market for sustainable buildings is such that current valuation methods do not appear to have significant evidential proof of increased property value through sales or lease evidence for sustainable buildings," it is clear that the development of "advanced valuation techniques than the standard methodology of DCF" will require empirical evidence (Myers, Reed and Robinson 2007). Survey responses from developer and investor perceptions in New Zealand are similar to those of Pivo (2007) in that the most significant findings are that "sustainable buildings will play an important part in property portfolios in the future" (2007). New Zealanders are found to be more receptive to RPI than those in many other nations with increasing adoption of the trend in the country. Both Myers (2007) and Myers, Reed and Robinson (2007) conclude that sustainability of buildings has not been incorporated in the investor mindset and the added value of sustainable buildings has not been quantified enough to be incorporated into the valuation process.

Toward the end of 2007, the literature on this topic reached a critical mass, a paradigm shift that had been building for the last several years was about to occur (Nelson 2007). With an established base of knowledge on the subject built on theoretical groundings and empirical evidence slowly emerging, Rosenburg Real Estate Equity Funds, a division of Deutsche Bank, accurately predicted that the “U.S. institutional investment real estate sector [was] likely to finally – and dramatically – embrace sustainable building principles” (Nelson 2007). Green building had reached a tipping point that would change market dynamics and LEED program activity. With the principles of RPI and the triple bottom approach becoming mainstream, “the halo effect cast from green projects, which rewards firms for undertaking environmental actions, while the growing corporate accountability movement compels greater disclosure of environmental impacts” (Nelson 2007). The number of green LEED projects had been “growing at a compounded annual growth rate of 50% to 100%” with 100 green office buildings built in 2000 skyrocketing to approximately 1700 in 2006 and a total of 32.4 million square feet LEED certified in 2006 (Nelson 2007). With approximately 8,000 projects in the LEED pipeline, the fundamental shift in the market during 2007 was evident (Nelson 2007). This small section of data from USGBC presented by RREEF served as a turning point in the literature, with much more convincing empirical evidence foreseen in the near future.

The following year, RREEF produced another study authored by Andrew Nelson that analyzed the changes in the number and geographical locations of LEED certifications with a focus on an emerging trend of office building development. According to Nelson (2008), new construction and retro-fitting with green features was a major worldwide trend nearly evenly distributed throughout developed countries with green office buildings gaining the most traction. It was noted that office buildings have the most to gain from energy savings with “higher-end offices… seeing the greatest interest and developer activity” (Nelson 2008). Office buildings were more likely to be Class A, centrally located, and driven by tenant demand (Nelson 2008). It was expected that these drivers would exponentially increase the 10% share of LEED certifications in the coming years (Nelson 2008). All of this speculation would be confirmed by later quantitative studies that demonstrated this rise in the green office building stock.

In early 2008, Lorenz and Lutzkendorf (2008) revisited on their several previous studies by publishing an analysis of the theoretical rationale for incorporating sustainability into property valuations. Although they concede that “conceptual and technical difficulties mean that it is difficult to prove empirically the financial benefits as well as the risk reduction potential of sustainable buildings,” they remain optimistic that the lack of data would be resolved in the near future (Lorenz and Lutzkendorf 2008). Lorenz and Lutzkendorf (2008) suggest that one of the major limiting factors toward sustainable building valuation is how to identify sustainable structures. Since they are located in Germany, they are faced with the difficult task of understanding a wide variety of rating systems and suggest that a more systematized, universal standard is necessary. They see this as a major inhibitor to empirical research. Lorenz and Lutzkendorf (2008) believe that this is a challenge for “property professionals, their professional bodies, and their educational institutions. Making these distinctions will not only move sustainable construction quickly into the mainstream, it will also apply greater pressure on investors and investment managers” to include environmental and social issues in their decisions. Similar to all of the other literature cited in this section, Lorenz and Lutzkendorf (2008) theorize that paradigm shift is currently taking place and it is only a matter of time before it is in full swing. Empirical, quantitative studies on sustainable property values will flourish as adequate data becomes available in the coming years.

Qualitative research reappeared in 2010 with Runde and Thoyre's (2010) publishing of *Integrating Sustainability and Green Building into the Appraisal Process*. In this publication, they outline how the appraisal process continues to "sidestep" sustainability even though extensive research has shown that green buildings have financial benefits. They site RPI, SRI, corporate social responsibility and the Triple Bottom Line literature while berating the ability of studies to "capture the nuances of local markets, nuances that are at the core of professional valuation" (Runde and Thoyre 2010). They suggest that this inability is not the quality of the methodologies of the study but of the heterogeneousness of green building features, observable location clusters and the real estate market in general. Statistics and quantitative studies are seen to have little explanatory powers for rent premiums, sales premiums, and other benefits. They argue that "suggesting that the DCF is the best method of valuing green building bypasses the critical question of whether sustainability matters to the market, and thus, to what degree green features should (or should not) be valued" and this form of valuation is dangerous to engage in if the stakeholders do not "ordinarily use the technique" (Runde and Thoyre 2010). They challenge appraisers to understand sustainability and make their own decisions about how certification affects the areas in which they conduct their valuations. They believe that focusing on the premium paid for the subject assets misses the "larger picture: that sustainability is affecting everything around us, including all of the real estate that is not in any way sustainable, green, or high performance" (Runde and Thoyre 2010). If valuers understand sustainability and certification – like most investors who own the assets do – they will include them in appraisals as the market indicates their value. If they don't understand sustainability in general, they should understand why a buildings with certification trade for a premium over non-green comps.

Sayce et al., (2010) provide a review of many qualitative and a few quantitative studies – most of which are present in this review. This article suggests that there is still little academic research on rent and price premiums of green office buildings. They make the case for a "linkage in theoretical terms" of qualitative findings to empirical results (Sayce, Sundberg and Clements 2010). Of all the quantitative studies, Sayce et al., (2010) believe that only Miller et al., 2008, Fuerst and McAllister, 2008, and Eicholtz et al., 2009 successfully demonstrate "rental value differentiation". Each of these studies is discussed in detail in the next section. Although Sayce et al., (2010) see the developing literature as promising, they reassert that it is in its infancy. "For now the value and sustainability link is argued strongly in theory and opinion," but empirical evidence continues to have its shortcomings. They are highly critical that even the three studies previously mentioned are static rather than dynamic – they are each just a snapshot of a dataset at one single point in time. The studies are also limited by having no official benchmark for measuring sustainability. Sayce et al., (2010), like many others, advocate for a universal sustainable development benchmark as well as building performance data sharing and access. This publication provides a great overview on the literature that question: "Has the link between sustainability features in property and value been established?" (Sayce, Sundberg and Clements 2010).

Kontrimas and Verikas (2011) is included in this discussion to review mass appraisal by computations intelligence or Computer Assisted Mass Appraisal (CAMA). CAMA typically uses Ordinary Least Squares (OLS) linear regression to get within 1% of accuracy limits (Kontrimas and Verikas 2011). Similar to the discussion in Appendix A, the authors discuss how suitable CAMA is for the homogenous aspects of the housing market. They review the equations that are used in the appraisal process for these assets and explore the various intricacies of “computational intelligence based techniques” to show how CAMA out-performs other methods of appraisal. This study is important for its insights into the ability of linear models to be applied to similar assets while identifying why they are not as useful for more heterogeneous assets such as green office buildings.

In 2012, Warren-Myers (2012) provided an overview of literature on sustainability in valuation research. In this document, they “synthesise the plethora of research” beginning with qualitative research and moving towards empirical research – of which the author remains very critical. The paper suggests that this body of research does not provide professionals with the evidence they need to incorporate eco-certification into valuations. An important limit to the theoretical evidence base is that “normative theories suggesting how sustainability ‘should’ affect value, have been interpreted into scenario (case) studies and cost studies, which are not applicable to valuation practice and the assessment of market value” (Warren-Meyers 2012). Most of the research to date has been normative rather than empirical research. In addition, the vast majority of studies are case studies. All of these studies fall into three categories (Warren-Meyers 2012):

- Cost-benefit analysis or ratios
- Quantitative studies
- Valuation methodology simulations:
  - Cost approach analysis
  - Residual approach analysis
  - Income approach analysis

Of the empirical non-case studies conducted, the vast majority of all three types of studies oversimplify the complexity of the market and how it behaves differently in various locations. Appraisers and practitioners must interpret the result of these studies in the correct context (Warren-Meyers 2012). “There is a need for extensive analysis of unbiased, evidence-based research in individual and broader markets to provide guidance, evidence and knowledge of the implications of sustainability in the valuation of real estate,” but the problems of generalizing are many (Warren-Meyers 2012). Alteration of methodologies and theories are what will allow the valuation process for these assets to become uniform and accurate – static quantitative analysis only tells us the results of existing practices and identify the symptoms not the disease. Even together, the existing empirical evidence base does not provide a conclusive answers the link that Warren-Meyers (2012) and this study explore. For Warren-Meyers (2012), market values of green buildings increased because of the following:

- Reduced operating costs
- Lower annual operating costs through more efficient asset management
- Further cost saving made through the sustainable building
- Increased occupancy productivity and well being, less absenteeism and less staff churn
- Marketing advantage
- Increased market value for asset
- Increased rents
- Higher relative investment returns

They conclude by recommending that that both the case studies and large scale, generalizing studies be shifted toward quantitative analysis of individual micro markets. “The review of literature and research to date has highlighted some of the inappropriateness for the valuation profession of research into the relationship between sustainability and market value” on the macro level (Warren-Meyers 2012).

In a study of Australia and New Zealand real estate trusts and funds investment perception of sustainability, Warren-Myers (2012) concludes that they are primarily concerned with cost, especially including operating cost, minimization. Warren-Myers (2012) uses surveys the established literature to investigate the following questions:

- What are owners' perceptions of the importance of sustainability in the commercial real estate industry?
- What do owners perceive as the most important aspect of sustainability in commercial real estate?
- To what level do owners believe they are implementing sustainability in their portfolios?
- Where do owners perceive the value in sustainability implementation?

Most importantly, the respondents did not "realize the market value of these sustainability initiatives through the appraisal process of these assets" so they were most motivated by the cost savings during the holding of the assets. Warren-Myers (2012) provides a summation of the existing literature by drawing the similarities between the terms sustainability and life-cycle costing. They suggest that in many ways the terms are synonymous. So, in effect, many investors – since they are motivated by cost savings – they are motivated by sustainability. "LCC has, essentially, been redeveloped as a concept under a new name, sustainability, which provides increased marketing and profile for owners as a result of market perceptions toward climate change and global warming" (Warren-Myers 2012). This also serves as limitation. There is continued trouble identifying and quantifying benefits, including improved marketing. It is possible that much of this is a lack of knowledge which creates an inability to determine best practices management to fully implement sustainability in real estate.

## 2.2 A Review of Quantitative Studies

The increasing green office building stock has resulted in an immense amount of empirical academic and professional research with a variety of outcomes. This section will review studies that are applicable to this research with a specific focus on quantitative results.

Kats, et al. (2003) serves as a good place to begin for reasons beyond the fact that it is the first study in this chronological review. Although Kats, et al. (2003) is much more commonly cited for other conclusions which are discussed later in this review, it does include a small quantitative section in which 33 LEED projects, 25 office buildings and 8 schools which are found to have a cost premium of 2% when certified LEED Silver and 6% when certified LEED Platinum. An additional finding from this was that Gold and Platinum LEED certification return higher proportions of productivity and health benefits – $50 PSF for Certified and Silver and $75 for Gold and Platinum respectively. Financial benefits in general are found to outweigh costs over the life-cycle. From the meager sample size, it was determined that these benefits are "over ten times larger than the average 2% cost premium- about $3-5 PSF in California – for the 33 buildings analyzed" and when discounting at 5% the benefits are triple the costs over a 20 year period (Kats, et al. 2003). The quantitative research results are of little significant compared to the outcomes presented in the next section which helped shaped the trajectory of further research.

Davis Langdon, a global construction consultancy that advises clients on investments in property, infrastructure, and construction, has contributed to this body of literature by researching the costs of constructing green buildings according to specific goals. Goals for LEED building construction usually involve achieving points in specific

LEED categories. "By assisting teams to understand the actual construction costs on real projects achieving green, and by providing a methodology that will allow teams to manage construction costs" Davis Langdon attempts to "get past the question of whether to go green, and go straight to working on how" (Costing Green: A Comprehensive Cost Database and Budgeting Methodology 2004). In *Costing Green* (2004), they accomplish this — and re-confirm their conclusions in later studies — by taking a cross section of 138 buildings built for institutions, 93 non-LEED and 45 LEED seeking, and dividing their cost PSF by their gross square footage to arrive at a total cost. The sample includes 52 academic buildings, 49 laboratories, and 37 libraries. Quantitative results for this study are inconclusive beyond suggesting that there is a "lack of statistically significant differences between the LEED-seeking and non-LEED buildings" and that "the way to budget for sustainable features within buildings is to identify the goals and build an appropriate cost model for them" (Costing Green: A Comprehensive Cost Database and Budgeting Methodology 2004).

Similarly, in *The Cost of Green Revisited,* Matthiessen and Morris (2007), in conjunction with Davis Langdon, study 221 buildings with the same results: "there is no significant difference in average cost for green buildings as compared to non-green buildings." Although these studies are small in scope, specifically focusing on institutional buildings and only from a construction costing standpoint, the lack of a statistically significant construction cost premium is important as we continue to explore the financial benefits that result from going green. An abundance of data going forward would allow empirical research to analyze the results of the increasing green building stock.

2008 saw the widespread emergence of credible empirical studies (with adequate sample sizes) on green buildings and price premiums. A market for green buildings began to materialize and data began to support more quantitative studies with practical results. Most of these studies in the U.S. are conducted on LEED and ES certified buildings using CoStar data.

Miller, Spivey and Florance (2008) provide “the first systematic study” of LEED and ES certified buildings quantifiable market benefits. As opposed to all previous research, which they propose are just case studies, this investigation utilizes a large sample size of 1200 ES buildings (893 are office buildings) and 580 LEED certified Class A office buildings of more than 200,000 square feet, 5 stories or more, built after 1970 and are multi-tenanted. Although the break down between the 643 ES and LEED buildings is not clear, the hedonic OLS regression analysis finds a 9.94% sales price premium for LEED buildings and a 5.76% premium for ES above the 2000 non-certified buildings in the same markets. Secondary results indicate that buildings to LEED certification costs 3% more (according to surveys) and have lower cap rates by 55 basis point – which would indicate higher values by 10% also. They claim to not have enough data to break the study down by level of LEED certification and admit that a limiting factor to the study is that LEED and ES buildings may tend to be newer or recently remodeled to obtain certification. Even with these limitations, it is concluded that “green does pay off” with “higher occupancy rates, and faster absorption all of which translates into higher values that almost certainly exceed the marginal costs to go green” (Miller, Spivey and Florance 2008). The study concludes with a call for further research and provides a call to papers from the American Real Estate Society (ARES). Like many others, Miller, Spivey and Florance (2008) call for greater transparency and a standardized measurement for sustainability in the built environment.

Norm Miller (2010) picked up where he left off with Spivey and Florance in 2010 by publishing *“Does Green Still Pay Off?”* which serves to update the previous study by exploring new data. Miller (2010) acknowledges that properties which entered the development pipeline before the economic downturn of 2008 and came online subsequently may alter the rental and sales price premiums that he previously discovered with the help of his colleagues. In this newer study, Miller (2010) explores rents, vacancy rates, cap rates and sales prices PSF on 378 commercial office-building sales. Of this sample only 5 sales were LEED and 12 were ES. Vacancy rates were discovered about 4% to 5% higher and rent PSF was approximately $2.5 more for LEED buildings. Cap rates were lower for LEED (7.26%) and ES (7.63%) as opposed to non-certified (8.8%), but, similar to the previous study, this could be because they are typically newer or have been renovated recently. Sales premium PSF for LEED was approximately $20 PSF while ES was approximately $20 lower than those in the non-certified category. Although this was follow-up study with similar results, Miller's (2010) small sample size and other limitations made this study not very representative of the green building stock.

Many of the most comprehensive studies on the green office building market are product of the duo of Franz Fuerst of the University of Cambridge and Patrick McAllister of the University of Reading. Their studies are the most relevant to this research because they predominately focus on green office buildings. The researcher had the pleasure of meeting and discussing this research with Patrick McAllister at an ARES conference. Their first and most widely cited study, *Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Property Values* (2008), utilizes CoStar data produce multiple hedonic OLS (Ordinary Least Squares) regressions with approximately 1,900 green buildings, of which 626 were LEED and 1,282 were ES. The non-certified sample included 24,479 buildings. With a total of 9,806 obervations between 1999 and 2009, Fuerst and McAllister (2008) conclude the following:

- Median asking rents for LEED and ES are approximately 35% higher.

- ES has 12% and LEED has 10% premium on net leases.
- Rental premiums are approximately 5% for LEED and 4% for ES.
- Sales price premiums are 25% for LEED and 26% for ES.

They conclude that the results are compelling with a few limitations. They indicate this small snapshot has many controls, but is bound to be imperfect. Although many variables are controlled for – since certified buildings tend to be homogenous and at the upper end of the market – Fuerst and McAllister (2008) emphasize that the premiums found are indicative of existing data only.

Fuerst and McAllister came out with another study focusing on occupancy rates the following year. With a sample size of approximately 292 LEED and 1,291 ES buildings, they found that occupancy rates were 8% higher for LEED and 3% higher for ES; however, “the effects are concentrated in certain market segments” (Fuerst and McAllister 2009). Once again using CoStar data they produce a hedonic OLS regression indicated that the demand for certified structures is growing as the market identifies value. They suggest that “occupiers can gain tangibly from lower utility costs and incentives or subsidies and, perhaps less tangibly, from improvements in business performance and marketing benefits” (Fuerst and McAllister 2009). Again they emphasize that this study is also a historical snapshot and encourage more empirical studies.

Later the same year, with the same data, Fuerst (2009) reached several other conclusions about regional markets and distributions between different levels of LEED certification. In 2009, LEED certifications were distributed as follows (Fuerst 2009):

- 30% Certified
- 34% Silver
- 31% Gold
- 5% Platinum

Additionally, clusters existed at the bottom end of certification thresholds: "once organizations realize that a higher certification level is within reach, they may opt to commit the additional funds necessary to obtain a higher level of certification rather than 'wasting' points on a level achievable with a lower point total" (Fuerst 2009). Also important is a major shift in the types of entities seeking LEED certification. In 2000-2002, only 3% of LEED seeking construction were private developers whereas 43% were corporate, while in 2006-2008, 26% were private developers and 34% were corporate, which Fuerst (2009) sees as particularly encouraging. Finally, Fuerst (2009) concludes that a consensus among the empirical literature has begun to take over what was formerly theorized: "that both LEED and Energy Star buildings achieve higher average prices than tier Class A peers." The premium depends on the study.

In 2011, Fuerst and McAllister (2011) released a study that analyzed whether commercial office buildings obtained premiums in multiple areas. With a sample of 2,688 LEED and ES buildings (313 of which were LEED, 2,111 were ES and 264 were both) and a total of 13,971 transactions and 36,236 rent observations, "both the OLS and robust models indicate substantial sale price premiums" of 18% for ES and 25% for LEED (Fuerst and McAllister 2011). Although they may be limited by the market downturn of 2007-2009, rental premiums of 3%-5% for both ES and LEED were also discovered (Fuerst and McAllister 2011). Fuerst and McAllister (2011) go on to suggest that eco-labeling has had the desired effect: shifting the demand curve to encourage the production and occupation of certified buildings. They believe that suppliers now have financial incentives to build green because of realized financial advantages of eco-labeling.

A shorter follow-up study by Fuerst and McAllister (2011) the same year which focuses on commercial properties with BREEAM certification and Energy Performance

Certificates (EPC), a form of eco-labels utilized in the UK, has very different results. With 708 commercial property assets in this cross-sectional study, they find “no evidence of a strong relationship between environmental and/or energy performance and rental and capital value” (Fuerst and McAllister 2011). They are surprised that EPCs do not indicate improved financial performance. They supplement these findings with several caveats. They suggest that the UK market has not been very responsive to EPC similar to ES in its infancy. Another suggestion is that the sample size is small and there is a lack of control for the various locations that are distributed throughout the UK. The conclusion that EPC did not influence market rent or market value in the UK by Fuerst and McAllister (2011) is encouraging in the fact they can be very subjective. Even though they are green building advocates, they can remain unbiased even in an examination of their own country.

In 2012, Fuerst picked up on the themes that he explored with McAllister by joining Reichardt, Rottke and Zietz to publish *Sustainable Building Certification and the Rent Premium: A Panel Data Approach* (2012). The sample for this study included 7,140 buildings, 1768 LEED certified (while the other serve as non-certified controls) in the 10 largest metropolitan statistical areas in the country. From 2004 to 2007, hedonic OLS regressions indicate that LEED buildings had a rent premium of 2.9% and ES buildings had a rent premium of 2.5%. Fuerst et al., provide an extensive literature review in this paper – the directly applicable of which is covered in this section – in addition to a large amount of quantitative analysis. Similar to Fuerst’s other work, Fuerst et al., concludes with a call for standardized certification standards for green buildings.

After tracing the history of papers that Franz Fuerst and his colleagues contributed to in the literature, we revisit the year 2008 with a study of LEED and ES lease rates, occupancy rates and price premiums by Wiley and Benefield (2008). They posit that there is a “relationship between energy-efficient design and the leasing/sales markets for commercial real estate” and test this theory empirically with a CoStar sample of Class A office buildings (Wiley and Benefield 2008). This sample includes 7,308 properties in 46 markets across the U.S. with current leasing and occupancy data and a second data set with 1,151 observations and controls for “property size, Year Built, and date of sale”. This two-stage approach results in “an R-squared of 63.2% for OLS and 58.4% for 2SLS”. The results suggest that the “premiums for green design are dramatic” with rents higher by 7% to 17% and occupancies higher by 10% to 18% while the “selling premium is estimated at the $30 PSF for ES and $130 PSF for LEED. This study indicates the largest premium PSF of all the studies covered in this literature review. It also indicates the largest improvement in occupancy as the result of LEED. Wiley and Benefield (2008) suggest that there must be benefits beyond operating expenses that explain these outcomes, but the researcher is of the opinion that the inflated PSF results may be a methodological or data error. This observation is the result of these conclusions being an extreme outlier compared to other studies with similar sample sizes.

Pivo and Fisher (2008) continue their investigation of RPI with a quantitative study that investigates whether “energy efficient properties, properties near transit, and properties in or near urban regeneration areas have performed as well or better than other properties without such characteristics.” Using NCREIF data from 1998-2008 with 4,460 properties, of which 648 to 1,450 were included in each quarter, they explore how RPI properties performed compared to non-green alternatives with comparative statistics and regression analysis. This study is based on ES and location characteristics such as “in or near a CBD regeneration area,” “in or near suburban regeneration area,” “near a CBD transit station,” and various other scenarios (Pivo and Fisher 2008). In the investment portfolio analysis section, they conclude that ES properties have “5.9% higher incomes and 13.5% higher market values PSF, and suburban transit-oriented properties 12.7% higher incomes and 16.2% higher market values than other suburban offices" (Pivo and Fisher 2008). These higher incomes for ES were driven by "9.8% lower utility bills, 4.8% higher rents and .9% higher occupancy rates" while transit-oriented properties had 1.6% higher occupancies and 6.2% lower expenses (Pivo and Fisher 2008). In addition, cap rates for ES were lower by 50 basis point or .5% (Pivo and Fisher 2008). Pivo and Fisher (2008) are one of the few authors that follow up their qualitative studies with solid quantitative analysis. They build upon the theoretical constructs that they developed over years of studies regarding RPI. Pivo and Fisher (2008) conclude with the notion that investors can have greater confidence in investing in RPI as empirical studies have proven what they proposed in previous research. They further suggest that portfolios can be developed around RPI – which we have seen private companies and REIT's do in recent years. A final suggestion is that, since these properties only provide marginal financial benefits, it is unlikely that mass investment in these assets will drive returns down.

In Newsham et al., (2009), an investigation of data from the USGBC and New Buildings Institute is used to analyze 121 LEED certified buildings with T-tests. In this dataset, "LEED certified buildings used 18-39% less energy per floor area" on average (Newsham, Mancini and Birt 2009). This reasonable finding is complicated by the fact that they find 28% to 35% of buildings in this dataset use more energy than non-certified comps. In addition, LEED certification level was not correlated with energy performance – higher levels of certification did not increase energy efficiency. The findings are preliminary and the sample size is small compared to other studies being composed at this time, but it provides one of the few energy performance analyses and, in 2009, "the best data we have so far with which to explore if green buildings are delivering on energy savings. The answer appears to be 'Yes, but…', which is likely no surprise to green building advocates" (Newsham, Mancini and Birt 2009).

Dermisi (2009) published a paper that is the most similar in its methodology and inputs to this study: *Effects of LEED Ratings and Levels on Office Property Assessed and Market Values*. This study, unlike many others, investigates assessor-generated values and utilizes the same inputs as this research – CoStar, USGBC, and jurisdictional tax assessors – however, it primarily investigates differences between levels of LEED certification. With three regression models including OLS, maximum likelihood spatial error, and fixed effects with location controls, Dermisi (2009) concludes that ES increases assessed and market value (MV) substantially, LEED-EB Gold has a strong positive effect on assessed value (AV), while LEED-EB Silver has a strong effect on both market and appraised value. The data includes 351 office buildings across 36 states with inputs from February to the summer of 2009. Similarly, LEED-NC (New Construction) Gold has a strong positive effect on market value while LEED-Core and Shell almost doubles this effect for AV in one model and does not have a significant effect in another model. Compared to other certification levels for new construction, LEED Silver decreases market value by 36% (Dermisi 2009). Existing buildings "at the Gold level are associated with a 77% increase in AV compared to other LEED properties, while LEED-EB at the Silver level are associated with a 118% increase in AV and a 95% increase in MV compared to other LEED properties" (Dermisi 2009). With LEED for new construction, Gold has a 50.7% positive effect on MV while effect on AV is not significant (Dermisi 2009). "In contrast, the AV and MV of LEED-NC properties at the Silver level are affected negatively by 51.3% and 42.8% respectively" (Dermisi 2009). LEED Core and Shell is found to have a 80.4% increase at the Gold level and 127% increase at the Silver level (Dermisi 2009). The researcher believes that this is often caused by the fact that minimal upgrades to core and shell can achieve basic certification while extensive renovation is often required for anything higher. This conclusion is further exemplified by the fact that LEED Core and Shell basic certification results in a 91.8% decrease in AV as compared to higher levels (Dermisi 2009). This paper concludes with the reaffirmation that LEED is here to stay due to increased investment returns and the realization of benefits to property owners. Dermisi (2009) suggests that empirical “research conducted by companies, associations, and now academics” has brought about this paradigm shift.

Beginning in 2009, Eicholtz and Kok published several articles on the subject matter, two with John Quigley and one with Erkan Yonder. Eicholtz, Kok and Quigley (2009) penned “the first credible evidence on the economic value of the certification of ‘green buildings’ – value derived from impersonal market transactions rather than engineering estimates.” This multiple regression study included 10,000 buildings divided into 900 clusters. LEED and ES buildings were compared to non-certified comps within 1,300 feet. They relate rent and sales premiums of properties within clusters of .2 square miles and control from 199 to 694 dummy variables in each regression. The results show that selling premiums may be as much as 16% for certified properties and ES buildings rent is about 3% – although the effective rents is estimated at 6% (Eicholtz, Kok and Quigley 2009). Using a 6% cap rate for valuation, they estimate the value for green certified buildings is about $5.5 million in their sample (Eicholtz, Kok and Quigley 2009). One unique finding from their hedonic regression is that “the premium is negatively related to the location premium for a building, within and between cities: a label appears to add more value in extreme climates when heating and cooling expenses are likely to be a larger part of total occupancy cost” (Eicholtz, Kok and Quigley 2009). This makes sense as both operating expenses and the energy line item are higher in extreme climates. Before echoing others calls for sharing of operating data and energy use, they remind the reader that intangibles such as health and productivity can effect rent and sales premiums, but they are of the opinion that energy efficiency is the main driver (Eicholtz, Kok and Quigley 2009). Although it was definitely not the first article to identify these premiums, this paper is a valuable contribution to the literature and the findings are important for this research.

In 2012, Eicholtz, Kok and Yonder (2012) picked up on the previously reviewed publication with a study of sustainability premiums for REITs. This study examines whether REIT performance is affected by ES and LEED. In August 2011, at the time there were "more than 700 LEED-registered properties on the balance sheet of 44 REITs" and "919 Energy Star-certified properties owned by 71 REITs". The results of multiple two-stage regression suggest that "if an REIT increases the share of green properties within the portfolio by 1%, the return on equity increases by 7.39-7.92% for LEED-certified properties and 0.66 percent for Energy Star-certified properties" (Eichholtz, Kok and Yonder 2012). A premium of this caliber seems optimistic to the researcher, but this REIT study is very unique and has not been studied effectively by any other researchers. Eicholtz, Kok and Yonder (2012) explain their models beta of 0.14 for LEED properties and 0.01-0.03 for ES, by suggesting that "green properties are less exposed to energy price fluctuations and occupancy risk." They conclude that REIT portfolio ownership of LEED and ES buildings yields higher performance and less risk including being less effected by real estate cycle.

Eicholtz, Kok and Quigley (2013) rejoined to publish *The Economics of Green Building* which explores how the market for green building changed during the economic downturn from 2007 to 2009. In this study, they explore approximately 21,000 leased buildings and approximately 6,000 transactions. They use a cross section of 694 clusters to determine that investors primarily investigate buildings operating expenses, not certificates themselves, to make green building investment decisions (Eicholtz, Kok and Quigley 2013). Secondary conclusions include that the economic downturn of 2007-2009 did not have an effect on ES and LEED building returns even with a large number of buildings were in the pipeline and delivered through the period, driving up supply (Eicholtz, Kok and Quigley 2013). When “green office space increased substantially in a stagnant or declining market for commercial office space”, sustainable certified properties held their value relative to non-certified properties (Eicholtz, Kok and Quigley 2013). Returns form certified buildings did not “significantly degrade” investment returns relative to conventional buildings (Eicholtz, Kok and Quigley 2013). This study controls for rent parameters including between gross and triple net leases. Sales premiums for green buildings were found to be 13% and rents were 3% higher on average between 2004 and 2009 (Eicholtz, Kok and Quigley 2013). Similar to their previous studies, they emphasize how significant energy performance and data sharing of operating expense is to the environment.

Issa et al., (2010) began an investigation into the Canadian perception of health and productivity benefits by citing Kats (2003) conclusion that these categories represent 70% to 78% of buildings benefits over their lifecycle. Using T-tests and ANOVA, Issa et al., (2010) show that Canadian practitioners “identify high cost premiums as the primary barrier to investing in green practices, and energy cost savings as the most important type of saving incurred in green buildings.” With a sample of 1200 practitioners, most indicate that they are not confident in the research and the researches involved in the process – a major problem is that practitioners are disconnected from those who are the most knowledgeable about green practices (Issa, Rankin and Christian 2010). As a result, more empirical and reflective research practices are encouraged by the authors.

Reichardt, et al., (2011) investigates how businesses consider sustainability when leasing office space. In a Heckman two-staged model with 235,960 tenants, 1,877 green buildings, and 47,112 uncertified comps, they find that businesses prefer to lease green office space because of "direct and indirect economic benefits of sustainable buildings and by their ecological responsibility" (Reichardt, Rottke and Zietz 2011). Reichardt et al., (2011) control for dozens of variables; most importantly, they control for age, renovations, stories, rentable area, lot size and class. They explore following questions:

- "First, which industries are more likely to lease office space in sustainable buildings rather than in conventional buildings?"
- "Second, does sustainable building certification affect the amount of space leased in the buildings?"
- "Third, is the preference for sustainable space uniform across types of space use?"

They discover that various industries have responded differently in their office leasing decisions – some have a much higher preference for LEED and ES space. Market competitiveness is seen as the motivating factor for these business decisions for the private sector while mandates, such as the one that requires all new federal buildings to be a minimum of LEED Silver, are driving the public sector (Reichardt, Rottke and Zietz 2011).

In a study that aims to "examine whether rental premiums accrue to environmentally certified Class 'A' office buildings and, further, to what extent such premiums vary with the political ideology of the local market", Harrison and Seiler (2011) discover that in liberal jurisdictions these assets obtain a 6% rent premium while in conservative jurisdictions a less than 2% rent premium exists. This interesting study seeks to ascertain the correlation between areas that are more politically ideological to the left or right and the rent paid for green office buildings. States are divided into red and blue states based on the presidential candidate won in each state in 2008. This is interesting to the researcher as in his experience studying these assets in various U.S. markets lead him to speculate about this trend. Further, the researcher is suspicious that variations in the tax appraisal process for these assets may be correlated with municipalities' predominant political ideology. With data from CoStar, Harrison and Seiler (2011) use OLS regression to study "certified structures as a function of techniques, the space market characteristics, economic environment, and political ideology within each local market area." *The Political Economy of Green Office Buildings* provides interesting ideas for analyzing the policy making process as it relates to taxing jurisdictions' political economies.

A research study in Sweden by Bonde and Song (2013) on the effect of Energy Performance Certificates (EPC), which is similar to ES, on green office building appraisals yields a another perspective of the subject assets. Based on a regression analysis with EPC data from 2003 to 2010 with 276 buildings and 1,572 observations, the authors' results show that energy efficient office buildings do not benefit from increased market values (Bonde and Song 2013). Values in Sweden are influenced by the normal things – rent, occupancy, location, Year Built – but do not show any correlation with EPC. Although they admit that transaction prices would have yielded more robust testing, Bonde and Song (2013) suggest that energy source and the cost of that source may be the cause as geothermal heating and cooling require a much higher capital expenditure but yield much lower operating expenses. This is an important conclusion for this research and one of the reasons this study is included. Although studying the appraisal process for green office buildings will lead to results, whatever is discovered quantitatively is just the underlying symptom of the root cause. If LEED certified office buildings obtain rent or price premiums, there are physical aspects of these structures that are the underlying disease.

## 2.3 Influential CBA and DCF Publications

The two publications that are the most influential and relevant to this study are *The Costs and Financial Benefits of Green Buildings* and *Value Beyond Cost Savings*. Although they both have relatively insignificant quantitative findings, they represent paradigm shifts towards CBA and DCF in this body of literature. They are, by far, the two most-cited publications in the applicable literature.

### *2.3.1 The Costs and Financial Benefits of Green Buildings*

This 2003 report to *California's Sustainable Building Task* Force is the most highly cited non-academic publication on this subject. Academic articles on subjects relating to green building routinely site Greg Kats, et al. (2003) as the foundational report for the CBA approach to green building valuation. Kats, et al. (2003) pioneered many new ideas and shifted the focus of green building research on breaking down the financial, quantifiable benefits of green buildings. It was one of the first to provide a thorough analysis of the state of green buildings and what was known about their costs and benefits. It suggested that benefits be separated into two categories: quantifiable financial benefits and those that are unquantifiable. The way that the private and public sector value these benefits is fundamentally important in green building appraisal — valuing benefits differently has a large effect on the subject assets appraisal. The private sector discounts the perceived value of the less-tangible benefits much more heavily than the public sector because, for the public sector, the value is derived from a more holistic approach.

The report suggests that, in 2003, building sustainably was a positive net present value decision. The widespread coverage that this document achieves in the academic literature suggests that this 134 page report was, as it set out to be, “the most definitive cost-benefit analysis of green building ever conducted” (Kats, et al. 2003). In addition to providing insight into the financial viability of green buildings, Greg Kats, et al. (2003) set forth several other new ideas that guided the green building literature.

This document is one of the first to suggest that differences in the adoption rates of green building practices between the public and private sectors stems primarily from their financing terms and objectives. The assumption was made that “while a government entity should care about the benefits their building may have for society, a private commercial entity may not” since a business is focused primarily on profitability (Kats, et al. 2003, 84). Although is not a new idea, the conclusion from this assumption was a realization that: “because of higher capital costs and hurdle rates, future financial benefits are discounted more heavily by private entities than by public ones, potentially further reducing the perceived value of future green building financial benefits for the private sector” (Kats, et al. 2003, 84). This finding has guided the academic research to two different spheres: privately and publicly owned assets. Similar to most other academic articles, this has important implications for this study. Not only did it guide the literature towards more studies focused on quantitative analysis of green office buildings, but it imposed the question: Since private assets are taxed differently, would integrating their unique financing arrangements affect taxation?

Similar to how Lorenz and Lutzkendorf (2008) divided the types of green building benefits into monetary and non-monetary categories, Kats, et al. (Kats, et al. 2003) separated the financial benefits into six categories: energy value, emissions value, water value, waste water (construction only) – 1 year, commissioning O & M value, and productivity and health value. The largest financial benefits were “reduced energy, water, and waste costs; reduced emissions; lower operating and maintenance costs; lower insurance and risk costs; and enhanced productivity and health” (Kats, et al. 2003).

The resulting analysis suggested that productivity and health value contributed over three quarters of the value of LEED certified and Silver buildings, while for Gold and Platinum this category represented even larger percentages. Also important was the suggestion that the results of the study should be kept in the context that productivity and health are much more difficult to analyze or predict. Although it was not as valuable as the first part of the study, the subsequent quantitative section of this study helped the authors arrive at their valuable qualitative conclusions.

The major contribution of the quantitative part of this study, which is based on an unreasonably small dataset of 33 green buildings, and the reason it is commonly cited, is for its effective use a lifecycle costing—a common financial analysis tool which is “based on discounting all future costs and benefits to dollars of a specific reference year that are referred to as present value (PV) dollars” (Hershfield, et al. 2005). Although lifecycle costing was already commonly used in real estate, many were critical of its applicability to green building finance and appraisal.

This report has changed the direction and theme of subsequent research on the green building appraisal. The resulting shift towards CBA to quantify the benefits of green buildings with particular regard to how these features affect the private and public sphere differently is in many ways the paradigm shift that made this research possible, especially from a financial, DCF analysis standpoint. It served to refine the conversation about “costs and benefits estimates (and probably increase estimated financial benefits) of property values" and suggested the subject merited further research, particularly that which focused on how the private sector was benefiting from "increased rent and lower vacancy," "higher IRR's," "faster tenant lease-up," and "increased income, lower expenses, and lower future liability," and the implications for appraisal processes (Kats, et al. 2003, 87-93). Although the report provides little empirical evidence to validate these claims, it set the tone and direction for further research by proposing that future studies concentrate on IRR case studies, specifically how cost savings increase financial returns, and how these savings should be accounted for during green building appraisals.

*2.3.2 Value Beyond Cost Savings (VBCS)*

The most comprehensive and current professional publication on sustainable development is *Value Beyond Cost Savings: How to Underwrite Sustainable Properties* (2010). This 2010 document, which was published by the Muldavin Company in accordance with their role as the founder and manager of the Green Building Finance consortium, is the culmination of over a decade of research conducted by all green building professionals and compiled by consortium members, an implementation team, and the consortiums advisory board (Muldalvin 2010). This all-inclusive overview includes both qualitative and quantitative information and documentation from hundreds of publications, which it utilizes as inputs to demonstrate the current state of financial feasibility for commercial green buildings. This publication serves as a primary source because it is generally regarded as the most well respected and valuable contribution to the underwriting and appraisal of sustainable real estate literature. Above all, the findings suggest that DCF analysis is by far the best-suited appraisal approach for sustainable properties. Accordingly, this document is intended to provide tools to aid in the extrapolation of financial data relevant to individual properties and the dynamics of the complex market which determines the demand for user space.

VBCS provides practical implications for sustainable development. It recommends a six-step process for sustainable property financial analysis (Muldalvin 2010, 97-145):

1. Select Financial Model: “The type of financial analyses required is significantly influenced by the sustainable property investment decision (see Exhibit II-3 in Chapter II). New construction, retrofits, existing building acquisitions, or leasing and financing decisions have always required different models and data. Sustainable property financial analysis requires some new thinking and analytic techniques to properly collect and analyze the data input to the models, but the fundamental approaches to decision-making used by the real estate industry will remain largely the same” (Muldalvin 2010, 100). A variety of financial analysis alternatives exist. Selecting the correct financial model given your specific objectives is the key to successfully determining the value of the investment decision given the investors individual context.
2. Evaluate Property “Sustainability”: “Definitions and certifications provide a basis for investors to measure and compare properties, a critical foundation for financial analysis. Most importantly, from a financial perspective, to determine which certification and assessment systems are important for a specific property, the underwriter/valuer must evaluate how regulators, space users and investors utilize and rely upon different assessment systems or tools, and the specific sustainability thresholds to achieve benefits from each group for the subject property”

(Muldalvin 2010, 106). Determining the certification system used and level of certification in accordance with the demands of prospective of future users of the space is crucial to deciding the value of sustainable features and certifications.

3. Assess Costs/Benefits of “Sustainability”: “After selecting the most appropriate financial analysis and assessing the property’s ‘sustainability,’ the valuer needs to evaluate the subject property’s sustainable costs and benefits. It is this detailed property specific analysis that separates independent valuation and underwriting of a sustainable property from the more prevalent ‘general business case’ analysis” (Muldalvin 2010, 106). Analyzing how the market value is increased or decreased given the costs and benefits of individual features improves the overall financial analysis.
4. Evaluate Financial Implication of “Costs/Benefits”: Link the costs/benefits to financial performance—development costs, development risks, space/user demand, operating costs, operations/capital costs, cash flow risks, public benefits, and investor demand. Then, evaluate the “net impact of costs and benefits” (Muldalvin 2010, 114). Finally, assess these net impacts in each of the financial performance categories. Breaking down each category for micro level analysis further improves the accuracy of the cost/benefit analysis.
5. Determine Financial Model Inputs: Consider “specific financial model inputs—rents, occupancies, tenant retention, etc.—taking into consideration, simultaneously, all factors, both sustainable and non-sustainable, that affect the financial model inputs” (Muldalvin 2010, 123).

"Key inputs influenced by sustainable properties include rental rates, annual rent growth, down time between tenants, renewal probability, utility expenses, tenant improvements and leasing expenses, and a growth factor for expenses other than real estate taxes" (Muldalvin 2010, 128). Finally, return to the categories in step 4 and "integrate all the information collected on both sustainable and non-sustainable factors, for each of the key financial model inputs, and make decisions" for each category (Muldalvin 2010, 130). Isolating the sustainable and non-sustainable model inputs allows the evaluator to more accurately forecast future DCF inputs.

6. Risk Analysis and Presentation (RAP): "One of the most important issues in underwriting the financial performance of sustainable properties is a full understanding of the risks associated with the pro-forma cash flows in the DCF model. For the purposes of improving sustainable investment decision-making, more detailed documentation of the risks of sustainable property investment, both positive and negative, are necessary to provide decision-makers with proper context for evaluating pro-forma financial performance. RAP should be part of the investment package that goes to decision-makers for any investment decision. The form and content of the RAP will vary based on the context of the investment decision, but should be directly linked in the presentation to the quantitative valuation and rate of return calculations" (Muldalvin 2010, 131). Reducing ownership risk by improving cash flow adds value by reducing capitalization and discount rates. Adjusting these rates, given the comparable market data and specifics of the subject property, is

critical to the overall success of feasibility study. “One of the most important issues in underwriting the financial performance of sustainable properties is a full understanding of the risks associated with the pro-forma cash flows in the DCF model. For the purposes of improving sustainable investment decision-making, more detailed documentation of the risks of sustainable property investment, both positive and negative, are necessary to provide decision-makers with proper context for evaluating pro-forma financial performance. RAP should be part of the investment package that goes to decision-makers for any investment decision. The form and content of the RAP will vary based on the context of the investment decision, but should be directly linked in the presentation to the quantitative valuation and rate of return calculations” (Muldalvin 2010, 135)

The culmination of many years of research of this subject, the most significant findings and conclusions related to property valuation are as follows (Muldalvin 2010, 136):

1. Sustainable properties should be more valuable
2. Valuation is not just about formal full narrative reports
3. Valuers have skills to make significant contributions to sustainability
4. Fundamental valuation methodologies do not need to change
5. Sustainable valuation must look beyond costs
6. Public value has increasing importance to private value
7. The income approach is critical to understanding sustainable value
8. Valuers need to get better at integrating risk analysis into value

9. Valuers must prove value of sustainability one property at a time
10. Performance measurement is key to sustainable property performance
11. Energy is a more critical issue for sustainable property valuation

The most significant findings for the purposes of this study is that, although the income approach is the most accurate way of appraising sustainable properties, most research conducted prior to 2009 overemphasizes development costs and operating cost savings. As a result, most of the prior research is inherently flawed because each of these factors does not incorporate risk analysis effectively (Muldalvin 2010). For this reason, Muldalvin is critical of a wide variety of studies that focus on development costs and operating expense savings rather than market transaction which are more apt to use in income valuations. Even though incorporating risk analysis is difficult, the DCF method of appraisal remains "well suited" to estimate the costs and benefits "into financial measures such as rate of return or net present value, traditionally used by real estate capital providers" (Muldalvin 2010, 98). This financial analysis must incorporate the effects of the subject properties sustainable attributes (Muldalvin 2010). More importantly, those who estimate the effects of sustainable attributes must recognize that "sustainable property financial modeling and analysis requires a more sophisticated and explicit analysis and documentation of the risks—both positive and negative—that influence the cash flow to provide decision-makers the proper context for interpreting rate of return, net present value, or valuation conclusions" (Muldalvin 2010, 98).

As one of the main themes of the Consortiums work, this document emphasizes that "different types of decisions require different types of financial models, analysis, and data" (Muldalvin 2010, 99) depending on the objectives of the parties involved. DCF analysis is heavily reliant on risk assessment. If future demand for a subject property is underestimated, DCF models underestimate property values. Even though a rate of return usually determines whether a project is feasible, which is the focus of this literature review, sustainable property decision-making is often unrelated to financial instruments as risk is difficult to quantify. Yet, in order to guarantee the continued use of sustainable development techniques, these projects must be financially feasible to be underwritten. This leads to a final key conclusion—"the biggest challenge to sustainable financial analysis is not the modeling, but the integration of sustainability considerations into the determination of input assumptions" (Muldalvin 2010, 99).

VBCS has a variety of conclusions that are relevant to this research. The main contribution is that DCF modeling is confirmed as the best method for appraising sustainable properties, but a lack of risk analysis often results in underestimating demand during financial forecasting (Muldalvin 2010). DCF analysis is heavily reliant on risk assessment. If future demand for a subject property is underestimated, DCF models underestimate property values. This is particularly troubling when considering that LEED buildings are most attractive for those in long term holding periods (Fuerst 2009). The confirmation of DCF as the best method of assessment is encouraging. Within its 323 pages, VBCS provides a big tent, seemingly comprehensive synopsis of the current state of research on this subject matter in the form of a professional publication.

## 2.4 Conclusion

This literature review has explored the applicable research on the emergence and continued spread of the green office building movement and resulting market for these assets. With the exponentially growing amount of literature that has emerged over the last ten years, it is evident that we have only seen the beginning of studies on this subject.

The first section of this review explored the start of the green building investment movement. During this period of qualitative research, RPI, SRPI, the Triple Bottom Line, and other namesakes were coined to identify, encourage, and advocate for the continued progress towards empirical studies. Although they lacked the quantitative data as a result of small market share, these studies were integral to driving home the fact that LEED and ES buildings should be more valuable given their economic, social and environmental benefits.

Quantitative studies were explored in the second category of this review. Although there is still no consensus on the amount that certification increases market and appraised value, it is promising that the vast majority of studies conclude that certification does increase market value. This section is further reviewed in the Quantitative Sources Matrix found in Appendix B. Appendix B includes a review of all applicable quantitative studies with sample sizes of over 500 green buildings. Although the results are encouraging, it should be noted that these studies tend to generalize their findings between unique sub-markets.

The third section of this review explored two studies that the researcher found to be the most comprehensive and, as a result, the most cited in the literature. Kats et al., (2003) and VBCS (2010) each served as a paradigm shift in the literature. Although green buildings and qualitative research existed before, Kats et al., (2003) drove qualitative research with renewed vigor. This foundational document spearheaded widespread market adoption of green buildings by streamlining research about the financial benefits these assets provide. VBCS (2010) created its own paradigm shift in the literature by promoting DCF analysis for these assets. It also provided the first comprehensive set of policy recommendations for valuers.

This research seeks to build upon the findings of the literature reviewed by analyzing the tax appraised values and the tax appraisal process in major Texas cities. A best practice methodology for sustainable property finance and appraisal will improve communities and advance our understanding of green office buildings while furthering this growing body of literature.

# Chapter 3

## Research Framework

### 3.1 Research Hypotheses

The literature covered in the previous chapter presents a broad range of established research. Although there are a broad range questions that can be drawn from the conclusions of existing studies, the following are the testable hypotheses that this study seeks independently test in both the ES datasets:

$H_1$: *Commercial office buildings with higher levels of ENERGY STAR (ES) certification have higher per square foot (PSF) tax appraised value of property improvements.*

$H_2$: *Commercial office buildings with higher levels of ENERGY STAR (ES) certification in the selected zip codes have higher per square foot (PSF) tax appraised value of property improvements.*

### 3.2 Data Collection

The hypotheses above will be tested using sales information gathered from tax appraisal districts in the five most-populated Texas cities – Austin, Dallas, Fort Worth, Houston, and San Antonio. Lists of buildings with ES certification are obtained from the EPA. The lists provide a wealth of data; however, identifying properties that are present in the local tax appraiser websites and the ES lists, independently, is complicated. For these reasons, various challenges with data collection, cleaning, and marrying of a variety of complex, and often inconsistent, sources exist. This section explains the reasoning behind this studies construction and data collection. Every method outlined herein has been made ensure the integrity of this research.

### *3.2.1 ENERGY STAR Dataset Collection*

The ES dataset is sourced from the EPA directory of all ES rated buildings. At the time of collection, the database had a total of 23,442 properties registered. Of these properties, 134 located in Austin, 135 in Dallas, 22 in Fort Worth, 334 in Houston, and 98 in San Antonio, for a total of 723 properties. The data includes the following variables for each structure: building ID, building name, building type, building owner, manager, address, city, state, zip, years certified, ratings, square footage, and year constructed. All the data is clean, consistent and concise. There are 14 building types which are defined by use. Building types include bank branch, hotel, K-12 school, medical office, office, retail store, senior community care, supermarket/grocery store, warehouse and storage, hospital, courthouse, auto assembly, cement, financial office and other. The category of office is the most applicable to this study for the reasons discussed in the previous chapters. All properties were certified in 2013 and provide a rating for that year. Data from previous years of certification is present, but not utilized in this study.

Of the 723 properties, 370 have all variables and are included in the sample for analysis. Sufficient data was collected on only five property types. Within the analyzed dataset there are 19 hotels,16 medical offices, 298 commercial offices, 5 other, 5 retail stores and 27 supermarkets (all of which are owned by the grocery chain H.E.B.). The 298 commercial offices provide the most consistent data for analysis. As the literature and introduction of this study indicates, commercial offices are the most homogenous and have the most plentiful data for the analysis presented in the following chapters.

*3.2.2 Property Tax Appraisal District Datasets*

Online resources for the property tax appraisal districts where the five subject cities are located are utilized to gather a variety of data points. Variables include land area, gross building area, net leasable area, land value, improvement value, and gross tax appraised value. Each property is identified by the address provided in the ES datasets and searched on the respective tax appraisal district. Data-points for each property are pulled individually from the property profile. The resulting data available for evaluation is inconsistent within and between appraisal districts – only 2013 data is used. Some properties do not have information for a variety of reasons including that a disproportional amount of green certified properties are government or institutionally owned compared to the general population. If a property does not have tax appraisal data, it is eliminated.

For the properties with tax appraised values, Dallas and Houston are the most consistent, providing all variables. Gross building area and net leasable area are inconsistent between cities with Austin providing only gross building area and Fort Worth and San Antonio only providing net leasable. As a result, the gross building area from the EPA is utilized.

*3.2.3 Data Conclusion*

As mentioned previously, the dataset was downloaded from the indicated online resources. The ES property list identifies the subject properties. These properties were searched on their respective county tax appraiser websites. Land area, gross building area, net leasable area, land value, improvement value, and gross tax appraised value are recorded and placed in a spreadsheet in row with their respective property. Many properties are missing variables or are simply not listed and therefore are eliminated as potential subject for the study. It should be noted that all references to PSF Values refers to PSF tax appraised value of property improvements unless otherwise stated as this study is focused on property improvements alone.

### 3.3 Dataset

Of the 723 properties on the ES list, over 51% of the properties supplying all necessary variables providing a final sample size of 370. All of the observed variables included in the analysis conform to the approximate means, ranges, and standard deviations of the raw dataset as observed in Table 3-1. Built prior to 1942, 6 properties do not have adequate data while several others at the higher threshold for tax appraised data are eliminated as discussed in section 4.1.

Table 3-1 Raw and Cleaned ENERGY STAR Dataset Descriptive Statistics Comparison

| | Raw ENERGY STAR Dataset Descriptive Statistics | | | | | Cleaned ENERGY STAR Dataset Descriptive Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | N | Minimum | Maximum | Mean | Std. Deviation | N | Minimum | Maximum | Mean | Std. Deviation |
| ES Rating | 719 | 75 | 100 | 83.88 | 6.67 | 370 | 75 | 100 | 83.65 | 6.56 |
| ES Square Footage | 686 | 4900 | 4331743 | 290698.36 | 375477.54 | 370 | 5000 | 4331743 | 326423.54 | 407241.26 |
| Year Built | 719 | 1905 | 2011 | 1987.59 | 13.86 | 370 | 1942 | 2011 | 1986.96 | 11.45 |
| Gross Square Footage | 380 | 100 | 3538915 | 438414.28 | 452933.43 | 276 | 4603 | 2626393 | 451551.41 | 411911.59 |
| Net Leasable Square Footage | 501 | 100 | 4586953 | 300873 | 380715 | 362 | 5827 | 4586953 | 308863 | 386986 |
| Land Value | 538 | $5,913 | $103,696,575 | $5,992,020 | $9,815,433 | 362 | $34,036 | $49,081,750 | $5,703,070 | $7,621,085 |
| Improvement Value | 534 | $0 | $401,551,193 | $36,347,387 | $58,421,890 | 370 | $83,740 | $401,551,193 | $37,089,950 | $57,715,022 |
| Tax Appraised Value | 548 | $5,913 | $414,051,193 | $41,187,317 | $64,514,697 | 370 | $117,776 | $414,051,193 | $42,654,608 | $62,845,797 |
| Tax Assessor SF / ENERGY STAR SF | 381 | 81.00% | 119.00% | 97.06% | 5.82% | 370 | 81.00% | 119.00% | 97.02% | 5.83% |
| Tax Appraised Improved Value PSF | 381 | $2.94 | $329.20 | $99.15 | $58.59 | 370 | $2.94 | $217.60 | $94.50 | $52.29 |

Exploration of the ES variables in Table 3-2 reveals that many of the variables are correlated with PSF Values. It should be noted that some of these correlations are the product of how the PSF is determined. As mentioned previously, the PSF Values are calculated by dividing the improvement value by the square footage of the structures as defined in Chapter 3. The result of this methodology is that correlations exist between the numerator and denominator of this ratio. Therefore, as seen in Table 3-2, all square footages besides land and all values are significantly correlated at the .01 level (2-talied) with PSF Value. Similarly, the Year Built is also significantly correlated at the .01 level (2-talied) with PSF Value.

Table 3-2 Correlations of All Variables

| Variable | Measurement | Per Square Foot Value | ES Rating | ES Square Footage | Land Square Footage | Gross Square Footage | Net Leasable Square Footage | Land Value | Improvement Value | Market Value | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Improved Value PSF | Pearson Correlation | 1.000 | .027 | .295** | -.090 | .500** | .274** | .335** | .633** | .622** | .315** |
| | Sig. (2-tailed) | | .596 | .000 | .082 | .000 | .000 | .000 | .000 | .000 | .000 |
| | N | 381 | 381 | 381 | 373 | 281 | 373 | 373 | 381 | 381 | 381 |

**. Correlation is significant at the 0.01 level (2-tailed).

The Years Built for the ES properties in the cleaned dataset include properties built from 1942 to 2011 with the mean year being 1987 and a standard deviation of 11.45 – the entire observed dataset is presented in Appendix D. With a total of 23 properties built in 1980, 15 in 1981, 44 in 1982, 30 in 1983, 26 in 1984, 28 in 1985, 16 in 1986 and 11 in 1987, the building boom of the 1980's leading into the savings and loan crisis is heavily represented in this dataset.

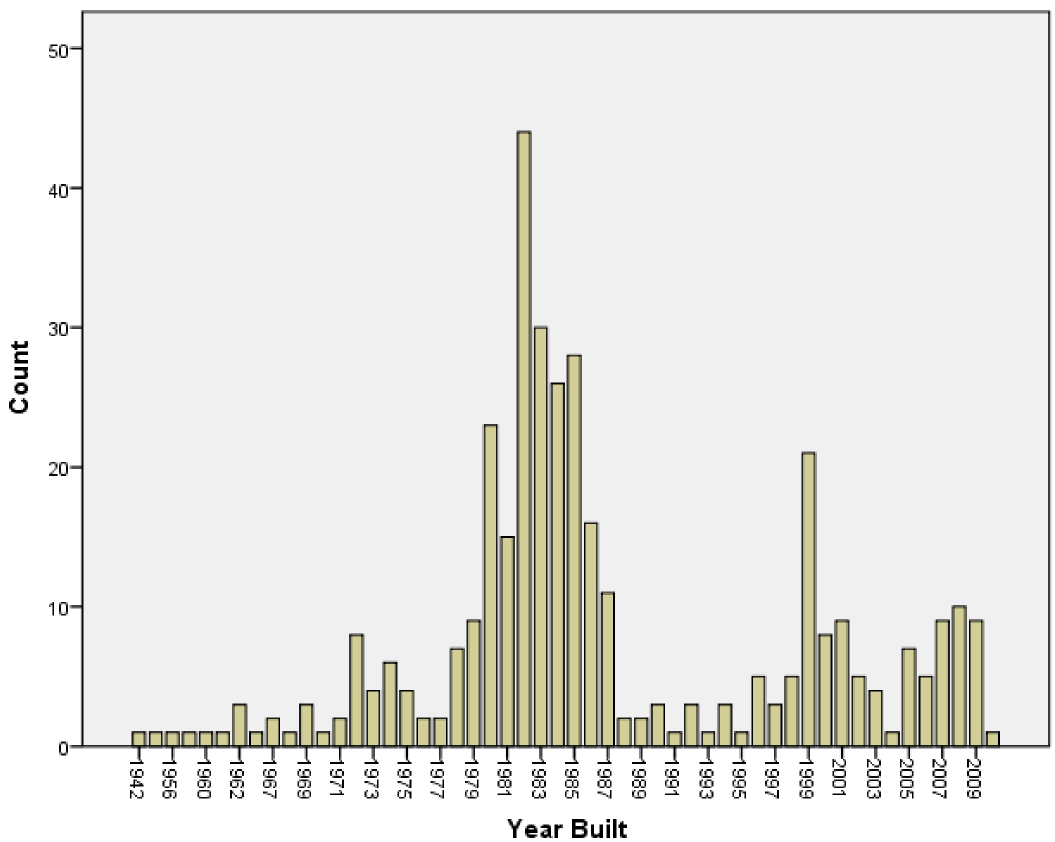


Figure 3-1 Graphical representation of number of properties in the ES dataset built in each year.

A total of 52 Austin (aus), 83 Dallas (dal), 10 Fort Worth (ftw), 186 Houston (hou), and 39 San Antonio (san) are included in the dataset. Houston is represented with over 50% of observations. The size of Houston compounded with the building boom of the early 1980's bolsters its representation in the ES dataset.

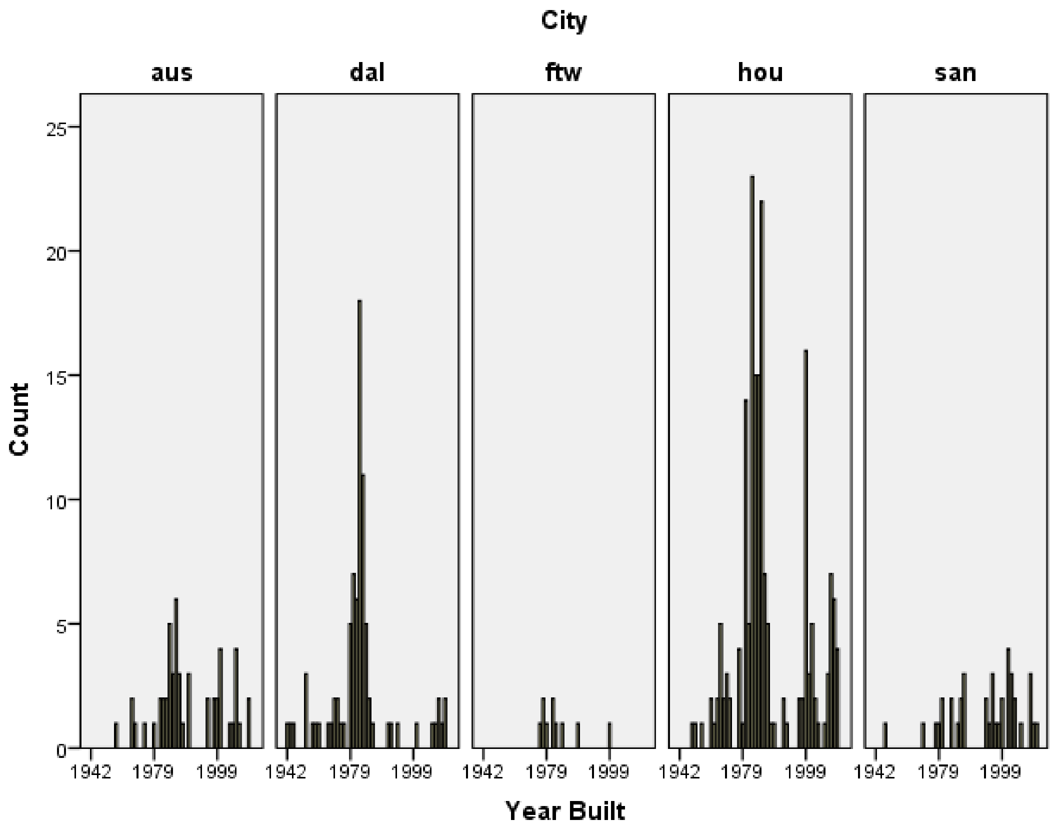


Figure 3-2 Graphical representation of the distribution of

ES properties by city and Year Built.

With a mean of 83.65 and a standard deviation of 6.56, the distribution of ES ratings in each city is skewed to the lower end of the 75 to 100 range with Houston again being represented the most. San Antonio has the most even distribution while Fort Worth's 10 properties are fairly sporadic.

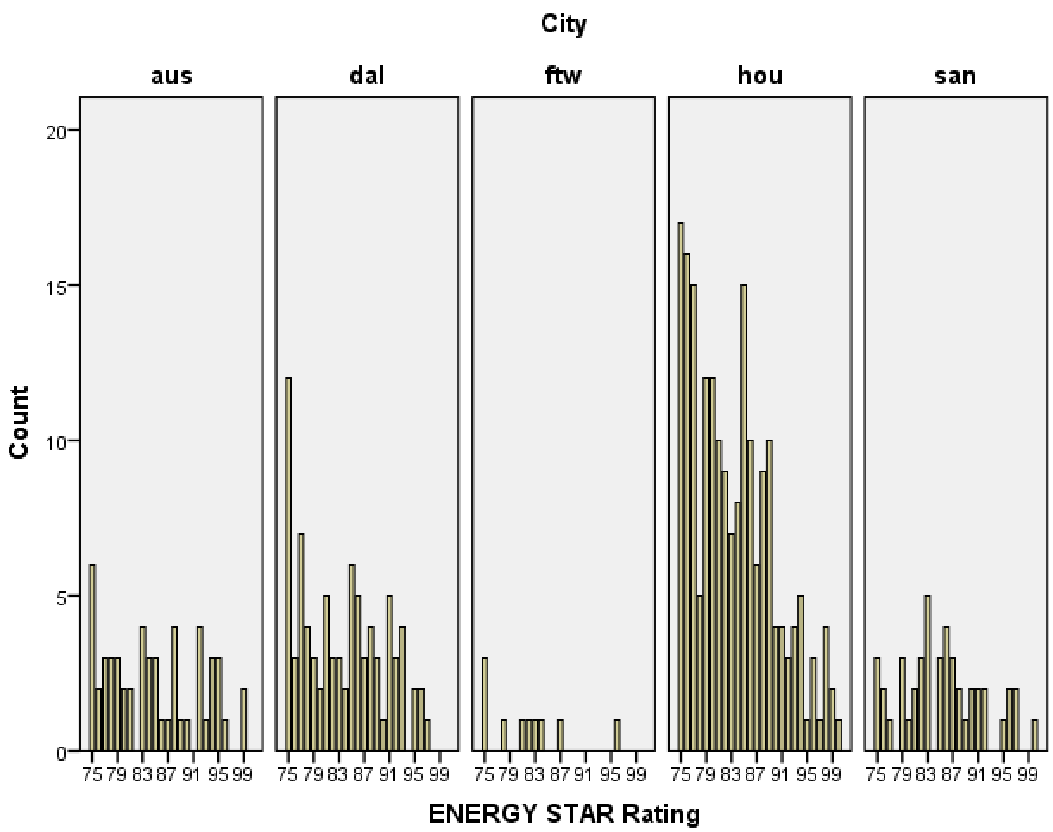


Figure 3-3 Graphical representation ES ratings categorized by city.

A total of 19 hotel, 16 medical, 298 office, 5 retail and 27 supermarket and 5 other properties are present in the ES dataset. With 80% of the properties being office properties, the dataset validates the literature regarding office properties by confirming that this use type is overwhelmingly represented in the commercial property market for green buildings. The homogeneity of commercial offices and availability of data provides a quality resource for comparing this dataset and study results to existing research.

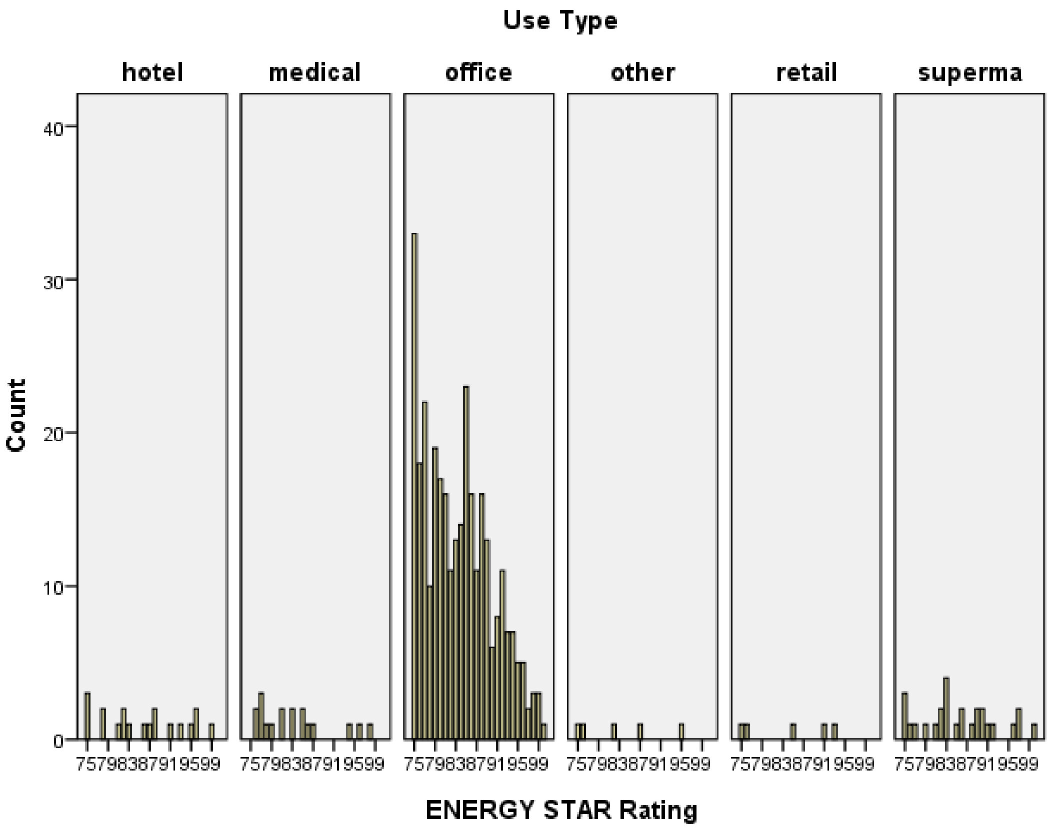


Figure 3-4 ES graphical representation of ES rating categorized by use type.

The overwhelming majority of use type as office is presented again in Figure 3-4. 39 of the offices in the dataset were built in 1982. Although not comparable in quantity, peaks related to office building construction occur in 1999 and 2008.

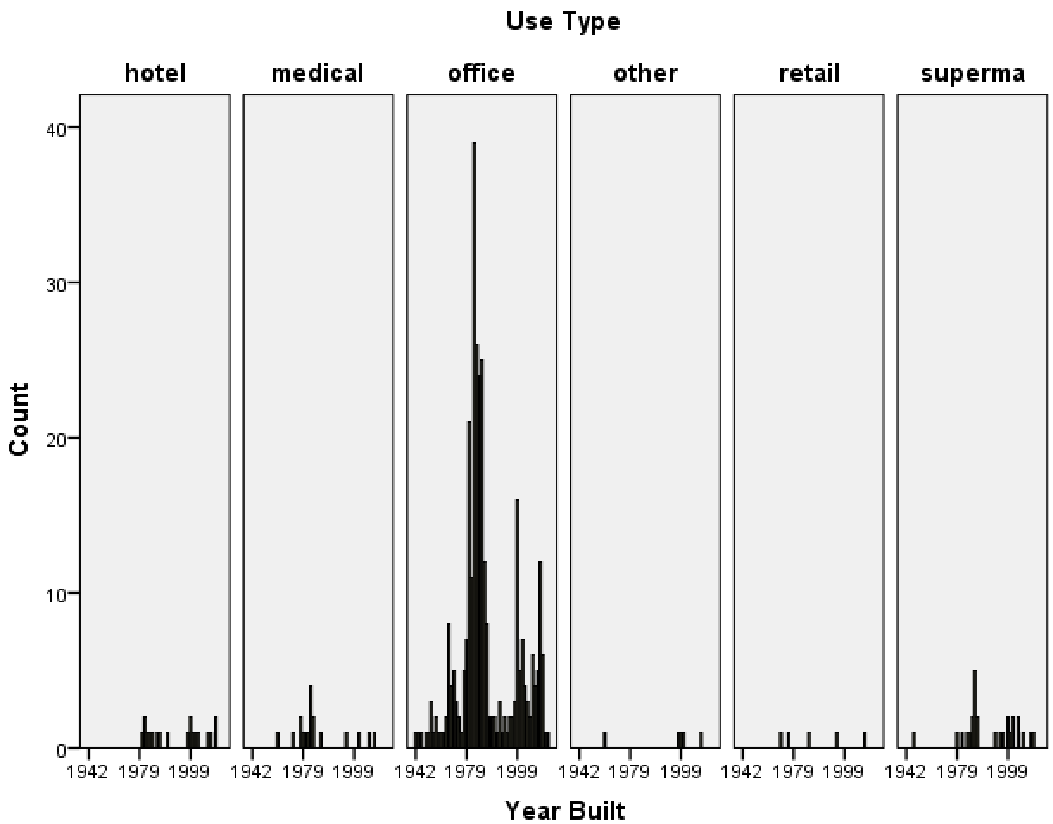


Figure 3-5 ES graphical representation of Year Built categorized by use type.

The ES dataset is relatively consistent in its representation of the raw dataset for each variable. In both datasets, a large proportion of the properties observed are offices and located in Houston. Approximately 46% of the properties in the raw dataset are located in Houston, while approximately 49% in the cleaned dataset are located there. Similarly, approximately 71% of the observations in the raw dataset are office properties while approximately 80% in the cleaned dataset are office properties.

Chapter 4

ENERGY STAR Research

This chapter presents the findings of the research outlined in the previous chapters. Linear regressions are utilized with the assistance of the software package Stata. Testing of the assumptions for linear regression and applicable bivariate analysis of interaction variables is included in Appendix C. The $H_o$ for the hypotheses is that ES Rating has no effect on *per square foot (PSF) tax appraised value of property improvements.* Although a large number of linear regressions have been run using various processes, the models contained herein test the following hypotheses:

$H_1$: *Commercial office buildings with higher levels of ENERGY STAR (ES) certification have higher per square foot (PSF) tax appraised value of property improvements.*

$H_2$: *Commercial office buildings with higher levels of ENERGY STAR (ES) certification in the selected zip codes have higher per square foot (PSF) tax appraised value of property improvements.*

This chapter is broken into two sections, each of which presents a linear regression model built to test one of the hypotheses. In the first section, the interaction between ES ratings, Year Built, and city are compared to the dependent variable of PSF tax appraised value of property improvements. Once this model is established, a model with the better defined locational characteristic of zip codes can be explored. The regression results suggests that ES ratings, Year Built, city and the dependent variable of PSF tax appraised value of property improvements are linear related for properties built since 1995. For every one-unit increase in ES rating, PSF tax appraised value of property improvements increase by $1.56 PSF when including cities as dummy variables.

In the second section, the relationship between PSF Values, ES ratings, and Zip Codes is explored. The results suggest that for every one-unit increase in ES rating, PSF tax appraised value of property improvements of commercial office buildings in the selected zip codes are increased by $1.58. This further supports $H_1$: *Commercial office buildings with higher levels of ENERGY STAR (ES) certification have higher per square foot (PSF) tax appraised value of property improvements.* With a difference of $0.02 between the models, the second model reinforces our conclusion.

## 4.1 ENERGY STAR Rating and Cities Model

This model explores the interaction between ES rating, Year Built, cities, and PSF tax appraised value of property improvements. The null hypothesis is that ENERGY STAR rating has no statistically significant effect on the tax appraised value per square foot of commercial office buildings in Austin, Dallas, Fort Worth, Houston, and San Antonio built since 1995. An alternative hypothesis is ENERGY STAR rating has a statistically significant effect on tax appraised values per square foot of commercial office buildings with higher built since 1995. This model seeks to explain how the dependent variable of PSF tax appraised value of property improvements are related to properties' ES rating and city.

### *4.1.1 Conceptual Model*

The general specifications for the model assume that PSF tax appraised value of property improvements are driven by the following equation:

$$PSF = \beta_0 + \beta_1 \text{ ES Rating} + \beta_2 \text{ Austin} + \beta_3 \text{ Dallas} + \beta_4 \text{ Fort Worth} + \beta_5 \text{ Houston}$$

where,

PSF = per square foot tax appraised value of property improvements,

$\beta_0$ = a constant term and intercept of the model.

The preceding model includes PSF Value as the dependent variable and ES rating and cities as the independent variables with years since 1995 utilized as fixed effects. Similar to the broader dataset reviewed in Appendix C, this selection of years have a linear, normal, homoscedastic and independent interaction with PSF Value. As mentioned previously, square footages and values are already included in PSF Value. The interaction between PSF Value and ES ratings also conforms to the assumptions of linear regression as outlined in Appendix C. The result of this regression is presented in Table 4-1. Cities are included in the model as dummy variables. San Antonio is excluded as a reference group in order to avoid what is commonly known as a dummy variable trap. By dropping San Antonio, multicollinearity is avoided.

### *4.1.2 Regression Results*

The collected dataset when run with the defined conceptual model yields the results presented in Table 4-1:

Table 4-1 Summary of ENERGY STAR Rating and Cities Model

| | |
|---|---|
| Constant | -49.94868 |
| | (78.5350) |
| Rating | 1.560451* |
| | (0.9274) |
| Austin | 99.73937** |
| | (17.4930) |
| Dallas | 40.80854* |
| | (21.2537) |
| Fort Worth | -8.63604 |
| | (59.7464) |
| Houston | 74.11726** |
| | (16.7015) |
| R-squared | 0.6343 |
| No. observations | 76 |

a. Standard errors are reported in parentheses.
b. * Correlation is significant at the 0.10 level.
c. ** Correlation is significant at the 0.05 level.

With the constant, the coefficient for each variable (besides San Antonio which is held out for reference), as well as the standard errors (presented in parentheses) in Table 4-1, the regression results indicate that the model is based on the formula:

$$PSF = -49.94 + 1.56 \times \text{ES Rating} + 99.73 \times \text{Austin} + 40.80 \times \text{Dallas} -$$

$$\qquad (78.5350) \qquad (.9274) \qquad (17.4930) \qquad (21.2537)$$

$$8.63 \times \text{Fort Worth} + 74.11 \times \text{Houston}$$

$$\qquad (59.7464) \qquad (16.7015)$$

*4.1.3 Observations*

1. We reject the null hypothesis, which stated that ES does not have a significant effect on PSF tax appraised value of property improvements, as the model demonstrates a statistically significant coefficient estimate for ES rating and the way that it interacts with PSF Value.
2. The model (ES rating, Year Built, and city) explains 63.43% of the variability in PSF Values.
3. For every one-unit increase in ES rating, PSF tax appraised value of property improvements increase by $1.56 PSF.
4. The coefficients of Austin and Houston are significant at the 5% significance level.
5. The coefficients of ES Rating and Dallas are significant at the 10% significance level.
6. San Antonio is the reference variable as it performs better than Fort Worth in terms of impact on PSF Values.
7. Austin has the most impact on PSF Values, followed by Houston, Dallas, Fort Worth, and San Antonio (in decreasing order).

*4.1.4 Overall Fit Testing*

The findings suggest that the model explains 63.43% of the variability in PSF Value, which is a good fit, but further testing is required to confirm the results. As a further test, we explore whether all variables included in the model have an effect on PSF Value and cannot be left out. For this testing we assume that none of the coefficients have a significant impact on PSF Values. The null hypothesis is that all coefficients are equal to zero. The alternative is that not all the coefficients are equal to zero. Accordingly, we assume that:

1. ES rating = 0
2. Austin = 0
3. Dallas = 0
4. Fort Worth = 0
5. Houston = 0

To test the model we perform an F test of linear restrictions and apply it to the model. The outcome of this test is identical to the model – a t-statistic on all coefficients of 9.42 with no significance. Since the probability of obtaining an F ratio as large as what is observed is .0000, we reject the null hypothesis under any significance level (the probability of incorrectly rejecting the null hypothesis) meaning that none of the coefficients can be excluded from the regression equation. With a p-value of .0000, which is less than the .05 level, the same conclusion can be reached; the model is a good fit.

*4.1.5 ES Rating Effect*

To further test the model we analyze ES ratings effect on the model to determine whether it has a significant influence on the model and therefore cannot be excluded from this model. The null hypothesis in this instance is that ES rating has no effect on PSF Value. An alternative hypothesis is that ES certification has a statistically significant effect on PSF Value. When we run the test on ES rating only in Stata, the result is $F(1, 57) = 0.0979$, which indicates that we reject the null hypothesis at any significance level up to 9.79% (the probability of incorrectly rejecting the null hypothesis).

*4.1.6 Independent Variable Correlation*

A final test of integrity for the model is executed to see if a statistically significant interaction between independent variables exists. The correlation coefficients among all independent variables are analyzed. With 76 observations, a t-test is conducted at the 5% level. The results indicate that the threshold value for r is 0.2 -- where the correlation coefficient is greater than 0.2, a significant correlation exists. The results indicate that ES Rating is not correlated to Year Built or city. Although there are four statistically significant correlations among city dummy city variables and two among Year Built and city dummy variables, it can be said that the fundamental assumption for linear regression, that independent variables are not correlated, holds true.

### 4.2 ENERGY STAR Rating and Zip Codes Model

This model explores the interaction between ES rating, Zip Codes, and PSF tax appraised value of property improvements. The null hypothesis is that ENERGY STAR rating has no statistically significant effect on the per square foot tax appraised improvement value of commercial office buildings built since 1995 in selected Texas zip codes. An alternative hypothesis is that ENERGY STAR ratings has a statistically significant effect on the per square foot tax appraised improvement value of commercial office buildings built since 1995 in selected Texas zip codes. This model seeks to explain how the dependent variable of PSF tax appraised value of property improvements are related to properties' ES rating and zip code.

*4.2.1 Conceptual Model*

The general specifications for the model assume that PSF tax appraised value of property improvements are driven by the following equation:

$$PSF = \beta_0 + \beta_1 \text{ES Rating} + \beta_2 X_1 + \ldots + \beta_n X_n$$

where,

| | | |
|---|---|---|
| PSF | = | per square foot tax appraised value of property improvements, |
| $\beta_0$ | = | a constant term and intercept of the model, |
| $X_{1\ldots} X_n$ | = | a series of Zip Codes. |

The preceding model includes PSF Value as the dependent variable and ES rating and 35 different zip codes as the independent variables. Similar to the previous model, the interaction between PSF Value and ES ratings conforms to the assumptions of linear regression as outlined in Appendix C. The results of this regression are presented in Appendix E. Zip codes are included as dummy variables. Zip code 78759 in Austin, Texas is held out as a reference variable to avoid multicollinearity in the model. A test for multicollinearity indicates that none exists.

*4.2.2 Regression Results*

The regression results of the conceptual model with 36 variables including ES rating and 35 zip codes are presented in Table 4-2 with all of the coefficients and other outcomes available in Appendix E.

Table 4-2 Summary of ENERGY STAR Rating and Zip Codes Model

| | |
|---|---|
| R-squared | 0.8308 |
| Adjusted R-squared | 0.6828 |
| F (35,40) | 9.42 |
| No. observations | 76 |

The regression results indicate that the model is based on the formula:

$$PSF = 9.5376 + 1.5878 \times \text{ES Rating} + \beta \text{ Zip Code}$$

*4.2.3 Observations*

1. We reject the null hypothesis, which stated that ES rating does not have a significant effect on PSF tax appraised value of property improvements, as the model clearly demonstrates a statistically significant coefficient estimate for ES rating and the way that it interacts with PSF value.
2. ES rating and 11 zip codes (out of 35) are statistically significant at the 5% level.
3. The model (ES rating and Zip Codes) explains 83.08% of the variability in PSF Values.

4. The larger $R^2$ of this model means that PSF tax appraised value of property improvements can be explained much better using zip codes rather than cities.
5. The coefficient outcome for ES rating is very similar to the previous model: for every one-unit increase in ES rating, PSF tax appraised value of property improvements increase by $1.58 PSF.
6. Since the difference in the coefficients of ES Rating is not statistically significant between the models ($0.02), it can be concluded that both models have identified accurate relationships between ES Rating and PSF tax appraised value of property improvements.
7. This model includes the same 76 observations of properties as the previous models which were built from 1995 to 2011 in 35 zip codes.

*4.2.4 ES Rating Effect*

To further test the model we analyze ES ratings effect. This allows us to determine whether this variable can be excluded from the model. The null hypothesis in this instance is that ES rating has no effect on PSF Value. An alternative hypothesis is that ES certification has a statistically significant effect on PSF Value. When we run the test on ES rating in Stata, the result is F (1, 40) = 0.0450. This result indicates that we reject the null hypothesis at any significance level up to 4.5% (the probability of incorrectly rejecting the null hypothesis).

*4.2.5 Independent Variable Correlation*

Similar to the first model (ES rating and Zip Codes), a final test is done to see if a statistically significant interaction between independent variables exists. The correlation coefficients among all independent variables are analyzed. With 76 observations, a t-test is conducted at the 5% level. The results indicate that the threshold value for r is 0.2 -- where the correlation coefficient is greater than 0.2, a significant correlation exists. The results indicate that ES Rating is not correlated to Year Built or Zip Code. This outcome suggests that the assumption for linear regression, that no correlation among independent variables exists, holds true.

Chapter 5

Summary of Findings

## 5.1 Research Findings

### *Research Hypothesis*

$H_1$: *Commercial office buildings with higher levels of ENERGY STAR (ES) certification have higher per square foot (PSF) tax appraised value of property improvements.*

This hypothesis was addressed in Section 4.1 using linear regression. The variables for this model included PSF Value as the dependent variable and ES rating, cities, and Year Built as the independent variables. 76 office properties in all five cities -- Austin, Dallas, Fort Worth, Houston, and San Antonio – are utilized with Year Built – from 1995 to 2011 – as fixed effects in this model. As a fixed effect, the Year Built is a categorical variable that is absorbed in the model – it is factored into the model but not computed on a year-by-year basis. Each of the cities is included as a dummy variable. San Antonio is left out of the regression results for reference to not compromise the model in error. The assumptions for linear regression are tested using an expanded sample of the year subsections explored in Appendix C.

The null hypothesis is that ENERGY STAR rating has no statistically significant effect on the tax appraised value per square foot of commercial office buildings in Austin, Dallas, Fort Worth, Houston, and San Antonio built since 1995. An alternative hypothesis is that ENERGY STAR rating has a statistically significant effect on the tax appraised value per square foot of commercial office buildings in Austin, Dallas, Fort Worth, Houston, and San Antonio built since 1995. The results suggest that ES rating, Year Built and city location explain 63.43% of the variability in PSF Values. For every one-unit increase in ES rating, PSF tax appraised value of property improvements increase by $1.56 PSF. The model rejects the null hypothesis as ES rating, Year Built, and cities are related variables, each of which improved the outcome of the model.

To more precisely interpret the result and confirm that each variable should be included, the model was tested for overall fit. For this test it was assumed that none of the coefficients have a significant influence on the model. The null hypothesis for the test was that the coefficients of the defined variables are equal to zero. An alternative hypothesis was that not all the coefficients are equal to zero. With a p-value .0000, significantly less than the .05 assumption, the result is that the model is a good fit. The result is that we reject the null hypothesis as ES rating, Year Built and cities have an effect on the PSF Value of property improvements.

A final test was run to determine the effect of ES rating on this model to confirm that this variable cannot be excluded from the model. In this instance, it is assumed that ES rating coefficient is zero. The null hypothesis in this test is that ES rating has zero effect on PSF Value while the alternative hypothesis is that ES rating has a significant effect on PSF Value. The result of this test when assuming that the ES rating is zero is $F(1, 57) = 0.0979$, which indicates that we reject the null hypothesis at any significance level up to 9.79% (the probability of incorrectly rejecting the null hypothesis). This result indicates that ES rating has an effect on PSF Values in this sample of 76 observations when excluding all other variables from the analysis. Office buildings in Austin, Dallas, Fort Worth, Houston and San Antonio built between 1995 and 2011 are influenced by ENERGY STAR certification.

*Research Hypothesis*

$H_2$: *Commercial office buildings with higher levels of ENERGY STAR (ES) certification in the selected zip codes have higher per square foot (PSF) tax appraised value of property improvements.*

This hypothesis was addressed in Section 4.1 using linear regression. The dependent variable was PSF tax appraised value of property improvements. The independent variables were ES rating and 35 different zip codes. With the same 76 properties built since 1995 as the previous model, the model explores the effect of ES rating on PSF tax appraised value of property improvements in each zip code independently. Each Zip Code is included as a dummy variable. As mentioned previously, zip code 78759 in Austin, Texas is held out as a reference variable to avoid compromising the model in error.

The null hypothesis for this test is that ENERGY STAR rating has no statistically significant effect on the per square foot tax appraised improvement value of commercial office buildings built since 1995 in selected Texas zip codes. An alternative hypothesis is that ENERGY STAR ratings has a statistically significant effect on tax appraised improvement values per square foot commercial office buildings with higher built since 1995 in selected Texas zip codes. The results indicate that ES rating and Zip Code explain 83.08% of the variability in PSF tax appraised value of property improvements of commercial office buildings built since 1995 in the five selected Texas cities. In addition, for every one-unit increase in ES rating, PSF Value increases by $1.58. Similar to the model with cities and years, this model rejects the null hypothesis as ES rating and Zip Codes have explanatory power for PSF tax appraised value of property improvements of commercial office buildings in the selected zip codes.

A final test was run to determine whether ES rating can be excluded from this model. The null hypothesis in this instance is that ES rating has no effect on PSF Value. An alternative hypothesis is that ES Rating has a statistically significant effect on PSF Value. When we run the test on ES rating in Stata, the result is $F (1, 40) = 0.0450$. This result indicates that we reject the null hypothesis at any significance level up to 4.5% (the probability of incorrectly rejecting the null hypothesis). The null hypothesis is therefore rejected as ES rating improves the model when excluding all of the other variables. The end result is that the selected buildings built between 1995 and 2011 are influenced by ES rating in the selected zip codes.

## 5.2 Final Conclusion

The primary finding of this research is that the improved tax appraised value of commercial office buildings in Austin, Dallas, Fort Worth, Houston and San Antonio are affected by ES rating and Year Built. This result permits conclusions regarding the relationship between sales price premiums and tax appraised values for ES certification. For office buildings constructed since 1995, every one-unit increase in ES rating increases PSF tax appraised value of property improvements by $1.56 on average when the city and Year Built variables are included. Alternatively, when the zip codes are utilized on the same sample, every one-unit increase in ES rating results in a PSF tax appraised value of property improvements increase of $1.58. The difference of $0.02 between the two models is not statistically significant and reinforces our conclusion that ES rating interacts with PSF Value similarly when using different independent variables. These findings are aligned with the established literature and, most importantly, the limited number of quantitative studies on sales price premiums with significant sample sizes. Although not completely related, there are many similarities between the outcomes of this study and the broader body of knowledge.

Most statistical research conducted on ES buildings suggests that there is a relationship between sales prices and ES. Utilizing regression analysis, the most relevant and comprehensive studies suggest that ES properties obtain sales price premiums somewhere in the range of 18% to 31% (Eicholtz, Kok and Quigley 2009, Fuerst and McAllister, 2008, 2009, & 2011). It is important to note however that these studies do not consider levels of ES certification; they simply compare ES certified buildings to those which are not certified. Nevertheless, a simple comparison between the cited research on sales premiums and the tax appraised data included in this study can be conducted. If the premium is applied to the overall average PSF Value of $94.50 included in this study, results in non-certified property values PSF of comparable properties computed by the reciprocal of the premiums mentioned by Eicholtz, Kok and Quigley (2009) and Fuerst and McAllister (2008, 2009, 2011) would range from $72.14 to $80.08. When dividing the spread between these two numbers and the $94.5 average by $1.56 PSF – the amount that every one-unit of ES certification increases PSF Value by – the approximate value added by ES certification is the equivalent of increasing ES ratings by approximately 9 to 14 points.

It appears the two models presented in the research are consistent with the broader research on sales price premiums – commonly delineated on a percentage basis rather than PSF – if it is assumed that tax appraised values are relatively indicative of market value. Although these results are not conclusive, we can estimate that comparable property sales of uncertified office buildings in the selected cities, if included in this research, would be in the range of $14.42 to$22.36 less PSF than their ES certified comparables. This simple comparison lends credence to the conclusion that improved tax appraised values in the selected cities are influenced by ES rating similar to the established literature on sales price premiums.

The second and third most insightful conclusions deal with the ability of the independent variables in each model to explain the variability in PSF tax appraised value of property improvements of office buildings in Austin, Dallas, Fort Worth, Houston and San Antonio. In the first model, cities, Year Built, and ES rating explain 63.43% of the variability in PSF tax appraised value of property improvements. In the second model, zip codes and ES rating explain 83.08% of the variability in PSF tax appraised value of property improvements. These finding are very significant for tax appraisal professionals and the broader community, but are also very consistent with a study presented in the literature review by Wiley and Benefield (2008).

Wiley and Benefield (2008) includes data from 7,308 Class A office properties with 1,151 sales observations and controls for “property size, Year Built and date of sale”. With nearly all of the same independent variables and a similar dependent variable (mean sales price divided by gross building square footage), Wiley and Benefield (2008) present a similar regression model of sales price premiums of ES and LEED properties across 46 markets nationwide. The outcome of the study by Wiley and Benefield (2008) suggests that the previously mentioned variables explain 82.4% to 83.1%of the variation in selling premiums using ordinary least squares regression and two-stage least squares regression. The model with zip codes and ES ratings as independent variables presented in this study results in an $R^2$ that is nearly identical to Wiley and Benefield (2008). The major differences between these studies is that our model does not include a date of sale characteristic and uses a tax appraised value rather than sale value as the dependent variable.

Unfortunately, the research methods section in Wiley and Benefield (2008) for the two models is not descriptive enough to confirm which method was used for each outcome. Again, although the study is on sales premiums rather than tax appraised values and a comparison between ES, LEED and non-certified comparable structures, the similar inputs “represent a high degree of explanatory power relative to most models of commercial office markets” with Dallas/Ft. Worth representing 4.17% of the sample and Houston representing 1.82% of the larger 7,308 property dataset – the sample size for these models was 1,151. Although only a small percentage of the broader dataset in Wiley and Benefield (2008), it appears that that the Texas cities in the two models presented in this research are representative of those in the broader study of 46 markets.

All of the significant findings from this study are similar to that of existing studies on sales price premiums. Unfortunately, since this is only study conducted solely on tax appraised values, comparing this research to the established literature is difficult. Some aspects of this research were able to be confirmed by the literature while others must stand on their own merit. This study was designed to produce the most conclusive evidence on this topic considering the broad, complex nature of public policy and green buildings. These results serve as a small step toward improving property tax policy for green buildings by making a small contribution to what is hopefully the beginning of a more progressive and accurate tax appraisal process for these assets.

### 5.3 Implications for Tax Appraisal Districts

In order to explore the significance of the research results and determine the implications for tax appraisal professionals, each county appraisal district was contacted via email and phone. Senior appraisers in the counties in which Austin, Dallas, and San Antonio are located all responded similarly when a simplified version of the findings of this study were presented. Each of their responses first included the fact that they do not consider LEED or ES when appraising properties. This was followed by comments including “we are way behind the curve,” “we don’t deal with that here or keep track of it so we couldn’t help you,” and, after acknowledging that they received the email which had been forwarded from the deputy chief appraiser, they simply stated that they “have no idea.” These responses were not unexpected and, in many ways, serve to validate the case for furthering tax appraisers’ knowledge of the subject.

Unlike the responses from the other appraisal districts, Lonnie Hendry the Tarrant County Appraisal District in Fort Worth expressed his interest in the study and provided a wealth of feedback regarding the potential reasons for some of the study’s findings and the implications for his profession. Most importantly, he acknowledged that appraisal districts do not currently have the equipment to deal with LEED or ES certification. Mr. Hendry believes that LEED and ES can increase property values given the long term operating expense savings yet he does not foresee this being integrated in the tax appraisal process in Texas. Secondly, he expressed a similar feeling of being behind the curve on the appraisal of these properties, but suggested that even with the correct tools and resources that large commercial properties, which are more likely to have obtained green certification, will still be taxed according to the results of judicial review. Owners of large properties in the state of Texas systematically protest their property taxes through a judicial review, 90% of which are resolved through an equity analysis using “a reasonable number of appropriate adjusted comparables.” Hence, the pool of large properties with a disproportionate amount of green buildings may not be affected even if appraisal districts began to consider LEED and ES.

With each appraisal district acknowledging that they predominately use the income approach to appraise properties except for some unique new construction, it is apparent that rents and operating expense savings will have the most effect on property values. The findings of this study suggest that this may be the case. This fact does not necessarily aid tax appraisers because owners of green properties are less likely to share the efficiencies of their structures if the potential outcome is that their property taxes could increase. There are a number of academic and practitioner publications that discuss this topic with some calling for more transparency in energy, water, waste and other utility use.

The researcher is of the opinion that disclosing utility information is likely to remain up to the owner. From an owner's perspective, there are both benefits and detriments to disclosing such information. In some cases it can be viewed as proprietary, which, depending on the lease structure, can be very valuable. For example, if a property owner is not passing through operating expenses he can effectively charge the market rate and reap the gross reward for his properties efficiency – in addition to keeping his taxes down. On the other hand, when an owner discloses such information, they often attract tenants who want to be seen as being environmentally friendly. If they are passing through these operating expense savings, then disclosing such savings should attract more sophisticated tenants who recognize how these savings can increase their bottom line. While it may discourage development and ownership of green buildings, forcing property owners to disclose utility expense information will improve tax appraisal professional's ability to conduct more accurate appraisals.

Operating expense savings are a great way of identifying value, but obtaining utility consumption information is not the only way to determine whether a property owner is benefiting from green features. Although not a new idea, determining what features or MMT (as mentioned in Chapter 1) a property has is indicative of value. This came up in a conversation with Carol Brown from the Travis County appraisal district in Austin. She mentioned that Travis county appraisers count the number of solar panels on a structure and make a note of them on the properties file. She then said that the county only adds their value at the owner's request. When an owner does make such a request, they self-identify what they spent on the panels. Then, they exempt the value of the solar panels – effectively removing any tax that would be paid on their value.  Ms. Brown said the owners most commonly identify the value of each panel as $900 to $1500 and estimates the average to be $1250. The researcher found this very unusual. If the appraiser's job is to arrive at the closest value of the property, why would they exempt a feature that adds value? Many other green MMT can be identified and valued without forcing the disclosure of utility consumption which many property owners proclaim as quasi proprietary information. Identifying such features and incorporating them into the tax appraisal process is the most accurate way to value a property and should be incorporated into the appraisal process.

As stated earlier in this research, green buildings are not treated any differently for property tax purposes than conventional structures. If taxing authorities want more accurate tax appraisals, they should acknowledge that ES may add value to a property as demonstrated in this study. If they want to encourage the supply and stimulate the demand for these structures in an honest, transparent way, it is first necessary to acknowledge that green building certification has value. Then they can include certifications and green property features into the tax appraisal process.  If a jurisdiction wishes to offer tax rebates, credits, or some other type of exemption for these certifications or improvements, there are many ways to incentivize construction and ownership after acknowledging the subject assets costs and benefits.

In many ways, the fact that private owners are incorporating green MMT into their properties and obtaining green certifications without incentives is a very positive development. Developers, owners, occupants, and consumers are beginning to identify the quantitative and qualitative value that such features add to a property and are adjusting their consumption decisions accordingly. The time has come for policy makers and the property tax appraisal profession to acknowledge this development and seek to get ahead of the curve rather than continuing to fall behind.

## 5.4 Limitations and Areas for Further Research

This study focused exclusively on ES certified properties in the five most populated cities in the state of Texas. The scope of the study is limited to properties with ES certification to establish a base for further research. Future studies should include comparable properties within a specified distance or other locational characteristic. The more established research on sales price premiums such as Pivo and Fisher (2008) provide examples of how locational characteristics such as “in or near a CBD regeneration area,” “in or near suburban regeneration area,” or “near a CBD transit station” can be utilized to refine results when larger sample sizes are available.

Although this study further breaks down the locational by zip code, specified areas such as CBD’s or other locational characteristics are absent from this research. Future studies should be refined by more specific locational characteristics and selecting comparable properties within these areas while simultaneously being broadened to additional markets. The approach established by this research can be expanded to other states or a national level with each property having at least one comparable property without certification within a specified area. These locational characteristics could include everything from distance from the property to a broader, less specific location quotient such as zip code or neighborhood. No matter how the area is defined, including comparable properties without certification will increase the validity of future studies.

An appraiser from the Tarrant County appraisal district whose valuable input was discussed in Section 5.4, Mr. Hendry, identified an issue with this study that the researcher was aware of but did not identify in the research – using PSF can cause an economies of scale problem. This is a valid criticism because as properties get bigger, they are typically worth less PSF. Although this study controlled for the size of the properties by using PSF Values, studies going forward should use other means to control for the economies of scale issue identified by Mr. Hendry. Controls for the size of the property can be included by breaking up the properties into separate categories of size or using weighted statistical methods for the property size variable.

This study is also limited by use type because of available data. The results were limited to office buildings. This allowed the model to be tightened, but resulted in the research results being applicable only to that use type. Commercial offices have served as a good basis for this and other research topics such as sales price premiums, rents, occupancy, absorption, operating expenses, but green building research must expand into other, less homogenous property types. Expanded sample sizes will offset some of the challenges. In the case of this research, the five major Texas cities, which are each in the top 16 most populous incorporated places in the US, provided sample sizes adequate for analysis. Larger samples would have provided more conclusive results. Future studies should be expanded to include multiple states and eventually to a national level.

An additional limitation to this study is that it is restricted to 76 properties built from 1995 to 2011. In order to have an adequate sample size, the years had to be restricted. The catch is that going too far back risks having properties that have been retro-fitted or rehabbed since original construction and the appraised value adjusted accordingly. Since the data did not include any type of depreciation or current state of the property improvement information, the study could not include controls for these property specific characteristics. Future studies should include a larger number of properties built in a broader number of years while controlling for depreciation and other factors that negatively affect property values.

As touched on briefly in Section 6.4, the MMT incorporated into green properties continue to be the most important and influential items for tax appraisal. Future studies should seek to extract the value of specific cost saving features utilizing CBA and DCF. The value of specific technologies can then be itemized and included in appraisals. Evidence from this study confirms that this has eluded public policy in Texas entirely while the continued growth of green MMT in the public and private sectors suggests that the benefits from their use continue to grow. Identifying and understanding the value of green MMT is increasingly important for both industry and government going forward.

# Appendix A

## A Review of the Appraisal Process

Professional appraisers within every state and federal jurisdiction must follow the appraisal process as defined by the Uniform Standards of Professional Appraisal Practice (USPAP) (Ling and Archer 2008, 183). Although a variety of organizations have differing suggestions for the process depending on their audience, in general, "the valuation process is a systematic set of procedures an appraiser follows to provide answers to… questions about real property value" (The Appraisal Institute 2008, 129). For professional purposes, this process always "consists of (1) defining the problem, (2) selecting and collecting data, (3) identifying the highest and best use, (4) applying the three valuation approaches, (5) reconciling the indicated values that result from the multiple approaches to valuation, and (6) preparing the appraisal report for submission to the client" (Ling and Archer 2008, 183).

Although each of the steps is integral to a correct indication of value, this study focuses primarily on the three valuation approaches and selecting the final reconciliation of value, which provides the most accurate results while remaining feasible for property tax purposes.

Three methodologies are commonly used to appraise the value of real estate – sales comparable, cost, and income. "One of the three approaches… may be especially effective in a given situation" (The Appraisal Institute 2008, 141). Each has its benefits and detriments which determine its appropriate and common uses. For example, the large supply and volume of transactions of single family homes make the sales comparable approach the ideal method for identifying the value of homes. A large amount of market data exists which allows for homes to be consistently and accurately appraised. This, coupled with the relatively homogenous construction of homes, makes the sales comparable approach ideal for single-family home valuation.

Analogously, LEED certified Class A commercial office building transactions are rare and often not comparable. Commercial buildings are often unique and demonstrate an endless number of configurations and features. In addition, the relatively small amount of buildings which integrate green-construction techniques complicates this study by reducing the pool of transactions to investigate. This is further exacerbated by the fact that many green buildings are owner-occupied or have owners in long-term holding periods.

The complex nature of these heterogeneous commercial properties coupled with infrequent transactions and imperfect information make the income approach to valuation much more effective than the cost or sales comparable approaches. Since "all three approaches are applicable to many appraisal problems," the literature on each valuation method is explored to reveal their respective limitations as it relates to this study (The Appraisal Institute 2008, 141).

## A.1 Sales Comparable Approach

The sales comparable approach, also known as the market approach, estimates subject properties market value by conducting a market analysis. This analysis examines recent transactions of similar properties. These like-kind transactions are then commonly referred to as comparables (comps). Of these comps, "the sale prices of the properties that are judged to be the most comparable tend to indicate a range in which the value indication for the subject property will fall" (The Appraisal Institute 2008, 141). To identify "the similarity or difference between the subject property and the comparable sales" (The Appraisal Institute 2008, 141), the following elements of the transactions and properties are compared:

- Real property rights conveyed
- Financing terms
- Conditions of sale
- Expenditures made immediately after purchase
- Market conditions
- Location
- Physical characteristics
- Economic characteristics
- Use/zoning

- Non-realty components of value

Each of these aspects is subsequently used to make adjustments to the comparability of the comparable transactions to the subject. A final adjustment of value can “then [be] applied to the known sale price of each comparable property to derive an indicated value for the subject property” (The Appraisal Institute 2008, 142). Through this process the sales comparable approach can accurately determine the value of properties for which accurate, ample, and recent comparable sales information exists.

## A.2 Cost Approach

The cost approach is based on the assumption that “market participants relate value to cost” and construct properties accordingly (The Appraisal Institute 2008, 142). In other words, since “market forces compel the market value of newly-constructed properties to approximate construction costs,” when the cost to produce properties becomes more than their market value, no further structures will be produced (Ling and Archer 2008, 195). Conversely, when the cost to produce houses is less than their market value, homes will be produced. If the market was static, all structures were new, and all construction data was available, the instantaneous construction and absorption would result in the cost approach being very accurate; however, this is certainly not the case. The production of property improvements takes upwards of several years, structures depreciate at varying rates, and perfect construction cost information is not available. These limitations make the use of this approach most pertinent when “valuing new or nearly new improvements and properties that are not frequently exchanged in the market” (The Appraisal Institute 2008, 142).

There a several assumptions that limit the cost approach. The first major assumption is that “the market value of new buildings is similar to the cost of construction today” (Ling and Archer 2008, 196). There are two common ways of estimating construction costs: reproduction and replacement. Reproduction is “the cost to construct the building today, replicating it in exact detail" while reproduction cost is "the expenditure required to construct a building of equal utility" (Ling and Archer 2008, 196). Although reproduction cost is useful for insurance purposes or historic building appraisal, "the theoretical base for the cost approach to valuation is reproduction cost" because it is easier to estimate. In fact, the construction costs estimates are aided by a number of private companies such as RS Means that track and monitor current construction costs according to physical location and property type.

The next step in the cost approach is to estimate its accrued depreciation— "the difference between the market value of a building (or improvement) and the total cost to reproduce it new"—which occurs over its useful life (Ling and Archer 2008, 196). There are three common types of depreciation:  physical deterioration, functional obsolescence, and external obsolescence.

Physical deterioration is "the loss in value of a building over time associated with the aging and decay of its physical condition"—over time, buildings become less valuable because they physically deteriorate (Ling and Archer 2008, 197). Functional obsolescence "represents the loss in value of an improvement associated with a loss in useful capacity" (Ling and Archer 2008, 197). Examples of functional obsolescence include the emergence of new construction techniques or technology such as the use of elevators rather than stairs. Similar to physical deterioration, "functional obsolescence tends to be associated with the passage of time… new building materials, construction techniques, and designs, couples with changing consumer tastes and preferences, generally making older buildings less desirable to tenants and thus not as valuable as newer buildings" (Ling and Archer 2008, 197). The third type of accrued depreciation is external obsolescence which "reflects the loss in value due to influences external to the physical improvement that affect value" (Ling and Archer 2008, 197). Deterioration to the area surrounding the property such as economic decline or waning aesthetics must be accounted and adjusted for. The sum of these three adjustments determines the amount of depreciation the property has accrued since its construction.

After accounting for the depreciation of property improvements, this accrued depreciation is deducted from the reproduction cost of the structure. Then, the estimated value of the property – which is usually determined using comps – is added to the depreciated cost of improvements to arrive at an estimate of market value. As seen below in Table A-1, the resulting value is the market value as indicated by the cost approach.

Table A-1 Cost Approach

| | |
|---|---|
| | Estimated reproduction cost |
| - | Accrued Depreciation |
| = | Building improvement depreciation |
| + | Estimated property value |
| = | Cost approach market value |

The use of the cost approach for green building tax appraisal has several major limitations and few advantageous aspects. Estimating construction costs for green buildings is very difficult because the structures are much more heterogeneous than those produced from traditional construction techniques. In addition, the cost of materials and technologies used, including but not limited to advanced engineering and architecture, are difficult to estimate. Green construction is not very common and structures are also owner occupied, further limiting available market and construction data. Although many other parameters limit the cost approach, one of the strongest benefits of this approach for green buildings is that this type of construction is relatively new and, as discussed previously, the cost approach is most apt for estimating the market value of newer structures.

## A.3 Income Approach

The income approach to valuation is most commonly used for commercial properties and is exemplified by the assumption: "common among commercial property owners is the anticipation that they will receive cash flows from the property in the form of income from rental operations and price appreciation" (Ling and Archer 2008, 206). Commercial properties are most often purchased for investment. Although some businesses own their own structures, the vast majorities of these properties—and those which are the focus of this study—have multiple tenants and are owned by a third party. Therefore, the value of these properties is most accurately determined by their potential to produce future cash flows. This "process of converting periodic income into a value estimate is referred to as income capitalization" (Ling and Archer 2008, 206).

The first step of conducting a valuation upon a properties income is to estimate "its annual net operating income (NOI), which is equal to expected annual rental income, net of vacancies, minus operating and capital expenses" (Ling and Archer 2008, 206). The NOI is always done prior to the properties annual debt service (ADS), which is the annual cost of servicing debt for a number of reasons. Investors often take on varying amounts of debt, and the terms very immensely. Commercial properties are analyzed by their NOI and assumptions made about "(1) the experience of similar properties in the market and (2) the historic experience of the subject property" (Ling and Archer 2008, 207). These assumptions allow interested parties to construct cash flow analyses using direct capitalization and/or DCF. Using these valuation approaches allows investors to estimate "the present value of future benefits of property ownership" (The Appraisal Institute 2008, 142).

Determining a properties present value by direct capitalization entails determining a capitalization rate (cap rate) or income multiplier. A capitalization rate is "the percentage that is obtained when the income produced by a property (or specified interest in a property) is divided by the value or sale price of the property (or the specified interest in the property)" (Ling and Archer 2008, 628). The cap rate serves as an important tool for direct capitalization. Cap rates represent risk. The direct capitalization approach is utilized to explore cap rates and how they relate current market value to NOI. The equations for determining present value and cap rates are demonstrated in Table A-2.

Table A-2 Direct Capitalization

$$\frac{\text{Net operating income}}{\text{Capitalization rate}} = \text{Present value}$$

$$\text{Capitalization rate} = \frac{\text{Net operating income}}{\text{Value}}$$

$$\text{Capitalization rate} = \frac{\text{Net operating income}}{\text{Sale price}}$$

The direct capitalization approach utilizes the NOI and cap rate of a property to estimate its current value. A high cap rate—such as 10% for the sake of simplicity— suggests that a property is very risky. At a 10% cap rate, ten years of cash flow is required to recoup the purchase price or initial cash outlay (excluding debt service and present values). Conversely, a low cap rate – such as 5% for the sake of simplicity – suggests that the potential for collecting the full NOI every year is very high. With a 5% cap rate, 20 years is required to recoup the initial cash outlay. This low of a cap rate is reserved for investment-grade properties, most of which have long-term leases to stable tenants with excellent credit ratings.

The capitalization rate can also be used for the DCF method of valuation, but only as a means to approximate a potential purchase price (using the going-in cap rate) and potential sale price (using the going out cap rate). In both of these cases, the direct capitalization approach is utilized to approximate the initial cash outlay or final sales price of a property. It should be noted however that DCF "valuation models differ from direct capitalization models in several ways" – (1) the analysis must include a holding period (2) NOI must be estimated for each year of the holding period and (3) "the appropriate yield, or required internal rate of return, at which to discount all future cash flows" must be selected according to the investors unique requirements (Ling and Archer 2008, 206-207). DCF is done by reconstructing the properties operating statement as demonstrated in Table A-3.

Table A-3 Operating Statement

| | | |
|---|---|---|
| | PGI | Potential gross income |
| - | VC | Vacancy & collection loss |
| + | OI | Other income |
| = | EGI | Effective gross income |
| - | OE | Operating expenses |
| - | CAPX | Capital expenditures |
| = | NOI | Net operating income |

It is important to note that "the reconstructed operating statement excludes some types of expenses (e.g., tax depreciation and mortgage payments) that usually are included in the accounting statements furnished to the appraiser or current owner" and that valuation is based on estimates of the future years cash flow (Ling and Archer 2008, 208). Although each of the individual elements of the operating statement can be further broken down and have a variety of extrapolation methods, they are pertinent to this study.

The literature on LEED certified commercial office buildings confirms that the income approach is the most accurate approach for valuation. There is a general consensus between researchers that DCF analysis produces the most accurate valuations. In the current state of green building appraisal, it is evident that the lack of market data in the Class A, LEED certified commercial office building market-exacerbated by their relatively heterogeneous construction—often renders each valuation approach inaccurate, incomplete, and/or unreliable. However, as green building construction becomes more widespread, systematic exploration of the resulting data will improve the ability to value these assets.

Appendix B

Quantitative Sources Matrix

| Study & Source | Year | Data | Approach | Findings | Secondary Findings |
|---|---|---|---|---|---|
| Miller, Spivey and Florence (Fuerst and McAllister, 2009) | 2008 | "Filtered sample of Class A buildings (larger than 200,000 sq ft, multitenanted, over five stories, built after 1970) to compare to 643 ES buildings. 927 sale transactions between 2003 and 2007. Breakdown between LEED and ES sale price observations is unclear." | "Hedonic OLS regression for sales price only. Controls for major markets but none for quality." | "Finds no significant sales price premium." | "Occupancy rate is 2%-4% higher for ES compared to non-ES filtered sample. Report 30% lower operating expenses based on energy costs." |
| Wiley, Benefield, and Johnson (Fuerst and McAllister, 2009) | 2008 | "Class A office buildings only. 46 metropolitan markets (25 markets for sales). Breakdown between LEED and ES is unclear. We estimate 30 LEED and 440 ES rental observations and 12 LEED and 70 ES sales observations." | "Hedonic OLS and 2SLS regressions for rental and occupancy rates. Control sample seems to be other offices in some metropolitan area. No controls for micro-location effects." | "Hedonic OLS and 2SLS find rental differentials of 15%-17% for LEED and 7%-9% for ES . Hedonic OLS model of sales prices in absolute form. Estimate sale price premiums of $130 PSF and $30 PSF for LEED and ES." | "Hedonic OLS and 2SLS with occupancy rate as dependent variable finds occupancy rate differentials of 16%-18% for LEED and 10-11% for ES compared to control group." |
| Eicholtz, Kok, and Quigley (Fuerst and McAllister, 2009) | 2009 | "Contract rents for 694 certified offices. Sale prices for 199 certified offices 2004-7. Breakdown between LEED and ES is unclear." | "Hedonic OLS regressions for rental and sales prices. Control sample is offices within .25 miles of certified building." | "No statistically significant rental premium for LEED; 3% rental premium for ES. No statistically significant sale price premium for LEED. 19% sale price premium for ES." | "Find a positive relationship between energy efficiency measure and level of rental premium." |

| | | | | | |
|---|---|---|---|---|---|
| Fuerst and McAllister (Fuerst and McAllister, 2009) | 2009 | "Contract rents for 990 ES and 210 LEED certified offices. Sale prices for 662 ES and 139 LEED certified offices 1999-2009." | "Hedonic OLS regressions for rental and sale prices. Control sample is based on offices within some CoStar submarkets." | "6% rental premium for ES and LEED certified offices. 35% and 31% price premium for LEED and ES." | |
| Fuerst and McAllister | 2008 | Asking rents, actual rents, and sales prices for 1,900 green buildings - 626 LEED and 1,282 ES. Total of 9,806 observations between 1999 and 2009. | Hedonic OLS regressions. May be limited by clustering of homogenous assets at upper end of the market. | Median asking rents 35% higher for LEED and ES. Net lease premiums 12% for ES and 10% for LEED. Rent premium 5% for LEED and 4% for ES. Sales premium 25% for LEED and 26% for ES. | |
| Fuerst and McAllister | 2011 | Rental premiums by cluster/area. 2,688 LEED and ES buildings (313 of which were LEED, 2,111 were ES and 264 were both) and a total of 13,971 transactions and 36,236 rent observations. | OLS and "robust models." | Sale premiums of 18% for ES and 25% for LEED. Rental premiums of 3-5% for LEED and ES. | Market rents may be negatively affected by the 2007-2009 market downturn, but not significantly. |
| Fuerst and McAllister | 2012 | Rental premiums 10 largest MSA's from 2004 to 2007. 7,140 buildings - 1,768 LEED. | Hedonic OLS regression. | Rent premium of 2.9% for LEED and 2.5% for ES. | |

| | | | | | |
|---|---|---|---|---|---|
| Pivo and Fisher | 2008 | NCREIF data from 1998-2008 with 4,460 properties, of which 648 to 1,450 were included in each quarter. ES analysis only. | ES and location characteristics such as “in or near a CBD regeneration area,” “in or near suburban regeneration area,” “near a CBD transit station,” and various other scenarios. | “5.9% higher incomes and 13.5% higher market values per square foot, and suburban transit-oriented properties 12.7% higher incomes and 16.2% higher market values than other suburban offices” | Driven by “9.8% lower utility bills, 4.8% higher rents and .9% higher occupancy rates” while transit-oriented properties had 1.6% higher occupancies and 6.2% lower expenses. |
| Eicholtz, Kok, and Yonder | 2012 | Sample of "more than 700 LEED-registered properties on the balance sheet of 44 REITs” and “919 Energy Star-certified properties owned by 71 REITs” in August 2011. | Multiple two stage regressions. Study of REITs portfolios. | “if an REIT increases the share of green properties within the portfolio by one percent, the return on equity increases by 7.39-7.92 percent for LEED-Certified properties and 0.66 percent for Energy Star-certified properties” | Models beta of 0.14 for LEED properties and 0.01-0.03 for ES, by suggests that “green properties are less exposed to energy price fluctuations and occupancy risk. LEED and ES yields higher performance and less risk to RE cycle and energy costs. |

| | | | | | |
|---|---|---|---|---|---|
| Eicholtz, Kok and Quigley | 2013 | 21,000 leased buildings and approx. 6,000 transactions. | Cross section of 694 market clusters. | Sales premiums for green buildings were found to be 13% and rents were 3% higher on average between 2004 and 2009. Investors primarily willing to pay for OPEX savings rather than certification. | When “green office space increased substantially in a stagnant or declining market for commercial office space”, sustainable certified properties held their value relative to non-certified properties. |
| Reichardt, Rottke, and Zietz | 2011 | Leasing information for 235,950 tenants, 1,877 green buildings, and 47,112 comps. | Heckman two-staged model. Controls for age, renovations, stories, rentable are, lot size, and class. | They discover that various industries have responded differently in their office leasing decisions – some have a much higher preference for LEED and ES space. | Market competitiveness is seen as the motivating factor for these business decisions for the private sector while mandates, such as the one that requires all new federal buildings to be a minimum of LEED Silver, are driving the public sector. |

| | | | | | |
|---|---|---|---|---|---|
| Bonde and Song | 2013 | EPC data from 2003 to 2010 with 276 buildings and 1,572 observations. | Regression analysis | Values in Sweden are influenced by the normal things – rent, occupancy, location, Year Built – but do not show any correlation with EPC. | Given the cold climate, energy source and the cost of that source may be the cause – geothermal heating and cooling require a much higher capital expenditure but yield much lower operating expenses. |
| *Studies With Sample Sizes > Than 500 Observations | | | | | |

Appendix C

Bivariate Assumption Testing

## C.1 Bivariate Testing for ES Rating and PSF Value

The premise of this study is that the value of green buildings may be affected by a rating given by ENERGY STAR. The literature on this subject suggests that as certification levels rise, the value of properties increase, but the researcher is not aware of any studies that test these conclusions with tax appraised values. This model tests whether tax appraised values PSF are affected by higher levels ES certification. The null hypothesis is that ES rating levels have no effect on PSF tax appraised value of property improvements. This section reviews the steps taken to create this model, evaluate its potential limitations, and test the null hypothesis.

For this bivariate regression, one regression with the dependent variable is PSF Value and the independent variable of ES rating is run. The PSF Value of the cleaned ES dataset ranges from $2.94 to $217.60 with a mean of $95.22 and a standard deviation of 52.27. The ES ratings from 75 to 100 have a mean of 83.66 and a standard deviation of 6.54. The data has a positive skew. A graphical relationship is somewhat visible with the highest values toward the upper threshold of ES ratings.

Table C-1 Descriptive Statistics for PSF and ES Rating Model

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Per Square Foot Value | 370 | 2.94 | 217.60 | 94.50 | 52.29 |
| ENERGY STAR Rating | 370 | 75 | 100 | 83.65 | 6.56 |

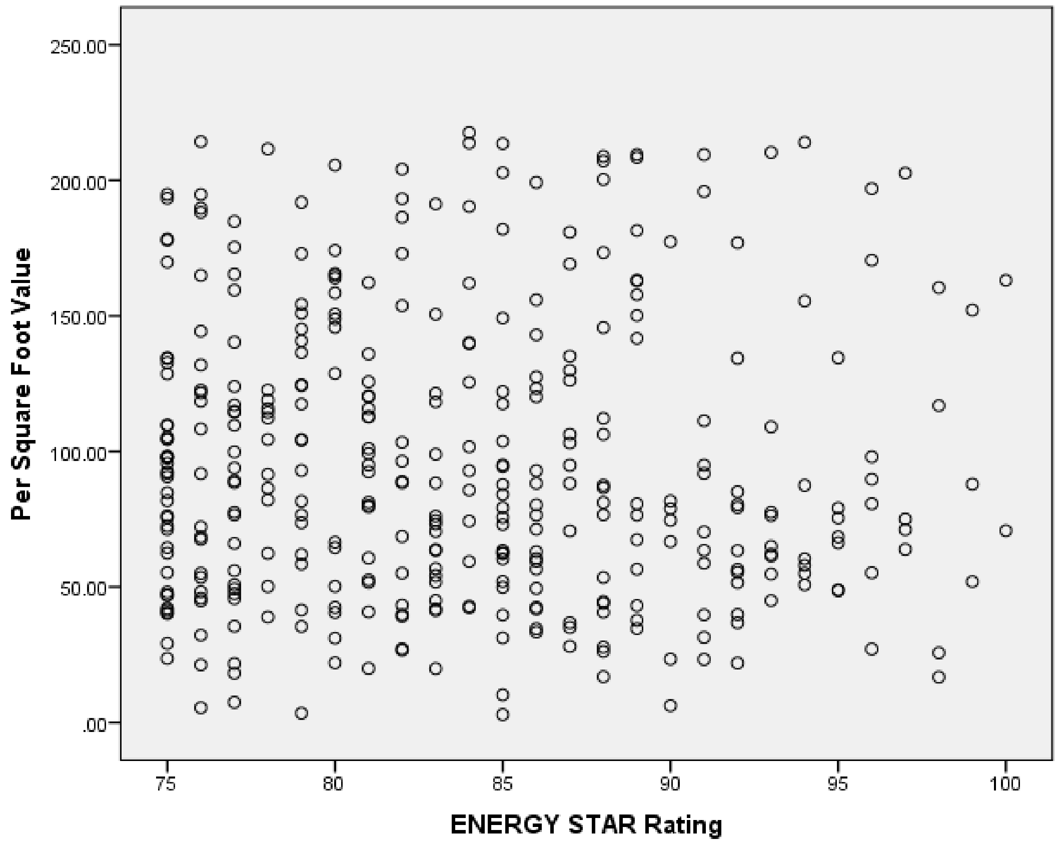


Figure C-1 Graphical representation of value PSF on the Y-axis and ES rating on the X-axis.

Figure C-1 suggests that there may not be a linear relationship between PSF Value and ES rating which would violate the linearity assumption for linear regression. The data appears to have a positive skew. There as several options for resolving the linearity that can be explored if the data is not linear related, but it is first necessary to further vet this dataset in order to make sure the normality, independence and homoscedasticity assumptions for this model hold true. The residual statistics are therefore explored to confirm that a linear regression model can be run using this data.

Table C-2 PSF and ES Rating Model Residuals Statistics

| Value | Minimum | Maximum | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| Predicted Value | 90.11 | 96.82 | 94.50 | 1.76 | 370 |
| Residual | -92.28 | 123.19 | 0.00 | 52.26 | 370 |
| Std. Predicted Value | -2.49 | 1.32 | 0.00 | 1.00 | 370 |
| Std. Residual | -1.76 | 2.35 | 0.00 | 1.00 | 370 |

a. Dependent Variable: Per Square Foot Value

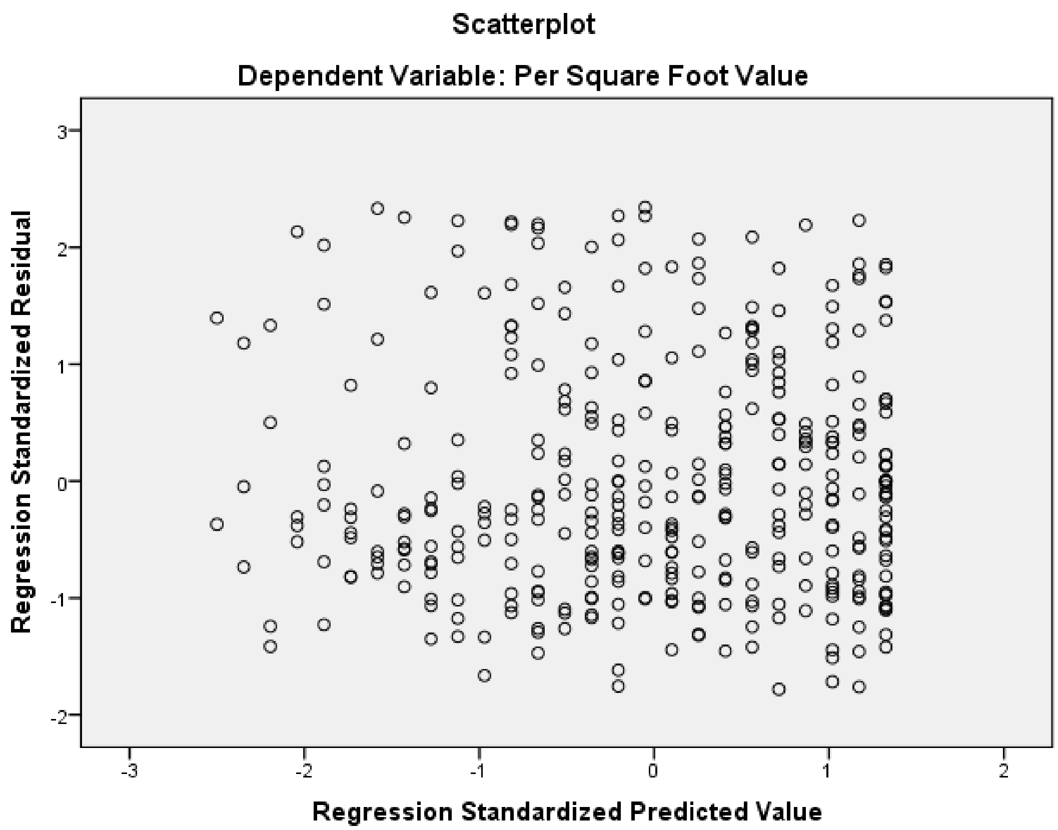


Figure C-2 Graphical representation of regression standardized residual and regression standardized predicted value for PSF Value as the dependent variable and ES rating as the independent variable.

The residual plot suggests that the data is homoscedastic and independent, but it does indicate another potential problem with the data – it may not be normally distributed. A histogram is necessary to explore this possibility.

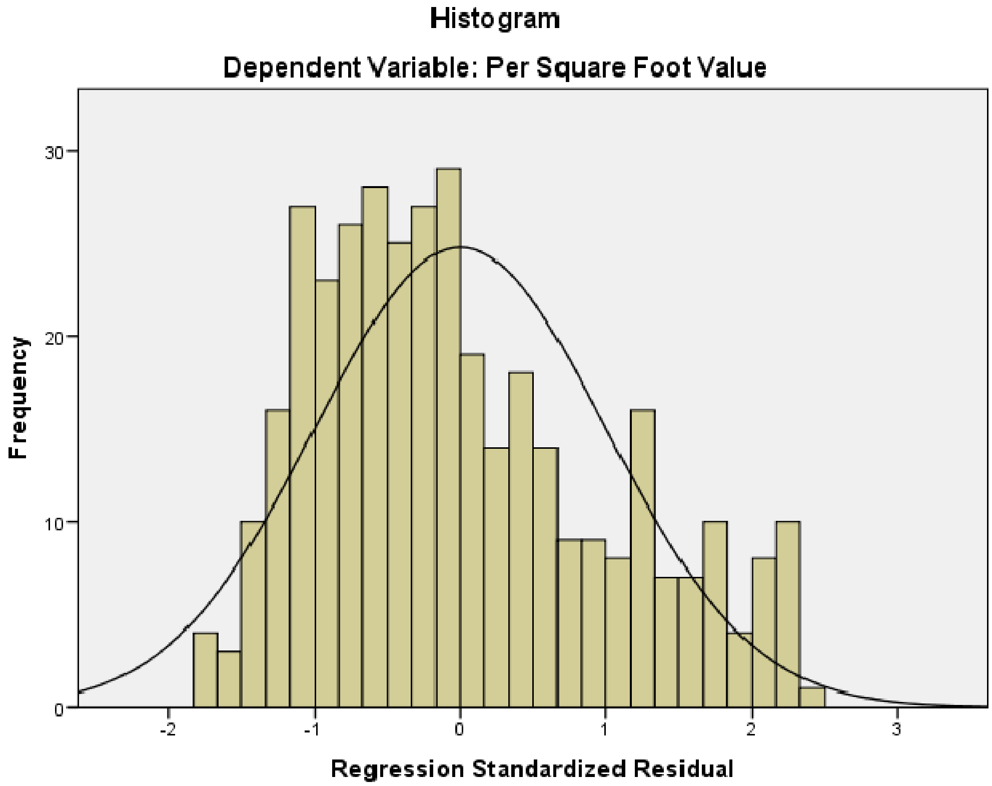


Figure C-3 Graphical representation of regression standardized residual and its frequency for PSF Value as the dependent variable and ES rating as the independent variable.

Figure C-3 suggests that the ES rating and PSF Value model is normally distributed with a positive skew. To further test this assumption, the normality of this data is explored in Figure 4-4.

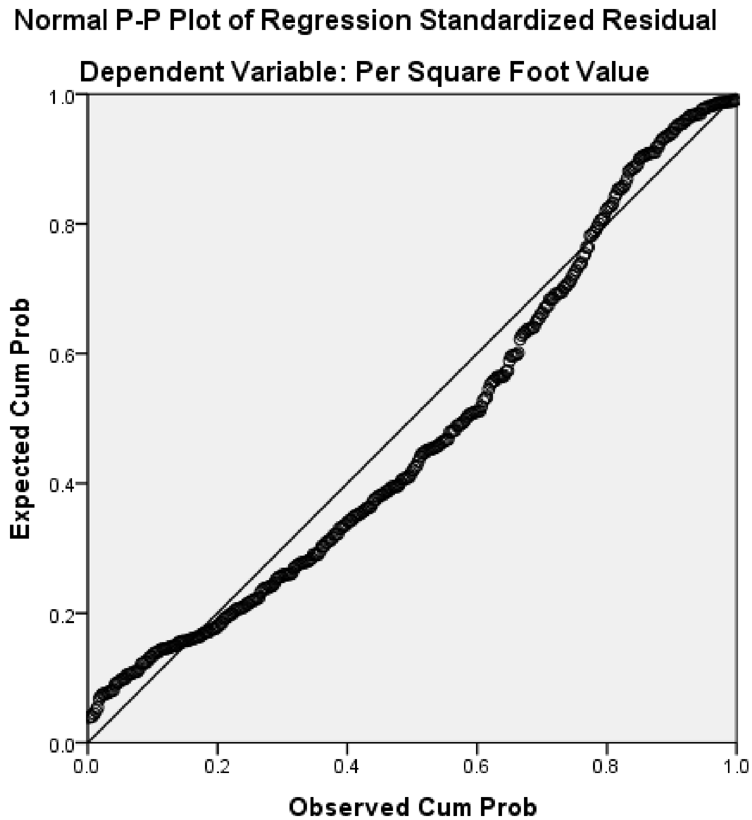


Figure C-4 Graphical representation of a probability-probability plot with the dependent variable of PSF Value and independent variable of ES rating.

The data in this model is normally distributed; therefore a regression is valid with all assumptions for linear regression validated. The results of the linear regression are presented in Tables C-3 and C-4.

Table C-3 Model Summary of PSF Value and ES Rating

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .034[a] | .00113 | -.002 | 52.32971 |

a. Predictors: (Constant), ES Rating

b. Dependent Variable: Per Square Foot Value

Table C-4 ANOVA for PSF Value and ES Rating Model

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 1142.335 | 1 | 1142.335 | .417 | .519[b] |
| Residual | 1007730.632 | 368 | 2738.398 | | |
| Total | 1008872.968 | 369 | | | |

a. Dependent Variable: Per Square Foot Value

b. Predictors: (Constant), ES Rating

Table C-5 Coefficients for PSF Value and ES Rating Model

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | t | Sig. |
| (Constant) | 116.953 | 34.871 | | 3.354 | .001 |
| ES Rating | -.268 | .416 | -.034 | -.646 | .519 |

a. Dependent Variable: Per Square Foot Value

In this section, the assumptions for linear regression are explored extensively to confirm the validity of the regressions. The determination is that the data is positively skewed but normally distributed, linear but with a weak correlation, homoscedastic and independent. The Durbin-Watson statistic of 1.535 is more than 1 indicating that the observations are independent.

The significance of the model as seen Table C-4 suggests that the outcome is not significant at the .05 (2-tailed) with a significance of .519. With a $R^2$ of only .00113, ES rating explains 0.1% of the variability in PSF Value when using the two variables. With a coefficient of --.268, the model suggest that for every one-unit increase in ES rating, improved property value decreases by $0.26 PSF, but, since the outcome is not significant, we cannot be confident that the variables are related. The null hypothesis for this model is, therefore, accepted since the data suggests that ES rating has no effect on PSF tax appraised value of property improvements of the observed properties.

C.2 Bivariate Testing for Year Built and PSF Value

The relationship between PSF Value and Year Built is a standard expectation for commercial properties; however, this relationship is often hindered by retrofits and rehabs. This is especially common in office buildings because of they are often constructed to be “fit-out” according to tenants, are of higher structural quality, and are more commonly located on more valuable property. It is not clear which properties have had improvements since initial construction; therefore, the data is examined as a whole and then in two spate time periods: from 1979 to 1987 and from 1999 to 2009. These two periods have 202 and 88 of the observations, respectively. For this linear regression model the null hypothesis is that Year Built has no effect on PSF tax appraised value of property improvements. In order to conduct this analysis, the data is first scrutinized to ensure that it conforms to the assumptions for linear regression.

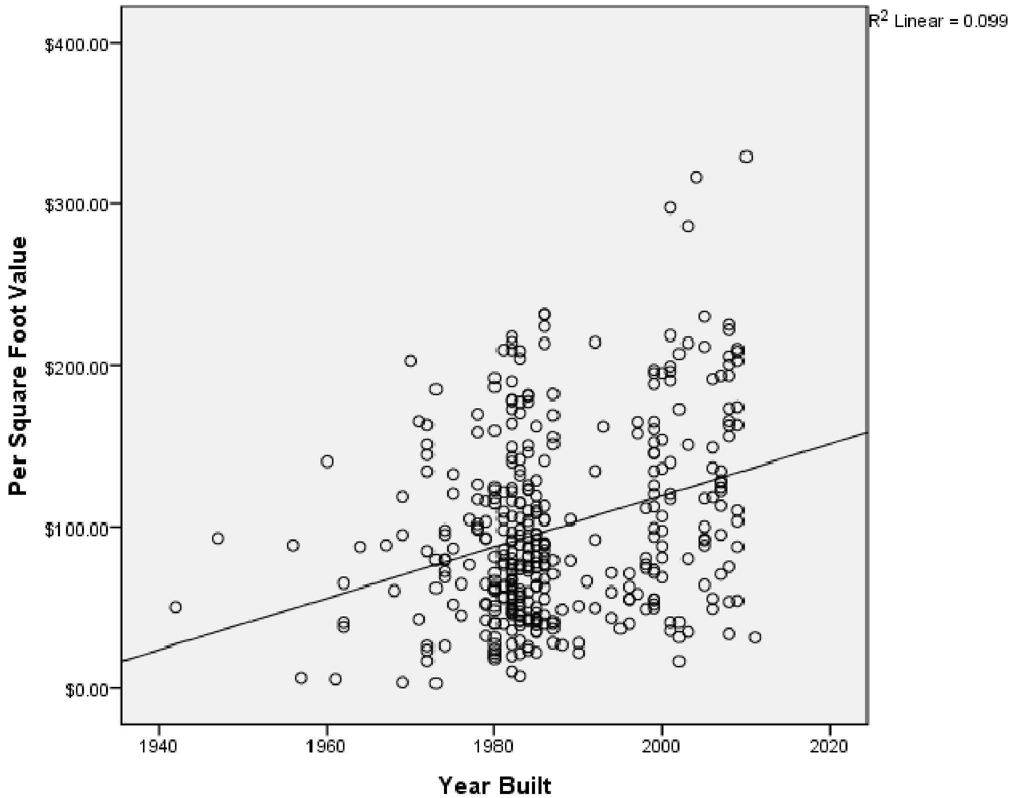


Figure C-5 Graphical representation of the relationship between PSF value and Year Built with line of best fit.

Figure C-5 suggests that there is a linear relationship between PSF Value and Year Built. However, further analysis is required to evaluate whether other assumptions for linear regression are violated. The residuals are presented in Table C-6 and graphically in Figure C-5.

Table C-6 PSF and Year Built Model Residuals Statistics

| Variable | Minimum | Maximum | Mean | Std. Deviation | N |
|---|---|---|---|---|---|
| Predicted Value | 27.04 | 136.81 | 99.15 | 18.43 | 381 |
| Residual | -105.74 | 193.98 | .00 | 55.61 | 381 |
| Std. Predicted Value | -3.91 | 2.04 | .00 | 1.00 | 381 |
| Std. Residual | -1.90 | 3.48 | .00 | 1.00 | 381 |

a. Dependent Variable: Per Square Foot Value

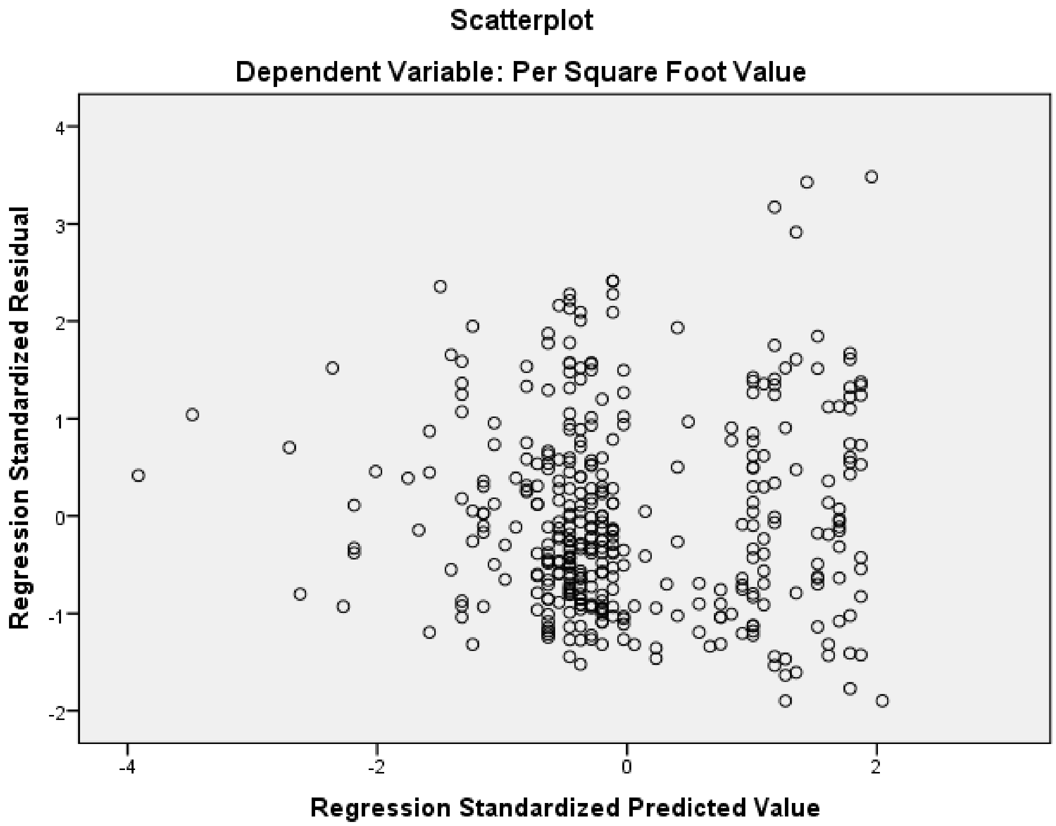


Figure C-6 Graphical representation of the residuals of PSF Value and Year Built.

The scatter plot of the standardize predicted values and the standardized residuals with PSF of the dependent variable presented in Figure C-6 suggests that the data may be slightly heteroscedastic.

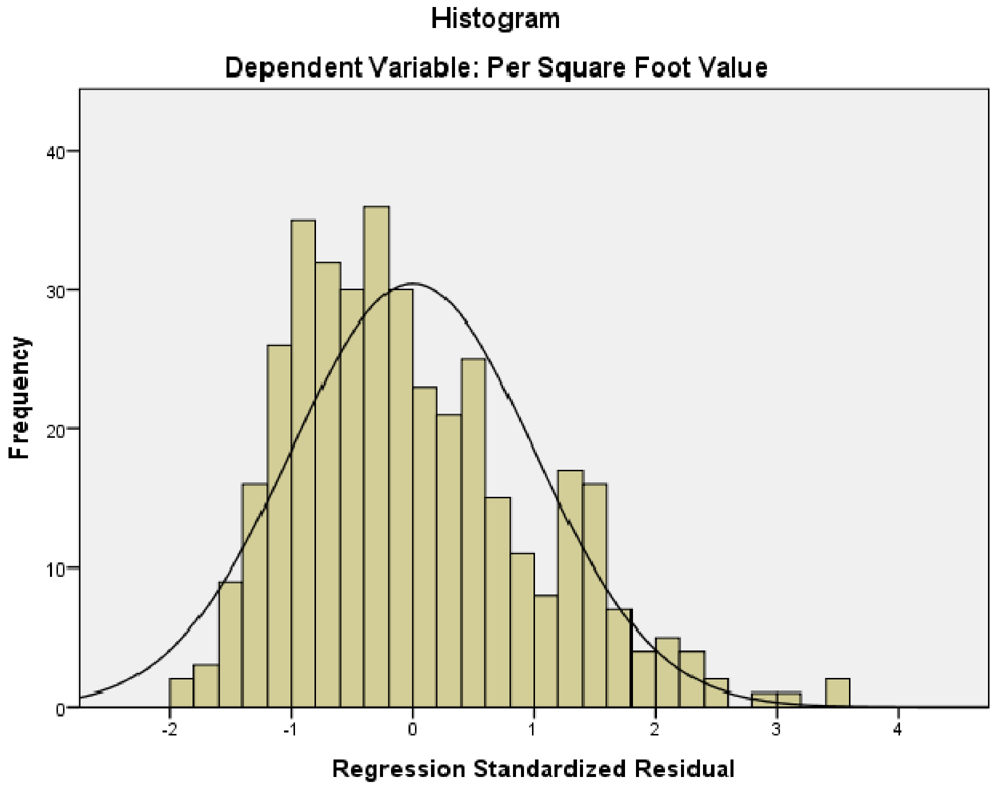


Figure C-7 Histogram of the residuals of PSF Value and Year Built.

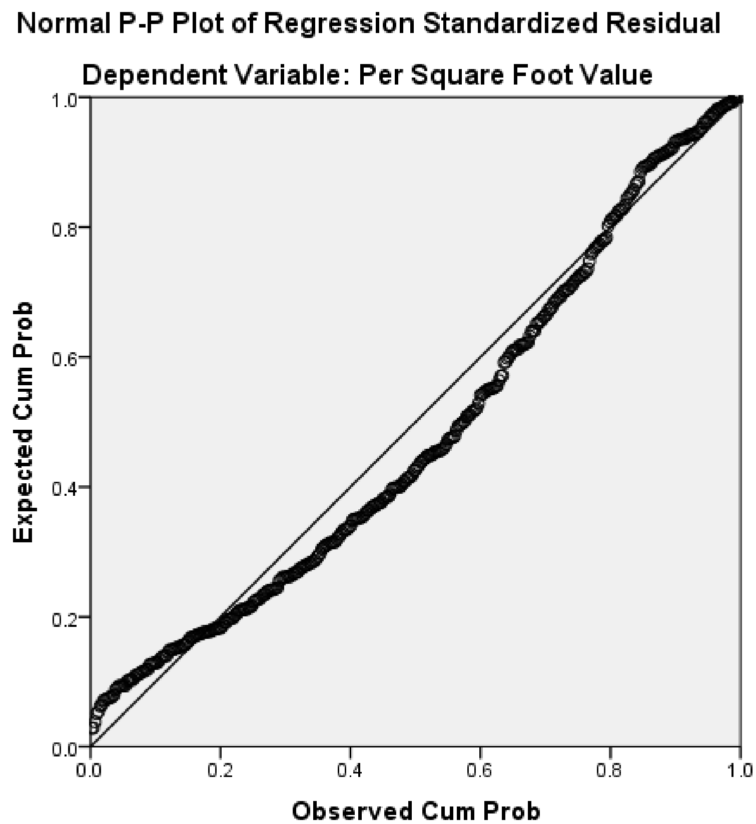


Figure C-8 Graphical representation of a probability-probability plot with the dependent variable of PSF Value and independent variable of Year Built.

The residuals depicted in Figures C-6 and C-7 have a positive skew and suggest that the data is normally distributed. As a result, a linear regression is run with PSF Value as the dependent variable and Year Built as the independent variable.

Table C-7 Model Summary of PSF Value and Year Built

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .315a | .09895 | .097 | $55.69 | 1.568213 |

a. Predictors: (Constant), Year Built

b. Dependent Variable: Per Square Foot Value

Table C-8 ANOVA for PSF Value and Year Built Model

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 129076.299 | 1 | 129076.299 | 41.622 | .000b |
| Residual | 1175332.105 | 379 | 3101.140 | | |
| Total | 1304408.404 | 380 | | | |

a. Dependent Variable: Per Square Foot Value

b. Predictors: (Constant), Year Built

Table C-9 Coefficients for PSF Value and Year Built Model

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | t | Sig. |
| (Constant) | -3062.454 | 490.064 | | -6.249 | .000 |
| Year Built | 1.591 | .247 | .315 | 6.452 | .000 |

a. Dependent Variable: Per Square Foot Value

Table C-8 suggests that this model is not significant at the .05 level (2-tailed) with a significance factor of .000. With a $R^2$ of .09895, the Year Built explains 9.8% of the variability in PSF Value of the ES dataset. The model suggests that one year increase in Year Built increases PSF Value by $1.59, but, similar to the model in section 4.1, the outcome is not significant and we cannot be confident that the variables are related.

Next, the potential for a series of years to be selected that fits the assumptions for linear regression is explored. The two obvious series of years to be utilized for further analysis are the periods with the most observations which include the years during the building boom in the 1980's and the 2000's. A series of years as outlined in the preceding frequency tables is selected for analysis. Then, a scatterplot with the dependent variable of PSF Value on the Y-axis and the year on the X-axis is presented.

Table C-10 Year Built Frequency from 1979 to 1987

| Year | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| 1979 | 9 | 4.5 | 4.5 | 4.5 |
| 1980 | 23 | 11.4 | 11.4 | 15.8 |
| 1981 | 15 | 7.4 | 7.4 | 23.3 |
| 1982 | 44 | 21.8 | 21.8 | 45 |
| 1983 | 30 | 14.9 | 14.9 | 59.9 |
| 1984 | 26 | 12.9 | 12.9 | 72.8 |
| 1985 | 28 | 13.9 | 13.9 | 86.6 |
| 1986 | 16 | 7.9 | 7.9 | 94.6 |
| 1987 | 11 | 5.4 | 5.4 | 100 |
| Total | 202 | 100 | 100 | |

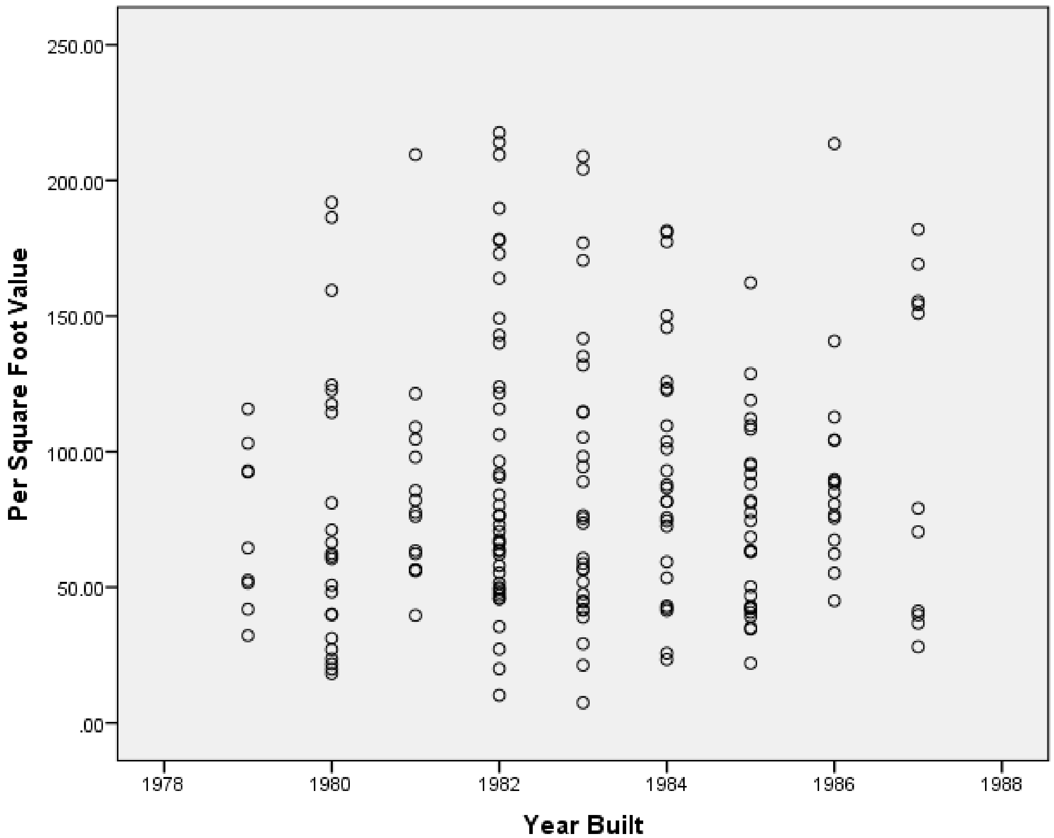


Figure C-9 Graphical representation of the relationship between PSF Value and years built from 1979 to 1987.

Even though this model does not meet the assumptions of normality and linearity for linear regression, a regression is run to confirm that the variables are not linear related. There is no predictive ability of the dependent variable of PSF Value for the years 1979 to 1987. For this model, the $R^2$ is 0.000229. As discussed previously in this study, it is possible that this is the result of property improvements that are likely to be undertaken for older, valuable commercial properties. For this reason, a more recent sample of observations is explored.

Table C-11 Year Built Frequency from 1999 to 2009

| Year | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| 1999 | 21 | 23.9 | 23.9 | 23.9 |
| 2000 | 8 | 9.1 | 9.1 | 33.0 |
| 2001 | 9 | 10.2 | 10.2 | 43.2 |
| 2002 | 5 | 5.7 | 5.7 | 48.9 |
| 2003 | 4 | 4.5 | 4.5 | 53.4 |
| 2004 | 1 | 1.1 | 1.1 | 54.5 |
| 2005 | 7 | 8.0 | 8.0 | 62.5 |
| 2006 | 5 | 5.7 | 5.7 | 68.2 |
| 2007 | 9 | 10.2 | 10.2 | 78.4 |
| 2008 | 10 | 11.4 | 11.4 | 89.8 |
| 2009 | 9 | 10.2 | 10.2 | 100.0 |
| Total | 88 | 100.0 | 100.0 | |

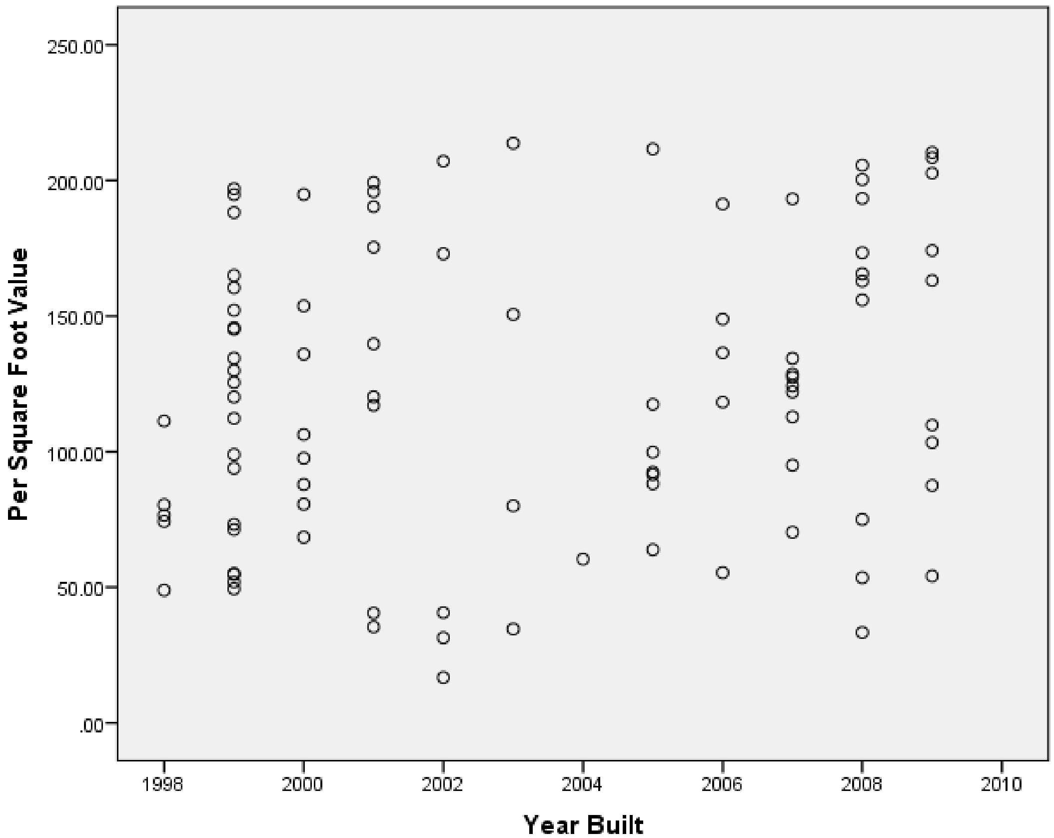


Figure C-10 Graphical representation of the relationship between PSF value and years built from 1998 to 2009.

The PSF Values for the period of 1999 to 2009 also do not conform to the assumptions for linear regression including linearity and normality. The result of the regression utilizing PSF Value as the dependent variable and Year Built as the independent variable suggests that there is no predictive ability for the years 1999 to 2009. For this model, the $R^2$ is 0.010351.

The lack of a strong linear relationship between PSF Value and Year Built may simply be a result of this relatively small, 381 observation dataset over an uneven distributed period of 69 years. To further test this regression analysis, two datasets of an 8 year period with 202 observations and a 11 year period with 88 observations was explored without improving the model's predictive ability. However, as a result of the broad dataset including previously defined outliers, the model fails to reject the null hypothesis as the data suggests that Year Built and PSF tax appraised value of property improvements may not be related.

Appendix D

ENERGY STAR Rating and Cities Model Regression Results

Table D-1 Model Summary of ES Rating and Cities Model

| N | F( 5, 57) | Prob > F | R-squared | Adj R-squared | Root MSE |
|---|---|---|---|---|---|
| 76 | 9.42 | 0 | 0.6343 | 0.5188 | 43.2341 |

Table D-2 Summary of ES Rating and Cities Model

| Variable | Coef. | Std. Err. | t | P>t | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| Rating | 1.560451 | 0.9274582 | 1.68 | 0.098* | -.296752 | 3.417654 |
| Austin | 99.73937 | 17.49306 | 5.7 | 0** | 64.71013 | 134.7686 |
| Dallas | 40.80854 | 21.25379 | 1.92 | 0.06* | -1.751449 | 83.36853 |
| Fort Worth | -8.63604 | 59.74642 | -0.14 | 0.886 | -128.2762 | 111.0041 |
| Houston | 74.11726 | 16.7015 | 4.44 | 0** | 40.67308 | 107.5614 |
| Constant | -49.94868 | 78.53505 | -0.64 | 0.527 | -207.2124 | 107.315 |

a. Year Built is utilized as fixed effects with 14 categories.
b. * Correlation is significant at the 0.10 level.
c. ** Correlation is significant at the 0.05 level.

Appendix E

ENERGY STAR Rating and Zip Codes Model Regression Results

Table E-1 Model Summary of ES Rating and Zip Codes Model

| N | F(35,40) | Prob > F | R-squared | Adj R-squared | Root MSE |
|---|---|---|---|---|---|
| 76 | 9.42 | 0 | 0.8308 | 0.6828 | 35.101 |

Table E-2 Summary of ES Rating, and Zip Codes Model

| PSF Value | Coef. | Std. Err. | t | P>t | [95% Conf. Interval] | |
|---|---|---|---|---|---|---|
| rating | 1.587843 | 0.7674334 | 2.07 | 0.045** | 0.036802 | 3.138883 |
| 75038 | -70.64365 | 37.7203 | -1.87 | 0.068 | -146.8792 | 5.591934 |
| 75201 | 5.14356 | 22.00411 | 0.23 | 0.816 | -39.3284 | 49.61552 |
| 75225 | -21.29384 | 28.58213 | -0.75 | 0.461 | -79.06048 | 36.4728 |
| 75240 | -85.26276 | 28.65159 | -2.98 | 0.005** | -143.1698 | -27.3557 |
| 75251 | -74.78207 | 37.7203 | -1.98 | 0.054 | -151.0177 | 1.453505 |
| 75254 | -17.89286 | 37.52463 | -0.48 | 0.636 | -93.73295 | 57.94724 |
| 76140 | -148.3962 | 39.72789 | -3.74 | 0.001** | -228.6892 | -68.1031 |
| 76155 | -17.73991 | 37.80608 | -0.47 | 0.641 | -94.14885 | 58.66903 |
| 77002 | 115.1834 | 24.65582 | 4.67 | 0** | 65.35215 | 165.0147 |
| 77022 | -76.67364 | 37.7203 | -2.03 | 0.049** | -152.9092 | -0.43806 |
| 77024 | 43.01587 | 29.38228 | 1.46 | 0.151 | -16.36793 | 102.3997 |
| 77027 | -42.71129 | 38.30134 | -1.12 | 0.271 | -120.1212 | 34.69862 |
| 77041 | -5.582914 | 18.931 | -0.29 | 0.77 | -43.84389 | 32.67806 |
| 77042 | 28.68081 | 20.1242 | 1.43 | 0.162 | -11.99171 | 69.35333 |
| 77043 | -17.49717 | 37.556 | -0.47 | 0.644 | -93.40068 | 58.40634 |
| 77056 | -59.44991 | 37.80608 | -1.57 | 0.124 | -135.8589 | 16.95903 |
| 77060 | 9.271463 | 37.556 | 0.25 | 0.806 | -66.63205 | 85.17498 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 77067 | -42.35854 | 37.556 | -1.13 | 0.266 | -118.2621 | 33.54497 |
| 77072 | -0.8417762 | 28.14608 | -0.03 | 0.976 | -57.72714 | 56.04358 |
| 77077 | 58.16871 | 29.17105 | 1.99 | 0.053 | -0.7881828 | 117.1256 |
| 77084 | -38.94855 | 28.18529 | -1.38 | 0.175 | -95.91315 | 18.01605 |
| 77086 | 87.44597 | 39.98648 | 2.19 | 0.035** | 6.630275 | 168.2617 |
| 77094 | 16.96509 | 28.51766 | 0.59 | 0.555 | -40.67126 | 74.60144 |
| 77494 | 57.5344 | 38.02355 | 1.51 | 0.138 | -19.31407 | 134.3829 |
| 78216 | -82.5156 | 38.02355 | -2.17 | 0.036** | -159.3641 | -5.66714 |
| 78229 | -70.2056 | 38.02355 | -1.85 | 0.072** | -147.0541 | 6.642869 |
| 78247 | -18.7958 | 37.80608 | -0.5 | 0.622 | -95.20474 | 57.61314 |
| 78248 | -23.07854 | 37.556 | -0.61 | 0.542 | -98.98206 | 52.82497 |
| 78249 | -36.3607 | 37.53247 | -0.97 | 0.338 | -112.2167 | 39.49525 |
| 78258 | -70.77452 | 28.88956 | -2.45 | 0.019** | -129.1625 | -12.3865 |
| 78259 | -61.70776 | 37.90721 | -1.63 | 0.111 | -138.3211 | 14.90556 |
| 78701 | 149.868 | 29.61189 | 5.06 | 0** | 90.02016 | 209.7159 |
| 78735 | -22.46423 | 37.64998 | -0.6 | 0.554 | -98.55767 | 53.62921 |
| 78746 | 43.29502 | 17.01254 | 2.54 | 0.015** | 8.91139 | 77.67865 |
| 78759 | 0 | (omitted) | | | | |
| Constant | 9.5376 | 63.56209 | 0.15 | 0.881 | -118.9262 | 138.0014 |

a. ** Correlation is significant at the 0.05 level.

Appendix F

ENERGY STAR Dataset

| id | type | city | zip | rating | sf | year | improved | psf |
|---|---|---|---|---|---|---|---|---|
| 18732 | supermarket | san | 78704 | 90 | 69586 | 1957 | 434014 | 6.24 |
| 1507388 | medical | hou | 77056 | 76 | 344185 | 1969 | 40780847 | 118.49 |
| 1610933 | other | dal | 77056 | 87 | 178468 | 1969 | 16935739 | 94.90 |
| 3213915 | retail | dal | 77002 | 91 | 1152002 | 1974 | 109373996 | 94.94 |
| 1505126 | medical | hou | 77027 | 81 | 356946 | 1975 | 42972814 | 120.39 |
| 1280900 | retail | ftw | 77056 | 75 | 254628 | 1977 | 26595680 | 104.45 |
| 1460252 | medical | hou | 77027 | 98 | 315500 | 1978 | 36883178 | 116.90 |
| 3215794 | medical | hou | 77060 | 87 | 230824 | 1978 | 29139350 | 126.24 |
| 1489376 | medical | hou | 77056 | 78 | 447275 | 1979 | 51796100 | 115.80 |
| 1201945 | supermarket | san | 78753 | 83 | 76332 | 1979 | 3201533 | 41.94 |
| 30295 | hotel | hou | 77056 | 78 | 473645 | 1980 | 54203250 | 114.44 |
| 1537980 | medical | hou | 77056 | 85 | 463802 | 1980 | 54511375 | 117.53 |
| 30394 | hotel | ftw | 77098 | 96 | 216000 | 1981 | 21169426 | 98.01 |
| 30028 | hotel | hou | 77042 | 93 | 191287 | 1981 | 20864660 | 109.08 |
| 1158770 | medical | hou | 77002 | 83 | 1418916 | 1981 | 172255227 | 121.40 |
| 18405 | supermarket | ftw | 77005 | 75 | 167727 | 1981 | 17538787 | 104.57 |
| 30398 | hotel | ftw | 77042 | 82 | 230952 | 1982 | 22270684 | 96.43 |
| 1748819 | medical | dal | 77056 | 85 | 67145 | 1982 | 684950 | 10.20 |
| 3209608 | medical | hou | 77046 | 81 | 534419 | 1982 | 61884250 | 115.80 |
| 1460258 | medical | hou | 77060 | 76 | 261983 | 1982 | 31863650 | 121.62 |
| 1509870 | medical | hou | 77027 | 77 | 236139 | 1982 | 29269830 | 123.95 |
| 30056 | hotel | dal | 78205 | 75 | 520195 | 1983 | 51112820 | 98.26 |
| 1051015 | medical | hou | 77067 | 77 | 209090 | 1983 | 23957712 | 114.58 |
| 1506253 | medical | hou | 77067 | 77 | 357056 | 1983 | 40959419 | 114.71 |
| 18712 | supermarket | san | 78756 | 76 | 49571 | 1983 | 1055184 | 21.29 |
| 30070 | hotel | hou | 77058 | 75 | 388500 | 1984 | 42579169 | 109.60 |
| 18413 | supermarket | aus | 78230 | 90 | 138540 | 1984 | 11319550 | 81.71 |
| 2242657 | retail | aus | 78216 | 93 | 166370 | 1985 | 12908620 | 77.59 |
| 18408 | supermarket | aus | 78217 | 75 | 285535 | 1985 | 23365854 | 81.83 |
| 18722 | supermarket | san | 78240 | 83 | 68378 | 1985 | 4339780 | 63.47 |
| 30055 | hotel | dal | 78216 | 96 | 220495 | 1986 | 19793100 | 89.77 |
| 2795493 | medical | san | 78701 | 83 | 454764 | 1986 | 101855697 | 223.97 |
| 18415 | supermarket | aus | 78209 | 96 | 184673 | 1986 | 14905390 | 80.71 |
| 18425 | supermarket | aus | 78232 | 92 | 109555 | 1986 | 9326690 | 85.13 |
| 18257 | supermarket | aus | 78212 | 83 | 136061 | 1986 | 12026320 | 88.39 |
| 18420 | supermarket | aus | 78232 | 77 | 165664 | 1986 | 14781390 | 89.23 |
| 1036059 | supermarket | san | 78748 | 85 | 72783 | 1986 | 4537350 | 62.34 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1711515 | hotel | aus | 78217 | 95 | 78604 | 1987 | 6220760 | 79.14 |
| 18727 | supermarket | san | 78660 | 82 | 82998 | 1987 | 3306399 | 39.84 |
| 18731 | supermarket | san | 78744 | 83 | 72206 | 1987 | 2978631 | 41.25 |
| 30297 | hotel | aus | 78204 | 88 | 88988 | 1990 | 2478800 | 27.86 |
| 18753 | supermarket | san | 78247 | 86 | 67978 | 1994 | 4043690 | 59.49 |
| 2988148 | medical | aus | 77017 | 94 | 73565 | 1996 | 4050310 | 55.06 |
| 3114212 | retail | san | 78213 | 76 | 76890 | 1996 | 4233020 | 55.05 |
| 18713 | supermarket | san | 78210 | 100 | 22305 | 1996 | 1578650 | 70.78 |
| 1036151 | supermarket | san | 78221 | 79 | 91916 | 1997 | 5371670 | 58.44 |
| 1036100 | hotel | hou | 77027 | 91 | 315500 | 1998 | 35121760 | 111.32 |
| 2245535 | other | san | 78223 | 95 | 95415 | 1998 | 4673640 | 48.98 |
| 1272770 | hotel | aus | 77058 | 99 | 55000 | 1999 | 2858556 | 51.97 |
| 1040795 | hotel | hou | 77041 | 78 | 136369 | 1999 | 15315900 | 112.31 |
| 1428282 | other | hou | 78746 | 76 | 195324 | 1999 | 38044861 | 194.78 |
| 18710 | supermarket | san | 78745 | 86 | 81880 | 1999 | 4052177 | 49.49 |
| 1551940 | supermarket | san | 78702 | 82 | 54259 | 1999 | 2988151 | 55.07 |
| 1046022 | hotel | dal | 78258 | 87 | 103223 | 2000 | 10974540 | 106.32 |
| 3029253 | other | hou | 78746 | 75 | 195639 | 2000 | 38119370 | 194.85 |
| 18414 | supermarket | aus | 78229 | 89 | 87936 | 2000 | 7092430 | 80.65 |
| 30075 | hotel | san | 78746 | 86 | 222567 | 2001 | 44340006 | 199.22 |
| 1096058 | medical | san | 78759 | 96 | 190891 | 2001 | 41710905 | 218.51 |
| 18669 | supermarket | hou | 78746 | 91 | 173304 | 2001 | 33944988 | 195.87 |
| 18728 | supermarket | san | 76107 | 75 | 73974 | 2001 | 3000000 | 40.55 |
| 30074 | hotel | san | 78746 | 88 | 192214 | 2002 | 39816328 | 207.15 |
| 18743 | supermarket | san | 78148 | 81 | 81593 | 2003 | 6532710 | 80.06 |
| 18165 | supermarket | san | 77043 | 89 | 64509 | 2003 | 2236189 | 34.66 |
| 1453400 | medical | hou | 77043 | 79 | 47829 | 2005 | 5618951 | 117.48 |
| 18750 | supermarket | san | 78224 | 97 | 169033 | 2005 | 10799740 | 63.89 |
| 1038936 | hotel | dal | 78248 | 83 | 107760 | 2006 | 12742190 | 118.25 |
| 30296 | hotel | hou | 77041 | 81 | 133068 | 2007 | 15019170 | 112.87 |
| 3254670 | medical | hou | 77041 | 86 | 158205 | 2007 | 20162494 | 127.45 |
| 1375100 | other | hou | 78746 | 82 | 256457 | 2007 | 49553877 | 193.22 |
| 1280929 | retail | dal | 77041 | 85 | 131908 | 2007 | 12534140 | 95.02 |
| 18717 | supermarket | san | 78258 | 97 | 163885 | 2008 | 12299600 | 75.05 |
| 30057 | hotel | dal | 78249 | 82 | 97478 | 2009 | 10077660 | 103.38 |
| 1046021 | hotel | dal | 78247 | 75 | 5800 | 2009 | 636990 | 109.83 |
| 18446 | supermarket | aus | 78259 | 88 | 645020 | 2009 | 56479440 | 87.56 |
| 1412294 | office | dal | 77002 | 78 | 588568 | 1942 | 29545093 | 50.20 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 27484 | office | dal | 77002 | 86 | 381165 | 1947 | 35418400 | 92.92 |
| 1483655 | office | dal | 77002 | 82 | 626906 | 1956 | 55463921 | 88.47 |
| 1121267 | office | hou | 77002 | 77 | 671344 | 1960 | 94215822 | 140.34 |
| 1120115 | office | hou | 78701 | 76 | 121677 | 1961 | 665348 | 5.47 |
| 2383111 | office | dal | 77030 | 89 | 299539 | 1962 | 11296700 | 37.71 |
| 2033212 | office | dal | 77002 | 80 | 435157 | 1962 | 17632880 | 40.52 |
| 3109997 | office | dal | 77002 | 93 | 478792 | 1962 | 31128429 | 65.01 |
| 15523 | office | hou | 78741 | 94 | 490706 | 1964 | 42945565 | 87.52 |
| 1614589 | office | aus | 77024 | 88 | 259657 | 1967 | 11434951 | 44.04 |
| 1422979 | office | dal | 77019 | 77 | 177713 | 1967 | 15728883 | 88.51 |
| 3117892 | office | dal | 77046 | 85 | 91216 | 1968 | 5505314 | 60.35 |
| 1506606 | office | hou | 75234 | 79 | 90057 | 1969 | 312600 | 3.47 |
| 1163160 | office | hou | 77002 | 85 | 628031 | 1970 | 127368272 | 202.81 |
| 3215809 | office | hou | 77002 | 77 | 918162 | 1971 | 151850000 | 165.38 |
| 2736133 | office | hou | 75206 | 86 | 296624 | 1971 | 12603170 | 42.49 |
| 3118789 | office | aus | 77046 | 75 | 386000 | 1972 | 32723048 | 84.77 |
| 1673934 | office | aus | 78205 | 88 | 154029 | 1972 | 2600000 | 16.88 |
| 3245676 | office | dal | 77056 | 91 | 155403 | 1972 | 3623790 | 23.32 |
| 1845557 | office | hou | 77024 | 92 | 152018 | 1972 | 20425375 | 134.36 |
| 23587 | office | hou | 77056 | 76 | 183620 | 1972 | 26502179 | 144.33 |
| 1867196 | office | hou | 77002 | 80 | 1049193 | 1972 | 158157600 | 150.74 |
| 15709 | office | hou | 77002 | 89 | 1199696 | 1972 | 195762658 | 163.18 |
| 15466 | office | hou | 75270 | 88 | 1917802 | 1972 | 50213730 | 26.18 |
| 1272547 | office | aus | 77008 | 79 | 54672 | 1973 | 3387590 | 61.96 |
| 3532 | office | dal | 77027 | 92 | 203932 | 1973 | 16171706 | 79.30 |
| 1121286 | office | hou | 77002 | 77 | 1597385 | 1973 | 295257365 | 184.84 |
| 1070110 | office | hou | 75251 | 85 | 129127 | 1973 | 379550 | 2.94 |
| 1138271 | office | dal | 77056 | 81 | 493456 | 1974 | 39252011 | 79.55 |
| 1114203 | office | hou | 78752 | 82 | 51868 | 1974 | 3560779 | 68.65 |
| 1121289 | office | hou | 78757 | 76 | 155194 | 1974 | 11203936 | 72.19 |
| 14782 | office | hou | 78731 | 75 | 101917 | 1974 | 9971293 | 97.84 |
| 2587415 | office | san | 77056 | 85 | 426226 | 1974 | 33779500 | 79.25 |
| 1200235 | office | dal | 77056 | 83 | 111261 | 1975 | 5763100 | 51.80 |
| 1331486 | office | dal | 77056 | 78 | 216975 | 1975 | 18749853 | 86.41 |
| 1403308 | office | hou | 78701 | 75 | 290619 | 1975 | 38568002 | 132.71 |
| 1330822 | office | aus | 77004 | 76 | 207616 | 1976 | 9305883 | 44.82 |
| 1180668 | office | dal | 77056 | 75 | 175495 | 1976 | 11325400 | 64.53 |
| 2503957 | office | dal | 77092 | 75 | 318680 | 1977 | 24321411 | 76.32 |

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|---|---|---|---|---|---|---|---|---|
| 3466487 | office | ftw | 77027 | 75 | 167388 | 1978 | 16419007 | 98.09 |
| 1518283 | office | ftw | 77056 | 84 | 350362 | 1978 | 35637029 | 101.71 |
| 3244860 | office | hou | 77010 | 80 | 1191310 | 1978 | 188790000 | 158.47 |
| 2061701 | office | hou | 77002 | 75 | 1050089 | 1978 | 178320200 | 169.81 |
| 1154763 | office | san | 77056 | 81 | 479932 | 1978 | 47631750 | 99.25 |
| 3179248 | office | aus | 77090 | 76 | 53066 | 1979 | 1710890 | 32.24 |
| 22922 | office | dal | 77060 | 81 | 206799 | 1979 | 10684489 | 51.67 |
| 23108 | office | dal | 77056 | 81 | 405476 | 1979 | 21340600 | 52.63 |
| 3109088 | office | dal | 77056 | 80 | 423309 | 1979 | 27307709 | 64.51 |
| 1255609 | office | dal | 77079 | 81 | 188496 | 1979 | 17429645 | 92.47 |
| 2236379 | office | dal | 77079 | 84 | 183268 | 1979 | 17029754 | 92.92 |
| 1518284 | office | ftw | 77042 | 87 | 278865 | 1979 | 28761841 | 103.14 |
| 1448374 | office | dal | 77036 | 77 | 64063 | 1980 | 1392915 | 21.74 |
| 1553610 | office | dal | 77060 | 96 | 64068 | 1980 | 1737543 | 27.12 |
| 7324 | office | dal | 77084 | 77 | 34089 | 1980 | 1733057 | 50.84 |
| 2612805 | office | dal | 77084 | 86 | 139834 | 1980 | 8461340 | 60.51 |
| 2535912 | office | dal | 77084 | 75 | 57125 | 1980 | 3569805 | 62.49 |
| 3109138 | office | dal | 77027 | 97 | 290936 | 1980 | 20698100 | 71.14 |
| 3117977 | office | dal | 77081 | 88 | 204849 | 1980 | 16619746 | 81.13 |
| 1180433 | office | hou | 77002 | 77 | 1414193 | 1980 | 225534600 | 159.48 |
| 1390335 | office | hou | 77002 | 82 | 1410801 | 1980 | 262898458 | 186.35 |
| 1601830 | office | hou | 76102 | 76 | 819249 | 1980 | 100482663 | 122.65 |
| 1600852 | office | hou | 76102 | 79 | 716533 | 1980 | 89271928 | 124.59 |
| 18835 | office | hou | 75244 | 77 | 49120 | 1980 | 893270 | 18.19 |
| 1798146 | office | hou | 75244 | 83 | 49619 | 1980 | 987030 | 19.89 |
| 1121288 | office | hou | 75244 | 75 | 123711 | 1980 | 2925650 | 23.65 |
| 3017092 | office | hou | 75231 | 85 | 387756 | 1980 | 12100770 | 31.21 |
| 1792785 | office | hou | 75244 | 76 | 153387 | 1980 | 7400140 | 48.24 |
| 1765746 | office | hou | 75201 | 93 | 1253232 | 1980 | 77024820 | 61.46 |
| 15499 | office | hou | 75206 | 80 | 376512 | 1980 | 25035930 | 66.49 |
| 1092556 | office | hou | 75225 | 79 | 100000 | 1980 | 19190000 | 191.90 |
| 3005416 | office | san | 78228 | 92 | 72550 | 1980 | 2890440 | 39.84 |
| 1438098 | office | san | 78223 | 75 | 70482 | 1980 | 2827170 | 40.11 |
| 1341444 | office | aus | 78205 | 78 | 253798 | 1981 | 15832960 | 62.38 |
| 1092893 | office | aus | 78229 | 77 | 192233 | 1981 | 14913090 | 77.58 |
| 1403989 | office | dal | 77057 | 77 | 77518 | 1981 | 4342560 | 56.02 |
| 1451646 | office | dal | 77024 | 92 | 212683 | 1981 | 12013236 | 56.48 |
| 18817 | office | dal | 77034 | 91 | 83637 | 1981 | 5314144 | 63.54 |

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|---|---|---|---|---|---|---|---|---|
| 1866688 | office | dal | 77092 | 83 | 313678 | 1981 | 23896476 | 76.18 |
| 1155924 | office | dal | 77057 | 78 | 120055 | 1981 | 9859032 | 82.12 |
| 3135574 | office | dal | 77081 | 84 | 221700 | 1981 | 18998355 | 85.69 |
| 1655993 | office | hou | 77079 | 89 | 414792 | 1981 | 86907761 | 209.52 |
| 1496107 | office | hou | 75251 | 85 | 196215 | 1981 | 7780730 | 39.65 |
| 1657222 | office | hou | 75254 | 89 | 181737 | 1981 | 10280760 | 56.57 |
| 1342041 | office | aus | 75240 | 87 | 357428 | 1982 | 25273160 | 70.71 |
| 1179156 | office | aus | 75207 | 85 | 366600 | 1982 | 30849800 | 84.15 |
| 2033125 | office | dal | 77042 | 77 | 128138 | 1982 | 4548627 | 35.50 |
| 1415255 | office | dal | 77008 | 77 | 181198 | 1982 | 8285520 | 45.73 |
| 5795 | office | dal | 77036 | 75 | 229239 | 1982 | 10794645 | 47.09 |
| 5944 | office | dal | 77008 | 75 | 216789 | 1982 | 10439380 | 48.15 |
| 2445829 | office | dal | 77042 | 85 | 120724 | 1982 | 6020678 | 49.87 |
| 1469742 | office | dal | 77094 | 75 | 113526 | 1982 | 6282349 | 55.34 |
| 1543559 | office | dal | 77042 | 93 | 179635 | 1982 | 11158142 | 62.12 |
| 1180686 | office | dal | 77060 | 92 | 242097 | 1982 | 15359490 | 63.44 |
| 1432222 | office | dal | 77079 | 95 | 109291 | 1982 | 7243688 | 66.28 |
| 1938139 | office | dal | 77040 | 90 | 253128 | 1982 | 16897859 | 66.76 |
| 1052586 | office | dal | 77079 | 76 | 130828 | 1982 | 8840670 | 67.57 |
| 23969 | office | dal | 77008 | 93 | 184642 | 1982 | 14096027 | 76.34 |
| 1553503 | office | dal | 77098 | 89 | 243100 | 1982 | 18598440 | 76.51 |
| 1732799 | office | dal | 77042 | 79 | 159596 | 1982 | 12230494 | 76.63 |
| 3117930 | office | dal | 77024 | 86 | 155070 | 1982 | 12450450 | 80.29 |
| 22820 | office | dal | 77057 | 75 | 141925 | 1982 | 12867555 | 90.66 |
| 2528789 | office | dal | 77042 | 76 | 147565 | 1982 | 13548732 | 91.82 |
| 1602082 | office | hou | 77042 | 84 | 402451 | 1982 | 56382184 | 140.10 |
| 1864730 | office | hou | 77057 | 86 | 517626 | 1982 | 74020961 | 143.00 |
| 3773338 | office | hou | 77042 | 85 | 506990 | 1982 | 75632857 | 149.18 |
| 1419510 | office | hou | 77056 | 80 | 398413 | 1982 | 65303850 | 163.91 |
| 2883510 | office | hou | 77010 | 82 | 1380227 | 1982 | 238800000 | 173.02 |
| 13559 | office | hou | 77042 | 75 | 619973 | 1982 | 110320328 | 177.94 |
| 1396944 | office | hou | 77056 | 75 | 1655703 | 1982 | 295228050 | 178.31 |
| 13815 | office | hou | 77002 | 76 | 2047796 | 1982 | 388550000 | 189.74 |
| 1876133 | office | hou | 77027 | 91 | 567396 | 1982 | 118849340 | 209.46 |
| 1338332 | office | hou | 77042 | 94 | 322783 | 1982 | 69081944 | 214.02 |
| 1441252 | office | hou | 77002 | 84 | 1845331 | 1982 | 401551193 | 217.60 |
| 3136087 | office | hou | 76102 | 88 | 1012558 | 1982 | 107629167 | 106.29 |
| 23669 | office | hou | 75244 | 81 | 49044 | 1982 | 978630 | 19.95 |

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|---|---|---|---|---|---|---|---|---|
| 1512435 | office | hou | 75244 | 82 | 227096 | 1982 | 6183990 | 27.23 |
| 13644 | office | hou | 75201 | 76 | 908350 | 1982 | 41662070 | 45.87 |
| 2012586 | office | hou | 75244 | 77 | 250600 | 1982 | 12349620 | 49.28 |
| 1559358 | office | hou | 75251 | 92 | 393234 | 1982 | 20286990 | 51.59 |
| 12917 | office | hou | 75231 | 94 | 310771 | 1982 | 18031800 | 58.02 |
| 14783 | office | hou | 75201 | 83 | 1113575 | 1982 | 71057210 | 63.81 |
| 1878 | office | hou | 78752 | 85 | 83031 | 1982 | 6061464 | 73.00 |
| 1330824 | office | aus | 77074 | 83 | 146937 | 1983 | 8347879 | 56.81 |
| 1331324 | office | aus | 78230 | 86 | 192431 | 1983 | 14720840 | 76.50 |
| 1386518 | office | dal | 77032 | 78 | 106677 | 1983 | 4152780 | 38.93 |
| 1111260 | office | dal | 77017 | 86 | 89363 | 1983 | 3738851 | 41.84 |
| 2384161 | office | dal | 77077 | 88 | 144084 | 1983 | 6428208 | 44.61 |
| 1588457 | office | dal | 77058 | 93 | 160080 | 1983 | 7205385 | 45.01 |
| 1469213 | office | dal | 77079 | 85 | 85026 | 1983 | 4422720 | 52.02 |
| 1328533 | office | dal | 77060 | 81 | 158817 | 1983 | 9638144 | 60.69 |
| 3103241 | office | dal | 77042 | 79 | 175801 | 1983 | 12952432 | 73.68 |
| 1469960 | office | dal | 77042 | 95 | 155314 | 1983 | 11717225 | 75.44 |
| 2638918 | office | dal | 77079 | 82 | 120651 | 1983 | 10733530 | 88.96 |
| 1331345 | office | dal | 77007 | 85 | 162477 | 1983 | 15344395 | 94.44 |
| 1488765 | office | hou | 77056 | 76 | 555176 | 1983 | 73223875 | 131.89 |
| 3245656 | office | hou | 77042 | 89 | 228726 | 1983 | 32416975 | 141.73 |
| 3245675 | office | hou | 77056 | 92 | 1210500 | 1983 | 214240000 | 176.98 |
| 1272360 | office | hou | 77002 | 82 | 1376797 | 1983 | 281027660 | 204.12 |
| 1115175 | office | hou | 77002 | 88 | 1266714 | 1983 | 264519938 | 208.82 |
| 1798174 | office | hou | 75148 | 77 | 20355 | 1983 | 152050 | 7.47 |
| 1339198 | office | hou | 75207 | 75 | 675031 | 1983 | 19721570 | 29.22 |
| 1227617 | office | hou | 75204 | 79 | 188913 | 1983 | 7838280 | 41.49 |
| 1055480 | office | hou | 75201 | 77 | 1329855 | 1983 | 63179200 | 47.51 |
| 1060014 | office | hou | 75251 | 86 | 385509 | 1983 | 21821080 | 56.60 |
| 3244871 | office | hou | 75254 | 91 | 165434 | 1983 | 9720770 | 58.76 |
| 2318802 | office | hou | 75219 | 75 | 233347 | 1983 | 24575000 | 105.32 |
| 1749274 | office | hou | 78701 | 96 | 470389 | 1983 | 80212160 | 170.52 |
| 1848337 | office | san | 77002 | 87 | 889133 | 1983 | 120152175 | 135.13 |
| 1335467 | office | aus | 77082 | 79 | 172202 | 1984 | 16014384 | 93.00 |
| 22406 | office | aus | 78216 | 75 | 152333 | 1984 | 11053060 | 72.56 |
| 3821995 | office | aus | 78229 | 83 | 271117 | 1984 | 20201230 | 74.51 |
| 1685677 | office | aus | 78229 | 85 | 92939 | 1984 | 7033370 | 75.68 |
| 1702548 | office | dal | 77017 | 75 | 89045 | 1984 | 3690088 | 41.44 |

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|---|---|---|---|---|---|---|---|---|
| 2612882 | office | dal | 77014 | 89 | 128981 | 1984 | 5566126 | 43.15 |
| 1866684 | office | dal | 77040 | 88 | 142194 | 1984 | 7605700 | 53.49 |
| 5791 | office | dal | 77079 | 79 | 307655 | 1984 | 25121629 | 81.66 |
| 11454 | office | dal | 77056 | 88 | 243348 | 1984 | 21074849 | 86.60 |
| 1262650 | office | ftw | 77027 | 81 | 237626 | 1984 | 24021281 | 101.09 |
| 1149882 | office | hou | 77027 | 89 | 665332 | 1984 | 99898453 | 150.15 |
| 1789839 | office | hou | 77057 | 87 | 1068186 | 1984 | 193217188 | 180.88 |
| 3244861 | office | hou | 77002 | 89 | 1224712 | 1984 | 222276275 | 181.49 |
| 1408036 | office | hou | 75254 | 90 | 151078 | 1984 | 3536040 | 23.41 |
| 2736159 | office | hou | 75202 | 98 | 302991 | 1984 | 7800000 | 25.74 |
| 2012672 | office | hou | 75248 | 84 | 153943 | 1984 | 6517740 | 42.34 |
| 12811 | office | hou | 75254 | 84 | 86750 | 1984 | 5153650 | 59.41 |
| 1227916 | office | hou | 75231 | 85 | 528075 | 1984 | 46364860 | 87.80 |
| 1106682 | office | hou | 75231 | 85 | 287052 | 1984 | 29794990 | 103.80 |
| 1328450 | office | hou | 75201 | 78 | 1245324 | 1984 | 152747120 | 122.66 |
| 2272716 | office | hou | 75204 | 86 | 145610 | 1984 | 17955200 | 123.31 |
| 1106651 | office | hou | 75225 | 80 | 211998 | 1984 | 30907900 | 145.79 |
| 3685127 | office | hou | 78744 | 81 | 161438 | 1984 | 20290210 | 125.68 |
| 1629915 | office | hou | 78701 | 90 | 523106 | 1984 | 92781090 | 177.37 |
| 2660311 | office | aus | 77055 | 80 | 108191 | 1985 | 2384018 | 22.04 |
| 2033200 | office | dal | 77042 | 86 | 109175 | 1985 | 3778876 | 34.61 |
| 28959 | office | dal | 77058 | 75 | 126140 | 1985 | 11591696 | 91.90 |
| 2440108 | office | hou | 77024 | 81 | 153658 | 1985 | 24939364 | 162.30 |
| 1279889 | office | hou | 76102 | 75 | 168393 | 1985 | 7901295 | 46.92 |
| 1694871 | office | hou | 75243 | 87 | 378575 | 1985 | 13280180 | 35.08 |
| 1477343 | office | hou | 75243 | 82 | 266412 | 1985 | 10436060 | 39.17 |
| 1229989 | office | hou | 75251 | 81 | 394324 | 1985 | 16083660 | 40.79 |
| 1163057 | office | hou | 75254 | 75 | 185420 | 1985 | 7816610 | 42.16 |
| 1630174 | office | hou | 75219 | 80 | 143461 | 1985 | 6093600 | 42.48 |
| 1803408 | office | hou | 75254 | 84 | 85579 | 1985 | 3675010 | 42.94 |
| 1928464 | office | hou | 75254 | 86 | 149392 | 1985 | 9415030 | 63.02 |
| 1441938 | office | hou | 75240 | 85 | 266000 | 1985 | 16885200 | 63.48 |
| 1635263 | office | hou | 75219 | 76 | 179450 | 1985 | 12300000 | 68.54 |
| 1375530 | office | hou | 75206 | 90 | 317342 | 1985 | 23683350 | 74.63 |
| 1051795 | office | hou | 75202 | 81 | 1390920 | 1985 | 113003160 | 81.24 |
| 1156335 | office | hou | 75231 | 86 | 493078 | 1985 | 43514480 | 88.25 |
| 2489 | office | hou | 75220 | 81 | 70197 | 1985 | 6670440 | 95.02 |
| 2526763 | office | hou | 75220 | 75 | 125932 | 1985 | 12044130 | 95.64 |

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|---|---|---|---|---|---|---|---|---|
| 1193496 | office | hou | 75201 | 76 | 1480562 | 1985 | 160350810 | 108.30 |
| 14922 | office | hou | 75206 | 88 | 428934 | 1985 | 48121200 | 112.19 |
| 1238314 | office | hou | 75204 | 80 | 295585 | 1985 | 38057700 | 128.75 |
| 1776920 | office | hou | 78754 | 80 | 47192 | 1985 | 2371064 | 50.24 |
| 2556184 | office | hou | 78759 | 77 | 135333 | 1985 | 14844612 | 109.69 |
| 2148 | office | hou | 78746 | 78 | 115039 | 1985 | 13685984 | 118.97 |
| 17334 | office | aus | 77056 | 75 | 650000 | 1986 | 49154480 | 75.62 |
| 1419212 | office | aus | 77002 | 81 | 173209 | 1986 | 19534329 | 112.78 |
| 3245662 | office | hou | 77060 | 79 | 374718 | 1986 | 52759491 | 140.80 |
| 2489631 | office | hou | 77002 | 85 | 1232161 | 1986 | 263134099 | 213.55 |
| 1449001 | office | hou | 75248 | 83 | 166971 | 1986 | 7522870 | 45.05 |
| 1496106 | office | hou | 75231 | 96 | 185000 | 1986 | 10217660 | 55.23 |
| 2304 | office | hou | 75231 | 89 | 305135 | 1986 | 20585840 | 67.46 |
| 2305 | office | hou | 75254 | 88 | 241933 | 1986 | 18547300 | 76.66 |
| 2589635 | office | hou | 75244 | 79 | 518888 | 1986 | 54038750 | 104.14 |
| 1442926 | office | san | 78701 | 87 | 442292 | 1986 | 102376922 | 231.47 |
| 1420636 | office | san | 78701 | 85 | 442292 | 1986 | 102376922 | 231.47 |
| 2703143 | office | san | 78216 | 79 | 247163 | 1986 | 25806890 | 104.41 |
| 1357401 | office | aus | 77074 | 83 | 202261 | 1987 | 14256609 | 70.49 |
| 1405058 | office | aus | 77089 | 79 | 119075 | 1987 | 18371780 | 154.29 |
| 24674 | office | hou | 75201 | 87 | 240581 | 1987 | 6759900 | 28.10 |
| 2748606 | office | hou | 75205 | 94 | 80250 | 1987 | 12477400 | 155.48 |
| 27766 | office | hou | 78759 | 79 | 246869 | 1987 | 37267030 | 150.96 |
| 1218943 | office | hou | 78704 | 87 | 158405 | 1987 | 26795760 | 169.16 |
| 1869326 | office | hou | 78701 | 85 | 557962 | 1987 | 101532991 | 181.97 |
| 1761323 | office | san | 78250 | 87 | 72113 | 1987 | 2652790 | 36.79 |
| 1226013 | office | aus | 75234 | 95 | 80488 | 1988 | 3917800 | 48.68 |
| 3296753 | office | hou | 75235 | 82 | 900000 | 1988 | 24000000 | 26.67 |
| 1357981 | office | ftw | 77058 | 78 | 174980 | 1989 | 18272264 | 104.42 |
| 1419843 | office | hou | 75204 | 90 | 1330574 | 1989 | 104961970 | 78.88 |
| 28352 | office | aus | 75220 | 92 | 80473 | 1990 | 1765800 | 21.94 |
| 2429997 | office | aus | 75231 | 94 | 89319 | 1990 | 4537300 | 50.80 |
| 2315161 | office | dal | 77098 | 77 | 106092 | 1991 | 7007717 | 66.05 |
| 8687 | office | dal | 77079 | 91 | 171000 | 1992 | 15713725 | 91.89 |
| 1532769 | office | hou | 77060 | 95 | 481943 | 1992 | 64838515 | 134.54 |
| 23648 | office | hou | 77079 | 76 | 588764 | 1992 | 126161990 | 214.28 |
| 1811034 | office | hou | 77077 | 84 | 328258 | 1993 | 53205925 | 162.09 |
| 22822 | office | dal | 77059 | 75 | 178126 | 1994 | 12691973 | 71.25 |

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|---|---|---|---|---|---|---|---|---|
| 2683424 | office | san | 78212 | 82 | 68134 | 1994 | 2950000 | 43.30 |
| 2336936 | office | san | 78230 | 92 | 87132 | 1995 | 3206610 | 36.80 |
| 1720632 | office | aus | 78258 | 85 | 38281 | 1996 | 2396530 | 62.60 |
| 1154207 | office | san | 78239 | 91 | 74325 | 1996 | 2951610 | 39.71 |
| 1391909 | office | hou | 77042 | 89 | 233537 | 1997 | 36846305 | 157.78 |
| 29373 | office | hou | 78746 | 76 | 115460 | 1997 | 19043454 | 164.94 |
| 1451959 | office | aus | 76109 | 92 | 55872 | 1998 | 4493515 | 80.43 |
| 1518473 | office | aus | 75207 | 84 | 195443 | 1998 | 14521720 | 74.30 |
| 2378 | office | hou | 78759 | 77 | 68533 | 1998 | 5247721 | 76.57 |
| 1340941 | office | aus | 78744 | 84 | 30424 | 1999 | 3818940 | 125.52 |
| 1600079 | office | ftw | 77067 | 83 | 73932 | 1999 | 7317002 | 98.97 |
| 2895690 | office | hou | 77084 | 75 | 154930 | 1999 | 20830245 | 134.45 |
| 2615822 | office | hou | 77042 | 79 | 192100 | 1999 | 27882683 | 145.15 |
| 1566721 | office | hou | 77042 | 99 | 487372 | 1999 | 74159885 | 152.16 |
| 3245617 | office | hou | 77024 | 96 | 330000 | 1999 | 64991416 | 196.94 |
| 1423454 | office | hou | 76155 | 87 | 76914 | 1999 | 9994242 | 129.94 |
| 1428285 | office | hou | 75240 | 93 | 398623 | 1999 | 21831010 | 54.77 |
| 1632035 | office | hou | 75251 | 86 | 277187 | 1999 | 19767490 | 71.31 |
| 1326747 | office | hou | 75240 | 83 | 306200 | 1999 | 22427330 | 73.24 |
| 1208365 | office | hou | 75225 | 77 | 273293 | 1999 | 25665200 | 93.91 |
| 1384638 | office | hou | 75201 | 88 | 247218 | 1999 | 36018740 | 145.70 |
| 1328845 | office | hou | 75225 | 98 | 218313 | 1999 | 35028270 | 160.45 |
| 27258 | office | hou | 78759 | 86 | 116564 | 1999 | 14005356 | 120.15 |
| 7346 | office | hou | 78746 | 80 | 115492 | 1999 | 19055410 | 164.99 |
| 1057553 | office | hou | 78759 | 76 | 201576 | 1999 | 37937765 | 188.21 |
| 1464196 | office | aus | 77070 | 99 | 73326 | 2000 | 6447802 | 87.93 |
| 2284623 | office | aus | 77070 | 81 | 68774 | 2000 | 9350384 | 135.96 |
| 1765929 | office | aus | 78759 | 95 | 73326 | 2000 | 5022534 | 68.50 |
| 28033 | office | hou | 78759 | 75 | 76473 | 2000 | 7465395 | 97.62 |
| 1937601 | office | hou | 78746 | 82 | 137763 | 2000 | 21179339 | 153.74 |
| 1196871 | office | hou | 77072 | 84 | 293452 | 2001 | 41006652 | 139.74 |
| 16840 | office | hou | 77042 | 84 | 542319 | 2001 | 103221120 | 190.33 |
| 1106714 | office | hou | 75254 | 81 | 383805 | 2001 | 46155190 | 120.26 |
| 1935386 | office | hou | 78759 | 77 | 200501 | 2001 | 23479245 | 117.10 |
| 2684105 | office | san | 78701 | 96 | 454225 | 2001 | 135159800 | 297.56 |
| 7487 | office | san | 76107 | 79 | 23998 | 2001 | 850108 | 35.42 |
| 2331713 | office | san | 75248 | 77 | 23890 | 2001 | 4190360 | 175.40 |
| 3245669 | office | hou | 77002 | 79 | 947989 | 2002 | 163946223 | 172.94 |

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|---|---|---|---|---|---|---|---|---|
| 1252140 | office | hou | 76140 | 98 | 5000 | 2002 | 83740 | 16.75 |
| 2873559 | office | san | 78259 | 91 | 63306 | 2002 | 1989180 | 31.42 |
| 2503531 | office | san | 78217 | 88 | 59874 | 2002 | 2435690 | 40.68 |
| 1485497 | office | aus | 77024 | 84 | 224138 | 2003 | 47910062 | 213.75 |
| 3773363 | office | hou | 77060 | 83 | 101111 | 2003 | 15227673 | 150.60 |
| 1410122 | office | hou | 77002 | 88 | 723322 | 2003 | 207198800 | 286.45 |
| 1677820 | office | aus | 76107 | 94 | 81595 | 2004 | 4929945 | 60.42 |
| 2564230 | office | san | 78701 | 90 | 569345 | 2004 | 180247301 | 316.59 |
| 1257928 | office | aus | 78744 | 78 | 23603 | 2005 | 2161136 | 91.56 |
| 1331380 | office | aus | 77082 | 75 | 75329 | 2005 | 6968221 | 92.50 |
| 1405016 | office | aus | 77024 | 78 | 150984 | 2005 | 31945828 | 211.58 |
| 1485532 | office | aus | 77054 | 75 | 176153 | 2005 | 40531330 | 230.09 |
| 1485526 | office | aus | 75231 | 77 | 116969 | 2005 | 11676920 | 99.83 |
| 1451747 | office | dal | 77056 | 87 | 101039 | 2005 | 8915130 | 88.23 |
| 1330836 | office | aus | 78258 | 92 | 98741 | 2006 | 5473020 | 55.43 |
| 1532862 | office | hou | 77072 | 79 | 292866 | 2006 | 39966016 | 136.47 |
| 1631350 | office | hou | 78759 | 80 | 148359 | 2006 | 22092383 | 148.91 |
| 3216004 | office | hou | 78746 | 83 | 91092 | 2006 | 17424391 | 191.28 |
| 1866686 | office | dal | 77084 | 91 | 121017 | 2007 | 8509080 | 70.31 |
| 1877075 | office | hou | 77041 | 75 | 160407 | 2007 | 20634910 | 128.64 |
| 2937980 | office | hou | 75201 | 79 | 405386 | 2007 | 50378460 | 124.27 |
| 1258144 | office | hou | 75201 | 75 | 501251 | 2007 | 67376040 | 134.42 |
| 1990917 | office | hou | 78735 | 85 | 164000 | 2007 | 20014974 | 122.04 |
| 1200253 | office | dal | 77022 | 76 | 93258 | 2008 | 4993206 | 53.54 |
| 3245674 | office | hou | 77094 | 86 | 174521 | 2008 | 27214899 | 155.94 |
| 1461604 | office | hou | 77094 | 88 | 244603 | 2008 | 42403005 | 173.35 |
| 2318910 | office | hou | 77024 | 88 | 332904 | 2008 | 66689750 | 200.33 |
| 13757 | office | hou | 77042 | 80 | 336000 | 2008 | 69081944 | 205.60 |
| 1178068 | office | hou | 77077 | 85 | 355869 | 2008 | 78905434 | 221.73 |
| 2506537 | office | hou | 77041 | 85 | 242374 | 2008 | 54560922 | 225.11 |
| 1441254 | office | hou | 77086 | 99 | 161301 | 2008 | 40999382 | 254.18 |
| 2557825 | office | hou | 75201 | 80 | 463053 | 2008 | 76691360 | 165.62 |
| 1898942 | office | hou | 78746 | 89 | 168238 | 2008 | 27402381 | 162.88 |
| 1572683 | office | san | 75201 | 75 | 472819 | 2008 | 91426100 | 193.36 |
| 2373141 | office | san | 78757 | 86 | 20898 | 2008 | 696952 | 33.35 |
| 1485481 | office | aus | 78758 | 80 | 73217 | 2009 | 12754405 | 174.20 |
| 2890525 | office | hou | 77041 | 100 | 183004 | 2009 | 29849180 | 163.11 |
| 1251608 | office | hou | 77077 | 97 | 365591 | 2009 | 74093075 | 202.67 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1115177 | office | hou | 77494 | 89 | 317888 | 2009 | 66243200 | 208.39 |
| 1357521 | office | hou | 77042 | 93 | 280219 | 2009 | 58936806 | 210.32 |
| 1394357 | office | san | 78244 | 83 | 133520 | 2009 | 7233677 | 54.18 |
| 1357523 | office | hou | 77002 | 94 | 1146559 | 2010 | 377441600 | 329.20 |
| 1436732 | office | san | 75231 | 80 | 104696 | 2011 | 3258980 | 31.13 |

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Kevin Hogan earned his bachelor's degree in markets in culture from Dedman College of Humanities and Sciences at Southern Methodist University in 2008. He earned his master's degree in real estate from the College of Business Administration and a certificate of asset repositioning and turnaround strategies from the College of Architecture at The University of Texas at Arlington in 2010. After completing the required coursework and passing a comprehensive examination, he earned his doctorate in Urban Planning and Public Policy from the School of Urban and Public Affairs at The University of Texas at Arlington with a dissertation entitled "Property Tax Appraisal for Green Buildings: ENERGY STAR Certification in Texas" in 2014.

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