Value Premiums of Sustainable Elements in Residential Homes in the Greater Philadelphia Area

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Abstract

Energy consumption in the United States has critical implications for national security, health, the environment, scarce resources, and the overall economy. Residential energy consumption is a major component of overall energy use. Conservation measures are of utmost importance as energy reduction may be the most cost effective means in order to reduce negative effects caused by energy generation. Most residential conservation efforts have been focused upon cost savings. Recent research shows that substantial sales premiums for homes are obtained for sustainability features and certifications (Aroul, 2009; Aroul & Hansz, 2012; Bloom, Nobe, & Nobe, 2011; Cadena & Thompson, 2015; Dastrup, Zivin, Costa, & Kahn, 2012; Kahn & Kok, 2013; Shewmake & Viscusi, 2015; Walls, Gerarden, Palmer, & Bak, 2017). These premiums are currently not systematically considered for promotional and decision-making purposes. Adding premiums with the cost savings into the decision process may help builders, remodelers, and real estate agents promote green items to buyers. This study shows the differences in labels that achieve premiums may be attributable to differences in consumer preferences unique to each geographic region, which may explain the lack of emphasis on sustainability in real estate marketing materials.

Previous studies of premiums on residential homes with green labels have been concentrated on the southern and western parts of the United States (Kahn & Kok, 2013; Walls et al., 2017). To draw results on an overall willingness to pay, this auxiliary study was done for the northeast region, filling a geographic gap. All study results were tabulated across the United States. This study adds to the establishment of a universal

acceptance that sustainable items add value to a home but cautions that consumer preferences modulate the acceptance and value of specific sustainable features.

The influence of different sustainability features and certifications on house prices was statistically analyzed using sales data obtained from the Realtor's® multiple listing service (MLS) TREND between 2009 and 2017 in the Philadelphia region. Drawing from 250,354 home sales transactions, matched pairs of sustainable featured and green certified homes with non-sustainable featured and non-green certified homes from the same school districts were used to determine their respective differences. Through propensity score matching, Energy Star showed a statistically significant sizable premium of 5.11%, while Other Green Certification showed an even higher statistically significant premium of 8.53%. Ground source heating showed a statistically significant premium of 12.31% while solar heating and biofuel did not show significant premiums.

Additionally, the number of sales per year of green-labeled homes in the Philadelphia region shows a bell curve pattern typical of an innovation adoption cycle. In such a cycle, increased use often comes by innovations including productivity improvements, technological advances, new customer appeals, or the additional of new customer segments (Rogers, 2005). Sale premiums may fulfill a similar role to promote the sale of homes with sustainable features and certifications. Thus, reliance upon premiums may be an innovation that is needed to push additional adoption past the point of considering cost savings alone. Otherwise, a decline in the number of green label homes sales is likely in the Philadelphia region.

Dedication

I dedicate this to all those that strive to make the world a better place.

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Required Disclosure: The data for this statistical report was retrieved by author who is a Realtor® member of the Trend multiple listing service and is based on information from TREND for the period January 1, 2009 through December 31, 2017.

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Definition of Terms

MLS — Multiple Listing Service – This is a clearinghouse of information on properties marketed through real estate agents.

TrendMLS — An MLS, or Multiple Listing Service, is an organization that provides the real estate community with products and services to facilitate the sale of properties and establish contractual offers of compensation. The term MLS also refers to the system that real estate professionals use to enter and access information. (TrendMLS, 2018, InfoCenter) TrendMLS has 32,207 members spanning 3,371 offices as of 6/30/2017.

Bright MLS — Bright MLS is made up of nine forward thinking MLSs (43 Associations) in the Mid-Atlantic region. Bright will serve parts of 6 states plus Washington, D.C. encompassing 85,000 real estate professionals who serve over 20 million consumers and facilitate approximately 250,000 transactions a year that are valued at more than $85 billion.
Bright is a consolidation of the MLSs of these organizations:

- Coastal Association of REALTORS® (Somerset, Wicomico, and Worcester counties, MD)
- Cumberland County Board of REALTORS®
- Greater Harrisburg Association of REALTORS® (Cumberland, Dauphin and Perry counties, PA)
- Lancaster County Association of REALTORS®
- Lebanon County Association of REALTORS®
- MRIS (MLS covering parts of MD, PA, VA, WV, and Washington, D.C.)
- REALTORS® Association of York and Adams Counties (PA)
- Sussex County Association of REALTORS®
- TREND (MLS covering the Philadelphia metropolitan region, including southeastern PA, northern Delaware, and parts of southern New Jersey)" (TrendMLS, 2018, News)

Certifications: specific to TrendMLS listing system. (TrendMLS, 2018, Definitions: Help Topic 11096)

Energy Star: To earn the ENERGY STAR, a home must meet strict guidelines for energy efficiency set by the U.S. Environmental Protection Agency. These homes are at least 15% more energy efficient than homes built to the 2004 International Residential Code (IRC), and include additional energy-saving features that typically make them 20-30% more efficient than standard homes.

HERS 90: Measures and rates, on a scale, the relative energy efficiency of any house, regardless of age, efficiency, or fuel use. HERS calculations include estimates of annual energy performance and costs and recommendations for cost-effective, energy-efficiency improvements. Rating is below 90.

HERS 90 – 100: Measures and rates, on a scale, the relative energy efficiency of any house, regardless of age, efficiency, or fuel use. HERS calculations include estimates of annual energy performance and costs and recommendations for cost-effective, energy-efficiency improvements. Rating is between 90 to 100.

LEED: The recognized standard for measuring building sustainability. The LEED green building rating system – developed and administered by the U.S. Green Building Council, is designed to promote design and construction practices that increase profitability while reducing the negative environmental impacts of buildings and improving occupant health and well-being.

National Green Building: For homes to become Green Certified, the Standard requires green building practices in six categories: Lot Design, Preparation, and Development; Resource Efficiency; Energy Efficiency; Water Efficiency; Indoor Environmental Quality; Operation, Maintenance, and Building Owner Education.

Other Green Certification: The home has other (not green) certifications that are not listed here.

MLS Type: (TrendMLS, 2018, Definitions: Help Topic 11008)

Single/Detached: A free-standing residential building that does not share a party wall with another property.

Twin/Semi Detached: A pair (two) of houses built side by side as units sharing a party wall.

Row/Town/Clu: Row/Townhouse/Cluster - A group of homes built side by side with the dividing walls being common on each.

Unit/Flat: A self-contained housing unit that occupies only part of a building.

Mobile Home: A factory-assembled residence consisting of one or more modules, in which a chassis and wheels are an integral part of the structure, and can be readied for occupancy without removing the chassis and/or wheels.

Conditions: (TrendMLS, 2018, Definitions: Help Topic 11044)

Average+: The structure, including walls, ceilings and floors are in average to above average condition.

FixUp/TLC: A property that needs work, either structurally and/or cosmetically.

As-is: A property will transfer in its current condition.

Shell: Typically consists of a foundation and the frame of the home including only exterior windows and doors. Some shell homes will also install the roof and siding. The buyer is then responsible for completing interior of the home.

Heat source (TrendMLS, 2018, Definitions: Help Topic 11093)

Geothermal: The home features a geothermal heat pump, which is similar to ordinary heat pumps, but instead of using heat found in outside air, it relies on stable, even heat of the earth to provide heating.

Biofuel: Biofuel is the fuel produced from dry organic matter or combustible oils produced by plants.

Statistical:

Propensity Score Matching (PSM): Propensity scores are an alternative method to estimate the effect of receiving treatment when random assignment of treatments to subjects is not feasible. Propensity score matching (PSM) refers to the pairing of treatment and control units with similar values on the propensity score, and possibly other covariates, and the discarding of all unmatched units (Rubin, 2001). It is primarily used to compare two groups of subjects but can be applied to analyses of more than two groups. (Thavaneswaran & Lix, 2008, Page 1)

Green certified/labeled homes are considered treated/treatments and non-labeled homes are considered control for this research.

Average Treatment on the Treated: The average effect of some treatment on the group that received treatment. For this research, the average increase in sales price of a home with a particular certification. The treatment equating to homes with a particular certification and the control group being the homes without that particular certification.

Chapter I

Introduction

As sustainability has become a major trend in recent years, it is driving the installation of green features in residential housing in the United States. Today there is a variety of green features such as solar panels and hot water systems to heat the home, biofuels to generate energy or heat, and geothermal heating which may be added to a house, making them more energy efficient and possibly more sustainable. In addition, many different certifications can be attained by accounting for such features in a home to represent its "greenness" or sustainability. A large choice of options often leads to difficulties in deciding which ones to select.

Many of these features can save money by saving energy compared to otherwise less efficient traditional alternatives. Decisions for these features are typically made based upon a potential for future savings. In addition to cost savings, recent research has shown that energy efficient features and certifications may also increase the value over comparable homes (Bloom, Nobe, & Nobe, 2011). For homeowners, buyers, sellers, remodelers, and developers it is unclear which sustainable feature or green certification will drive a price premium for a home. Uncertainty lies not so much in payback periods, which are a main selling feature, but how these features add value to the houses upon resale.

The process of house buying is a major personal and financial event in the lives of most people. Buying a home is typically the largest purchase of one's life. Additionally,

real estate is considered a long-term investment. Thus, the decision to include green features in their home purchase is often costly and has long-lasting repercussions on a buyer's economic situation (Dastrup, Zivin, Costa, & Kahn, 2012). The repercussions often entail the payback periods, maintenance requirements, life expectancy of the components, and the future obsolesce, disposal, or upgrades that may be needed. These all amount to future outlays of capital. In some cases, these costs are not readily quantifiable at the time of purchase which adds to the uncertainty and makes decisions more complex and difficult.

A host of factors affect these premiums, including the overall economy, consumer perceptions, and local climate conditions (Cadena & Thompson, 2015; Kahn & Kok, 2013; Shewmake & Viscusi, 2015). In addition, the pace of adoption for new technologies affects overall sales. In a typical sales cycle for new technologies, innovations create demand, which eventually diminishes over time (Rogers, 2005). For both buyers and sellers, it is financially important to have knowledge about the factors affecting premiums.

While technology advances may only produce marginal improvements in the adoption of energy saving features (Salari & Javid, 2016), the effects of green premiums in residential housing are a potentially large lever to increase implementation. If added premiums to sale prices can be widely demonstrated throughout the United States, they could systematically be utilized in the purchase process and could serve as a driving factor in decisions for sustainable features and certifications.

Research Significance and Objectives

Despite the importance of green features in housing, very few studies have focused on the effect of sustainability certifications on home prices. By evaluating a wide range of industry recognized sustainability certifications, this study determined which ones significantly contributed to improved resale price. This knowledge is of critical importance to stakeholders to reliably evaluate the financial return on their investments. This study estimated these returns in a case study in the Philadelphia metro area. The results of this study could lead to a better understanding of price premiums throughout the country and thus could be used to push the sales cycles of sustainable features and certifications in houses to the next level of adoption.

In addition, the studies that have been done so far are limited geographically in the south, south central, west, and northwest regions of the United States. This study fills in the geographic gap by addressing the northeast region. Such an overview may also lead to a better understanding of the effects throughout the country, as this study is one of the first to do an overall comparison of each region. A comprehensive understanding of premiums in the country would help serve as a reliable basis for decision makers.

These considerations lead to the two main objectives of the research effort, which were to:

Evaluate the contribution of sustainable features and certifications to price premiums

Develop a holistic view for sustainable features and certifications utilizing premiums in the decision-making process

Background

The level of energy consumption in the United States is a national security concern, has serious environmental and health implications, depletes vital resources, and is a large economic factor for individual consumers and the national economy. For example, the energy crisis of 1973/1974 revealed the extent to which the United States was vulnerable from a national security point of view because of its dependence on foreign energy sources. Energy production is a large contributor to greenhouse gas emissions and other environmental pollution. These factors have serious repercussions on human health and they foster environmental-related diseases, lower quality of life, and shortened life span. Little public attention is given to the fact that scarce resources like water are used in large quantities to generate electricity. In addition, household energy consumption is a significant part of the consumer expenditures. In 2016, households were responsible for six percent of the total energy consumption in the United States (EIA, 2017). Energy conservation has significant unrealized implications on national security, health and the environment, scarce resources, and the economy in America.

Sustainability Features and Home Resale Price Premiums

There is limited research on the effect of sustainability features on residential house values. The few studies identified varying degrees of premiums across certain sections of the United States. These studies reference the fact that more investigation is needed in the residential sector, especially in comparison to a larger amount of existing studies regarding the commercial sector. For the commercial sector, studies conclude that there is a statistically significant premium for green designations, such as Energy Star and LEED (Miller, Spivey, & Florance, 2008). The consensus is that there is an identifiable

dollar value associated with obtaining and promoting green certifications in the commercial sector.

An early study researching the residential sector (Aroul & Hansz, 2012) is derived from thesis work by the lead author (Aroul, 2009), which examined the reportedly first mandatory residential green building program. This program was established in the city of Frisco, TX with enactment of green legislation in May 2001. The study examined the valuation of green feature premiums in residential housing and researched what this study refers to as "artificial" price premiums from public policy mandates. Essentially, with the imposition of laws and regulations to force green items and methods in buildings, it resulted in a vast number of homes on the market with such features. With these mandatory regulations the supply of homes with green features increased, while demand did not necessarily change. The study postulated a supply lag from a learning curve and reluctance of builders to change. That reduced supply was used to explain the premium for a mandatory greening of new buildings, which changed the otherwise free market equilibrium point (intercept) in the supply/demand curve with a higher price point (the premium). The study concluded that 2.07% and 2.43% price premiums were paid for mandatory and elective green features respectively at a 99% significance level. The R-squared were 78% and 75% respectively for single family homes settled between January 2002 and July 2009 in Frisco and McKinney, TX. For the dataset in Frisco, greenness of homes was defined by properties built after government ordinance took effect and by searching keywords in home sales data prior to that enactment. In the city of McKinney, the greenness of homes was defined by similar keyword searches. Pairing was done on a

city level basis as the two cities are adjoining and otherwise considered demographically similar. Ordinary least square (OLS) was used for analysis.

The pricing methodology in Aroul and Hansz (2012) is aligned with the procedures of appraisal employed in loaning on value in real estate. It generated a specific percentage for a home's feature, in that case a green certification, which added to the property value as compared to a house that did not have that feature. It was shown to be highly significant and provided a formula that explains nearly all such differences. This is a credible way of establishing a dollar value for greenness that can be relied upon in valuations. The study utilized the hedonic pricing model that has been used for real estate valuations since the early 1970s (Rosen, 1974). Hedonic modeling is a multi-regression method that identifies the significance of the accumulation of variables to the final price. That study is extensive in its analysis, yet it pairs on the city level, not the individual house level.

Bloom et al. (2011) employed a matched pair sample design. They used a data set of 150 Energy Star certified homes. They matched them by twelve variables which included age, total square footage, lot square footage, basement square footage, whether the basement was finished, stories, bedrooms, bathrooms, quality of construction, where there was a covered porch, total garage square footage, and whether the home was Energy Star rated. They were matched to another set of 150 homes without the label. This selection method suggests that the data were not randomly selected, thus limiting the ability of the results to being applied to a larger set of homes. The randomness of the selection is important for any type of statistical analysis, as it allows for broader inferences to the population. The study limited all the data to single family homes built

after 1999. The results were displayed in dollars per square foot, which all the other studies used percentage of sales price. The prevailing method is to use the log of the sales price in the regression to generate results in the percentages of sales price. Compounding this issue is that this study did not give a range of square footages in which the data were extracted, nor a confirmation of homoscedasticity, which is important for reliance on the data. Also, not apparent is the sales timing differential, nor did the study control for different market values over time. It seems highly unlikely that an additional premium of $8.66 per square foot for an Energy Star rated home would apply in both 1999 and 2005 as the study infers. Alternatively, results in percentage change as compared to absolute dollar value changes could alleviate this glaring concern that is not addressed in the study.

Readily identifiable green features such as solar panels were studied in two major regions of California (Dastrup et al., 2012). The study used hedonic regression and a repeat sales approach. The repeat sales approach compared data on homes sold without solar installation and later resold with solar installed. The average appreciation of the census tract of that property was factored out of the subsequent sales price, inferring a difference due just to the addition of the solar panels. That study utilized sales data on a quarterly basis since prices showed seasonal changes. The data set were single-family homes sold between 1997 and 2010 in San Diego County, California. The study concluded that solar panels on a home added 3.6% to the sales price as compared to non-solar panel homes, which equated to $22,554 on the average house sampled.

A statewide study of California (Kahn & Kok, 2013) concluded that third party green labeling resulted in a 2-4% premium upon sale, with an R-squared of 89.7%

indicating high explanatory power. The study results also showed that ideology was a highly correlated aspect of observing a premium. The data suggested that financial returns from climatic and energy pricing were another component. The authors postulated that green minded consumers paid a premium for green certified homes. When the results were adjusted for house age the resulting premium was changed to 3.6% in metropolitan areas. The study did not initially break out the individual labels as variables, but after they reviewed these variables, only Energy Star showed significant effects. Four additional findings of the study were: hotter climates commanded a higher green premium, differences in electricity pricing from one location to another did not have a significant effect on premiums, visible signs of "green-minded" homeowners as attributed to concentrations of Prius owners in a zip code had a substantial correlation, and proximity to other labeled homes had a slight negative effect on a premium compared to non-clustered labeled homes.

Cadena & Thomson (2015) pointed out the general limitations of interpreting study results about green premiums because of a lack of associated sales pricing or square footage data, i.e., larger and higher-priced homes have experienced an even higher percentage premium than smaller, typically starter type homes with generally lower pricing and lower square footage. Their study used the hedonic regression modeling with a significantly large data set and a significantly larger control set. The study utilized information supplied through the local Realtor's® multiple listing service, which has a green label section. Their analysis explained the issues of cross correlation and the methods employed to isolate the true effect of a green feature. They found, with a significant R-squared value of 87%, that an Energy Star label raises the sales price 1.1%.

The study also noted the possible importance of non-monetary considerations of greenness such as a quieter home, occupant comfort, and a lower environmental impact that may have been decision-making drivers for socially conscious consumers.

A study of greenness premiums in Austin, TX (Shewmake & Viscusi, 2015) demonstrated the importance of separating correlated variables. The inclusion of bedrooms and square footages as independent variables had a negative impact on the significance of the study results, as these variables are highly correlated. Accordingly, the qualifiers of the variables used were shown to have a major influence on the significance of the results. The study originally used census tract as the location distinguisher, which resulted in a minor, not statistically significant influence on price. A change to zip code as location distinguisher showed a significant positive influence on premiums. This demonstrated that the way the data is analyzed was very important. The study results were a 5% premium on average for a green label, with one particular category of green label showing a 20% premium. The Austin Energy Green Build (AEGB) is the most well-known local certification in that particular marketplace and it received the most significant premium. The level of green differentiation between competing products was statistically significant. Additionally, through statistical analysis the study detailed that builders reached for identifiable label thresholds and went no further. It was assumed that builders did not spend above a threshold, as they did not believe that it would lead to additional returns. It also inferred that low levels of differentiation were not promoted in marketing efforts.

A recent study compared three cities: Portland, OR, Research Triangle, NC, and Austin, TX (Walls et al., 2017). The study aimed to be suggestive of other cities around

the country. The study uses several analytical methods, including propensity score matching. They analyzed the three markets individually, intending to compare the findings, which emphasized the uniqueness of each market. For example, Research Triangle and Portland both showed that an Energy Star rating had about a 2% premium. They estimated this would roughly equal the energy savings obtained in a home by the components of that rating in Research Triangle, though in Portland that premium was higher than the estimated energy savings. This gives rise to additional benefits that buyer's receive in that market for the same Energy Star label. Also, they surmised that labels are believed to bestow a symbol of higher quality of the home. This may account for some of the added premium over and above the capitalization of the energy savings.

The studies reviewed above, of the effect of green items on residential house premiums, show that a 1.1% to 8.2% price premium is paid for a green label, and as high as a 7% price premium for solar installations (Aroul, 2009; Aroul & Hansz, 2012; Bloom et al., 2011; Cadena & Thompson, 2015; Dastrup et al., 2012; Kahn & Kok, 2013; Shewmake & Viscusi, 2015; Walls et al., 2017) (Table 1).

Still, as indicated above, these studies are limited to the South and West regions of the US. If uniformity and consistency of premiums can be demonstrated throughout the United States, then this knowledge would be reliable for promotional purposes. However, regional differences may be revealed from additional research that would give further insight into drivers of these premiums.

Table 1. United States residential green premium study results.

Study	Premium	Feature/label	Significance	r^2
Frisco/McKinney, TX (Aroul, 2009), (Aroul & Hansz, 2012)	2.07% / 2.43%	Green Indicator	99%	78% / 75%
Fort Collins, CO (Bloom et al., 2011)	$8.66 per Square Foot	Energy Star	99%	73.5%
San Diego, CA & Sacramento, CA (Dastrup et al., 2012)	3.6%	Solar Panels	99%	64%
State of California (Kahn & Kok, 2013)	5.3%	LEED, Green Point, Energy Star	99%	91.9%
San Antonio, TX (Cadena & Thomson, 2015)	1.1%	Energy Star	95% (assumed)	87%
Austin, TX (Shewmake & Viscusi, 2015)	5%	Local AEGB	99%	85%
Austin, TX Research Triangle, NC Portland,OR (Walls et al., 2017)	8.2% 2.7% 8.0%	Local AEGB Energy Star Local Earth Advantage	99% 99% 99%	90.3% 87.7% 82.3%

Visible Markers of Greenness Influencing Premium

Distinct identifiable markers of greenness have had a significant influence on premiums (Aroul, 2009; Aroul & Hansz, 2012; Bloom et al., 2011; Cadena & Thomson, 2015; Kahn & Kok, 2013; Shewmake & Viscusi, 2015). For example, solar panels, which

are highly visible, and the Energy Star rating, which is well known among home buyers, both favor a higher premium. Having these visible items gives home builders a branding opportunity, recognized by consumers (Dastrup et al., 2012). Conversely, the absence of visible and well-known sustainability attributes has led to reluctance of builders to invest in changes, as consumers were believed to be unwilling to pay additionally for such sustainability items. For instance, the start of the Austin Energy Green Build (AEGB) label began in 1985. This had a statistically significant effect on higher premiums for this label, compared to nationally known labels such as Energy Star for new homes, which started in 1995 (Shewmake & Viscusi, 2015).

Differentiation as a Factor

Certifications often have multiple levels of designation based upon the number of sustainable features included. For example, the LEED certification distinguishes between platinum, gold, silver, and certified levels. Similarly, the Austin Energy Green Building (AEGB) label has five levels. The differentiation between the levels had an impact of the effects of the premiums in the marketplace (Shewmake & Viscusi, 2015). A low level of internal differentiation resulted in smaller price premiums due to less marketing efforts and consumer awareness. Conversely, highly differentiated categories within a particular label received the highest premiums. Shewmake & Viscusi (2015) showed that the level of green differentiation between competing products was statistically significant. They found homes with lower category labels had an initial level of green certification that did not result in large premiums over similar products that were already mandated to have a sizable minimum energy efficiency. Conversely, they found that homes with higher

category labels had large percentage premiums. They also found that homes with higher category labels were larger and more expensive.

In addition, clustering had a smaller effect on price premiums, as demonstrated for labels (Kahn & Kok, 2013) and solar homes (Dastrup et al., 2012). The latter study showed that in Sacramento, CA, premiums of solar homes were reduced to 3% when these homes were clustered on a street. In comparison, solar homes surrounded by non-solar houses showed as much as a 7% premium.

Weather and Climate Factors Affecting Premiums

The value of green items is dependent on regional weather and climate conditions. Examples are water conservation measures in San Antonio, TX, cooling features in San Diego, CA, and heating attributes in Sacramento (Cadena & Thomson, 2015; Dastrup et al., 2012). Cadena and Thompson (2015) separated green features in San Antonio and found that items such as rainwater catchment led to a 7.7% premium in that marketplace. Drought tolerant plants and low-flow toilets were also statistically significant and increased values (Cadena & Thompson, 2015). Projection from these results that such water features would lead to general price premiums in any other part of the country seems ambitious, since this might only be regionally correlated. The results suggested that water conservation was a major concern in San Antonio and buyers were willing to pay a premium for items that reduce water consumption or collect storm water for reuse.

In contrast, in the Philadelphia area, which rarely experiences a drought, it is less likely that these items would experience a premium. The Philadelphia region is part of the Delaware Valley River Commission territory, which was the first intergovernmental

compact to manage water resources, formed into law in 1961 (Delaware River Basin Commission, 2018). The commission has successfully managed water resources throughout New York, Pennsylvania, New Jersey and Delaware. In contract, San Antonio often suffers from drought conditions (Henry, 2011). The south Texas area around San Antonio has an average rainfall of 30.64" (Eckhardt, n.d.) compared to 41.5" in Philadelphia (Miller et al., 2014). San Antonio consequently has mandated water restrictions as well as frequent water rate hikes. This makes water conservation items valuable in that area. Conversely, there may be items that demonstrate a premium which are unique to the Philadelphia market but would not be applicable to other markets like San Antonio.

In another study, premiums were shown to differ in San Diego and Sacramento, two locations within the same climate zone yet different in heating and cooling degree days (Dastrup et al., 2012). Thus, there are many determining factors besides climate zone in the premiums. Energy efficiencies are often tied into climate zones. So this also alludes to their being additional factors besides energy savings, even though most of the certifications are based on energy efficiencies.

Marketing and Consumer Attitudes Influencing Premiums

Several studies examined the predictors or identifiers of the attributes of people who pay a premium for green features (Bloom et al., 2011; Dastrup et al., 2012; Kahn & Kok, 2013; Shewmake & Viscusi, 2015). Toyota Prius owners, Democrats, and contributors to liberal causes correlated with paying a premium for green homes compared to pickup truck owners and Republicans that were less likely to be associated

with green premiums (Kahn & Kok, 2013). Additionally, a correlation of solar panels with the home occupants found them to be wealthier, predominantly Caucasian, with higher levels of education completed, higher income, and having larger homes than non-solar panel homeowners (Dastrup et al., 2012). Similarly, affluent buyers with more expensive homes were willing to pay even more of a green premium (Shewmake & Viscusi, 2015). Therefore, there is a correlation between the attitudes of consumers and their buying behavior. One aspect of this is that conservation minded households or ones that want to display their conservation pay a premium for sustainable or energy conservation attributes in their homes. These correlations show that of the many factors that affect premiums, consumer attitudes and perceptions are also key components to adoption, which may vary regionally.

In summary, financial returns may not be the only motivating factor in a buyer decision process. Typically, marketing solar panels to a consumer is based on focusing on the importance of payback periods of the initial investments, although solar panels were not considered financially beneficial for homeowners without government incentives (Dastrup et al., 2012). Conversely, because of government incentives, solar panels have been installed in vast parts of the state of California. Further, the net investment after government incentives was shown to roughly match the premium obtained in a sale. Consequently, this seems to net out the financial aspects which may question the existence of other reasons for purchasing these items.

Internal, Financial, and Social Norms

Some non-monetary factors have been revealed in the research reviewed above suggesting sustainable items with the highest consumer perception in a specific region such as visibility, awareness, local recognition, and favorability commanded the highest effects on premiums for housing (Dastrup et al., 2012; Kahn & Kok, 2013; Shewmake & Viscusi, 2015). This may be due to conspicuous consumption or more particular conspicuous conservation (Delgado, 2015). Prius and solar panels are classic examples of signaling environmental consciousness.

Three factors have been identified with environmental purchasing: internal, financial, and social norms (Dastrup et al., 2012). Internally it is characterized by the buyer's benefit from the "warm glow" of aligning with their belief system, doing good gives a good feeling (Andreoni, 1990). Financially, the buyer may expect to receive a benefit, usually in the form of a cost savings over alternatives. Third, there is a benefit to the buyer for fitting in with society or showing their social status. There is a host of reasons that motive the American consumer, in fact, innovation diffusion theory is based on social interactions in buyer behavior (Rogers, 2005). The effects of these reasons may be layered components, meaning a premium a buyer pays may represent an addition of public and private benefits to them. Only a portion of the premium may be due to energy savings. A portion of that same premium may be from social status. And a portion of the premium may be from comfort, etc. Additional studies like this one could add to the understanding the financial decisions of consumers in environmental purchases.

Solar panels, the Energy Star certification, and mandatory regulations have added value to residential housing at scattered locations in the western and southern United

States (Aroul, 2009; Aroul & Hansz, 2012; Cadena & Thomson, 2015; Dastrup et al., 2012). Research is thus revealing there is a host of factors that influence these premiums.

But more studies are needed to replicate these results in different regions, especially in the Northeast, since it has not been a research focus. In addition, the limited numbers of studies that have been done in the residential real estate market in the United States have been done with different variables and often different methods. A more consistent and uniform approach utilizing and analyzing a larger number of appropriate variables might further characterize and validate these premiums. More research is needed to identify the full set of factors that affect these premiums. Because of a number of consistent confirmatory studies, it is accepted in the commercial field that labels add value (Kahn & Kok, 2013). A critical mass of residential studies is needed to also become common acceptance of premiums for homes.

In an ideal experiment, an individual house would be evaluated for the price it obtains in the market without the certification and then with the certification. This is known as the counterfactual issue (Caliendo & Kopeinig, 2008). This, of course, is impossible as the exact counterpart does not exist at the same point in time. It is also not probable that the same house could be built and sold without and then with certification. Alternatively, another scenario would involve nearly identical houses built near each other; some with certification and some without it. If these houses were then sold at the same time, then any price difference observed could be attributed to the certification. Still, these experiments are of limited matched sets and as such do not equate to robust statistical results throughout a region. Also, limiting the difference to only new construction biases the results accordingly. The amount of capital to set up an experiment

of such matches in large numbers to produce statistical reliable results is totally impractical.

Similarly, early statistical studies of smoking on lung cancer, low level radiation exposure on longevity, and even causes of food poisoning outbreaks have been after the fact data analysis on matching and isolating a variable to draw a conclusion as to the cause and effect (Cochran & Chambers, 1965). The data were of historical events and no experimental preplanning of a randomized nature existed. Similarly, what is available for this study is the data from previous sales, i.e. after the fact historical data. There can be no preplanning nor randomization possibility for the research design. However, houses have numerous attributes including certifications, so matching and isolating variables is possible. The task at hand is to isolate the effect of the certifications in a way to limit bias and do so in a way to compare each different certification under the same method so comparison between them can be evaluated.

Research Questions, Hypotheses, and Specific Aims

This research study aimed to determine if the incorporation of energy sustainability features and efficiency certifications increased the value of a home. The features examined in the study were solar hot water heating, biofuel heating, and ground source heat pumps, while the efficiency certifications studied were MLS categories of Energy Star, HERS, LEED, National Green Building, and Other Green Certifications.

The research question covers the effects of sustainable items on the added value of single family residential homes in the Philadelphia area. Based on extensive literature

research and the observation of trends in the urban real estate market, two main hypotheses were formulated:

Hypothesis 1: Having the Energy Star label adds a 2-4% premium to the value of a single family residential home, whereas other sustainability labels such a HERS<90 , HERS 90-100, LEED, National Green Building, and Other Green Certification have no effect.

Hypothesis 2: Having solar hot water heating as a feature adds a 5-7% premium to the value of a single family residential home, whereas other sustainability features such as biofuel heating and ground source heat pumps have no effect.

Specific Aims

The specific aims of this study were to:

Select a sample that matches the sales price data for green certified and green featured homes with comparable non-green certified and non-green featured homes

Analyze the price differences between green certified and non-green certified homes and between green featured and non-green featured homes

Quantify the premiums for green certification and features so that they can be relied upon in the decision-making process in a real estate transaction

Determine the relative importance of various sustainable green certifications and features on the sales price of residential homes

Compare and contrast the effects of green certification and green features on price premiums throughout the United States

Chapter II

Methods

The sales data from the Philadelphia area Realtor's® multiple listing service (TrendMLS), specifically for sold and settled properties, was used as the basis for this research. The TrendMLS contained 32,207 real estate profession members as of June 30, 2018 in the Philadelphia metropolitan area (TrendMLS, 2018). It covered 14 counties over three states in and around Philadelphia and had data distinguishing green features and labels since 2008.

The Philadelphia region MLS had definitive, and thereby also consistent, information on sustainability with six categories of labels: Energy Star, HERS <90, HERS 90-100, LEED, National Green Building, and Other Green Certification. Presumably this information was disclosed in the MLS as owners, agents representing owners, and agents representing buyers, as well as the buyers all had vested interests in knowing this information accurately. Owners were at one time buyers and as such this information may have been relevant to their purchase, therefore they were likely eager to ensure it is used as a selling feature upon resale.

The methodology of using MLS for green identifying data and categories was employed because MLS services are a clearinghouse of information used in the sales process. All the data was based upon sold properties, which according to MLS rules means they are actually settled properties that have transferred ownership, providing the

most reliable dataset (TrendMLS, 2018). This study evaluated the actual effect on values from the marketing of the certification.

Propensity Score Matching (PSM)

Uniqueness and the extensive number of variables that affect real estate values makes the broad comparison of house price averages of green label certified homes versus non-certified homes too diluted to be meaningful. Matching of samples, with all relevant observable independent variables, was chosen to isolate the effect of certifications. When the observable variables that affect home values are incorporated into a model that match certified, or otherwise known as treated units, to non-certified, or non-treated units, the resulting difference between the two matched sets can be attributed to the certification or treatment. This type of matching is known as propensity score matching (PSM) and assumes that all the independent variables that have an effect on values are accounted for in the model. To the extent that matches are made in large numbers, resulting in a large sample size, statistical significance can be examined.

Methods for matching of data have long been an issue in analysis of causal effect for many different disciplines (Dehejia & Wahba, 2002). PSM has been used for over three decades in a broad range of research studies, including ones on human subjects, to analyze the effects of the treatment, especially with already established data that was not set up as a randomized experiment. PSM is especially useful with binary treatment (Rosenbaum & Rubin, 1983). Binary treatments are straightforward and as such lends themselves well to obtaining differences between matches. This dichotomy is the case with data being isolated for analysis of each particular label compared to the rest of the

dataset. The objective of PSM is to assess the effect of each variable while controlling for covariates.

Additionally, utilizing large sets of data helps with analysis and often the usefulness of the results. However, the appropriateness and accuracy of the results very much depends on how the data is being used. General overall average comparison, such as with all treated/certified versus all non-treated/not certified gives too broad a comparison to isolate the treatment effect. This type of average matching is used a lot in comparison analysis though it often "smooth outs" the individual effect of what is being researched. Such matching, even if believed to be on a non-bias basis, often introduces unintended biases. For example, the possibility that one of the two housing sets, such as the ones with certification, may be concentrated in higher priced areas. If that is the case, location would be affecting the average prices of that one set, which would convolute the true effect of the certification.

Numerous other factors besides location affect housing valuations and need to be accounted for and put into any matching appropriately. Accordingly, in order to reliably determine data sets are directly comparable, and thus being good matches, all relevant and significant independent variables that sizably affect value must be taken into consideration.

There are some independent variables that are fixed determinants and universally recognized as important in the valuation of real estate such as location. Real estate categories such as single family and age restricted community are two other unique distinctions that vastly separate real estate comparisons. It is not generally acceptable to weight these in determining value, i.e. one school district does not usually have a

comparison dollar value weight versus another, nor a single family house weighted for value against another category of housing. In the same manner, an age restricted home would not have a proportionate value of one not age restricted. Age restricted homes are considered a niche market. In contrast, a three bedroom home could be financially and value adjusted compared to a four bedroom home, if by nothing else just to add the depreciated cost to construct the additional bedroom. Similarly; square footage, bathrooms, swimming pools, garage spaces, etc. can all be evaluated or weighted for value consideration. For these reasons, the data was limited to comparing only single family homes that are not age restricted. In addition, location was used to match all data points, this was accomplished by restricting matches to within the same school district.

Alternative to generalized average matching, the method of choosing an individual certified home, and then matching it randomly with another from the set of non-certified homes, has its own set of limitations. Even if reasonable parameters were allotted for the independent variables for the matching, the choices would bias the data. The choice of parameters for each independent variable would thereby be arbitrary. In addition, the quality of the resulting matching would be very difficult to evaluate for appropriateness. For example, square footages of the matches could be limited to an arbitrary amount such as twenty percent more or less, but this eliminates data without seeming reasonable justification. Just as limiting the number of bedrooms to one more or less would also bias the resulting dataset. These arbitrary decisions of the independent variables would make it difficult to assess which have more of an effect on value. Such parameters would eliminate matches that otherwise might be more appropriate and/or might otherwise match less appropriate data. This type of seemingly random matching

would add bias and be very difficult to take into account a large number of independent variables that may affect values. Replicating such a process, even beyond guidelines for minimum matches based on the number of variables (Field, 2013), would be difficult. Results could be obtained, though the resulting matches may not be robust.

Propensity score addresses these critical issues by creating a weight or score which is used to match for all observable independent variables (Rosenbaum & Rubin, 1983). It uses all the data in initial input. It systematically matches on these weights using all variables, even with a large number of variables. Additionally, it provides tools to evaluate the effectiveness of its matching weights. In the case of propensity score matching (PSM) all independent variables in the model are analytically equalized by a weighted score being generated. The analysis initially assigns this weighing without regard for the dependent variable. This system systematically correlates the sets as for their propensity to be in the treated set based on the independent variables used.

PSM first balances the matches based on their covariates without regard for outcome, and then matches and calculates the differences in the matches. With good balancing, taking into account all independent variables affecting the dependent variable, the outcome is representative of the difference attained by the treatment. A large sample size of these matches produces statistical confidence in the results. For these reasons, PSM was chosen as the methodology for this study.

Application of PSM to Sample Set of Homes

Property condition was limited to average or above defined in this particular multiple listing service as, “the structure, including walls, ceilings and floors are in

average to above average condition" (TrendMLS, 2018, Help topic 11044). This gave a large data set that could be easily evaluated by computer software. Houses characterized with either of the three other multiple listing condition alternatives; As-is, Shell, FixUp/TLC (TrendMLS, 2018) would need to actually be seen to be evaluated on an individual basis to analyze their value comparison. This is due to the wide discrepancy that exists with properties within each of these three condition categories. The vagueness of these other three categories leaves properties in them with a wide range of conditions and wide range of corresponding values, which makes their matching speculative. For example, a shell condition home includes a wide range of properties from ones with and others without a kitchen to ones that have no siding and/or a roof. In addition, FixUp/TLC has a wide interpretation from needing "paint and paper" to needing structural work. Also, As-is is often used when someone does not know the condition of the property such as an executor, trustee, and others who has not lived in the home. With these varying conditions there exists large discrepancies and accordingly it was determined that they would not match up appropriately with each other.

As recommended with this method of matching, as much data sets as possible were used with as many independent variables as relevant (Caliendo & Kopeinig, 2005). The independent variables that were used were: quarter and year of settlement, bedrooms, full baths, half baths, basement, new construction, central air conditioning, garage spaces, fireplace, water frontage, swimming pool, short sale, bank owned, as well as age and acres. Stata15 was the statistical software utilized. Matching was done with propensity score implemented using logistic regression and then Stata command psmatch2 using nearest neighbor with a limitation of one and a trim of zero. "One of the most common,

and easiest to implement and understand, methods of Propensity Score is k:1 nearest neighbor matching" (Stuart, 2010, pg. 10, Rubin, 1973). Generally, this method of propensity score matching is considered the most effective (Stuart, 2010). The average treatment effect is viewed as more precise with weighing by a good propensity score.

> Nearest neighbor matching nearly always estimates the Average Treatment of the Treated (ATT), as it matches control individuals to the treated group and discards controls who are not selected as matches. In its simplest form, 1:1 nearest neighbor matching selects for each treated individual i the control individual with the smallest distance from individual i. (Stuart, 2010, pg. 10).

Evaluation of the quality of the matching was done numerically by a balance table showing the corresponding matches of each of the independent variables. The quality of the matching was also evaluated visually with a graph of the original and fitted data. All certification obtained convergence using logistic regression and with Stata's psmatch2 of nearest neighbor upon segmenting some variables, notably age and acres, from their original state of continuous variables. Conversely, nearest neighbor was the only method that produced convergence and results for all certifications. Most variables were within a standard of ten on the balance tables and accordingly aligned favorably graphically, which was considered good matching for each (Figures 1, 2, & 3).

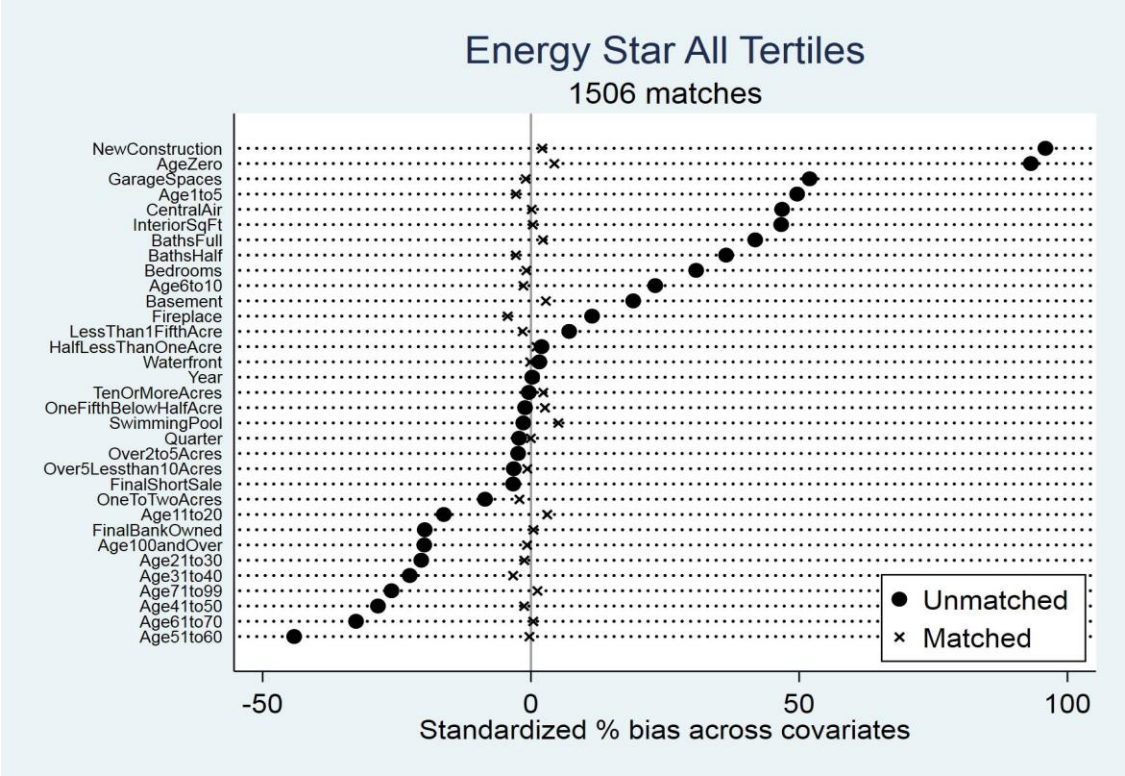

Figure 1. Propensity score matching graph for Energy Star.

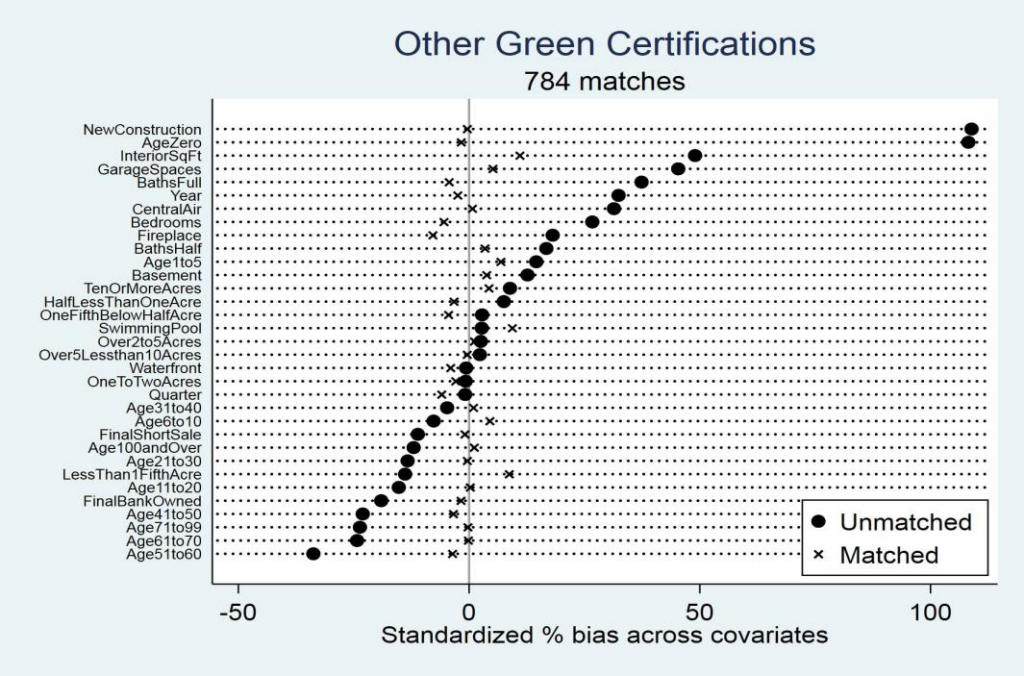

Figure 2. Propensity score matching graph for Other Green Certifications

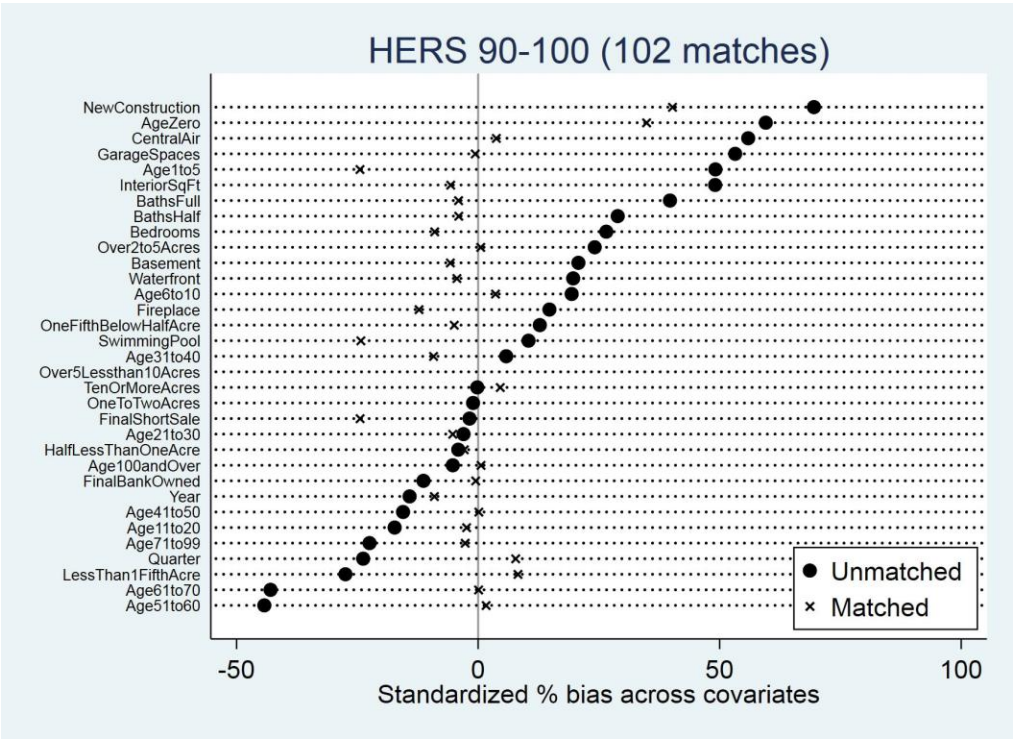

Figure 3. Propensity score graph for HERS 90-100.

As can be seen from the balance graph the unmatched variable values have been closely balanced with propensity score. This is very evident with Energy Star in all tertiles (Figure 1). This is even evident with Other Green Certification (Figure 2). The matching is still marginally acceptable with HERS 90-100, which was the least favorable matching set (Figure 3).

The certification with the largest set of data, Energy Star, was further separated into high priced areas from low priced areas to evaluate if the effects were being convoluted by high priced locations. This was done by first segmenting into three the median prices of each of the school districts throughout the entire dataset, then separating the Energy Star certified data by those top, middle, and bottom median priced school districts. The same analysis of Stata's psmatch2 of nearest neighbor with the same variable criteria was run on each of those three tertile groupings. Additionally, the same analysis was done on the three sustainability features dataset (solar hot water heating, biofuel heating, and ground source heat pump). The closeness of the matches was evaluated with the balance tables and the graphs of the matching. This also revealed quality matching as most variables also were within a standard of ten on the balance tables and therefore aligned favorably graphically.

The house sale prices were converted into natural log for analysis to give results in percentages. Results were converted back from natural log to give common percentage as well as display into dollar terms. Analysis was done at 95% confidence levels and t-stats were generated. The confidence intervals that included zero percent and resulting under 2.00 t-stat could not reject the null hypothesis and thus were not statistically significant.

Chapter III

Results

This study was an observational retrospective analysis of the effects that six different "green" certifications labels had on house prices in the Philadelphia, PA metropolitan area for the time period of 2009 through 2017. The results are limited to single family homes that are not senior communities as they are not restricted to age 55+ or 62+. They are further constrained to homes defined as average or above condition. This condition represents two thirds (66.65%) of the entire single family not age restricted transactions during that timeframe (250,354 of 375,598). TrendMLS's analysis of the single family resale market homes, not including condominiums, above $50,000 during a middle year of the timeframe of the analysis herein, concludes that 82% of the housing transactions are accounted for in their system (TrendMLS, 2014). Accordingly, the data was statistically analyzed as a sample rather than the population entirety, though it is surmised that the overall real estate market in the Philadelphia metropolitan area was reflective of the data.

The limited amount of data forced analyses to include the entire timeframe of 2009-2017 and further limited use of the results from certain certifications, especially LEED which had only started with 37 data points over the entire timeframe. The initial extraction of data of single family non-senior restricted housing resulted in 2390, 1110, 139, 37, 135, and 972 sales transactions between 2009 and 2017 for Energy Star, HERS< 90, HERS 90-100, LEED, National Green Building, and Other Green Certification

respectively. After restriction of average or above condition the data were trimmed to 1706, 670, 114, 29, 102, and 859 respectively with resulting matches of 1,506, 655, 102, 25, 88, and 784 through the analytical process (Table 2).

Table 2. Trimming process results.

	Energy Star	**HERS< 90**	**HERS 90-100**	**LEED**	**National Green**	**Other Green**
MLS original Single Family	2390	1110	139	37	135	972
Average or above condition	1706	670	114	29	102	859
Actual PSM matched	1506	655	102	25	88	784

Of the six categories of certifications defined in the Philadelphia area multiple listing service, Energy Star certification and Other Green Certification were the only ones that met standard statistical significance threshold at 95%. The t-stat, appropriate for this type of analysis, indicated the results from the Energy Star and Other Green Certification categories were statistical significant, with Energy Star having a t-stat of 2.40 and Other Green Certification being 2.38. HERS<90, HERS 90-100, LEED, and National Green Building certifications were not shown to be statistically significant, with t-stats of 0.63, 0.87, -0.01, and 0.26 respectively (Table 3). A t-stat score at or above 2.00 would be considered statistically significant as their resulting confidence intervals would not cross zero in such cases.

Table 3. Philadelphia area green label results.

	Label	Premium (Δ%)	Significance (%)	t-stat
1	**Energy Star**	**5.11**	95	**2.40**
2	HERS < 90	4.98	95	.63
3	HERS 90-100	4.76	95	.87
4	LEED	-0.12	95	-.01
5	National Green Building	2.25	95	.26
6	**Other Green Certification**	**8.53**	95	**2.38**

*bold noting statistically significant

There were 1506 matches for Energy Star Certification over the time frame. The analysis resulted in a statistically significant Average Treatment of the Treated (ATT) effect of 5.11% with at 95% confidence interval of between 0.92% and 9.46% for the

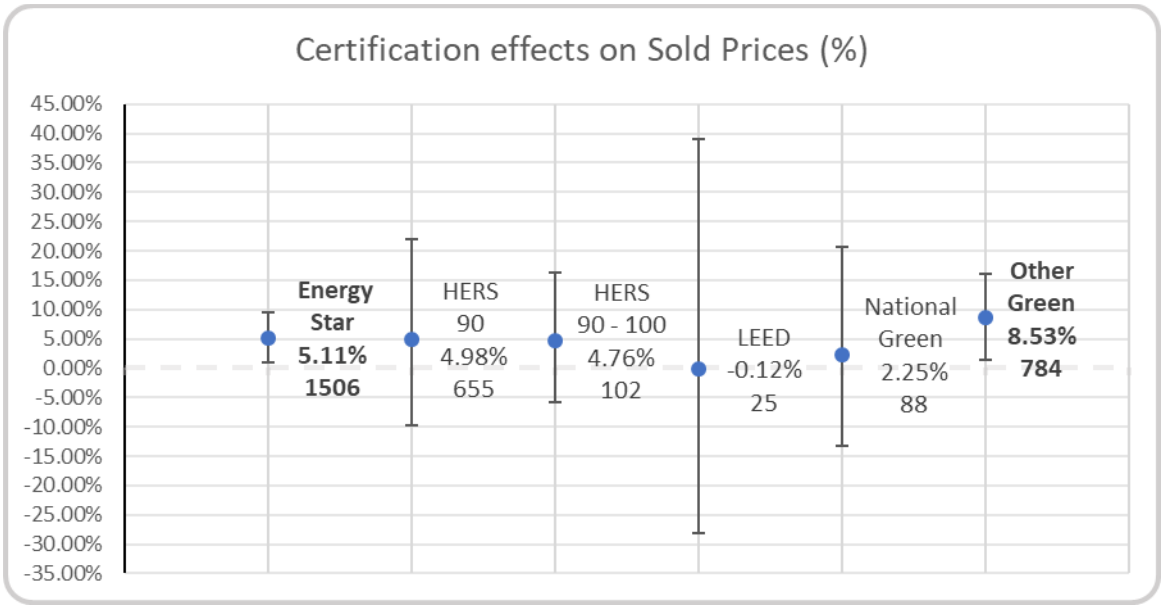

Figure 4. Philadelphia area green certification results comparison in percentages.

Energy Star certification and for Other Green Certification of 8.53% with a 95% confidence interval of between 1.45% and 16.10% attributable to their respective certifications (Figure 4). The matched pair average baselines were $358,569 and $375,321 for Energy Star and Other Green Certifications with a conclusion that an average amount attributed to having Energy Star and Other Green Certification increased the sold price by $18,306 and $31,997 to $376,876 and $407,319, respectively (Figure 5).

Further analysis was done to determine if high priced areas were influencing the percentage of added value. Median sold prices for each of 806 school districts throughout the region were used to separate areas into bottom third, middle third, and top third priced homes. This resulted in the school districts being divided into 269, 270, and 267 top, middle, and bottom tertiles.

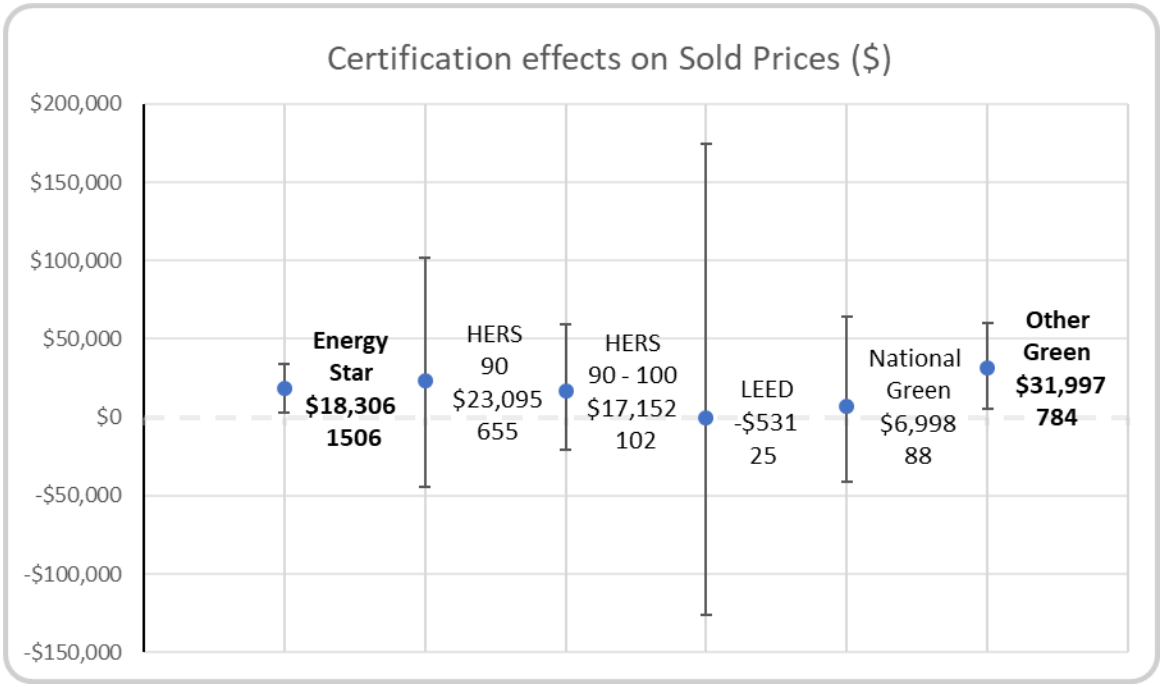

Figure 5. Philadelphia area green certification results comparison in dollars.

Energy Star data, having the largest dataset of each category of certification marketed in the region during the timeframe, were separated into these tertiles. The data had homes marketed with Energy Star certification in 219 of the 806 school districts in the region. There were 85 in the top, 87 in the middle, and 47 in the bottom school districts tertiles when separated by median sold home prices. There were 1142, 1066, and 182 homes sold in these top, middle, and bottom tertiles with Energy Star certification. This was narrowed to 837, 708, and 161 Energy Star certified homes that were average or above condition. Upon propensity score analysis, there were 748, 618, and 140 matches for the top, middle, and bottom tertiles. When Energy Star was segregated into such tertiles it achieved statistical significance only in the lowest tertile, with a t-stat of 2.04 (Table 4).

Table 4. Detail Energy Star summary by tertile.

Energy Star	**Matches**	**Lower**	**Mean**	**Upper**	**t-stat**
Top Tertile	748	-0.65%	4.58%	10.08%	1.71
Middle Tertile	618	-1.11%	3.46%	8.25%	1.48
Bottom Tertile*	**140**	**0.32%**	**8.88%**	**18.17%**	**2.04**

*bold noting statistically significant

Although the number of Energy Star certified homes was skewed to the higher median home priced school districts, the results revealed the opposite effect on premiums; the lowest median home priced school districts actually had a higher

statistically significant premium of 8.88% with a 95% confidence interval between .32% and 18.17% and a t-stat of 2.04 (Figure 6). The conclusion being the average matched baseline price of $207,282 resulted in an average increase of $18,411 with the Energy Star certification to $225,693 (Figure 7).

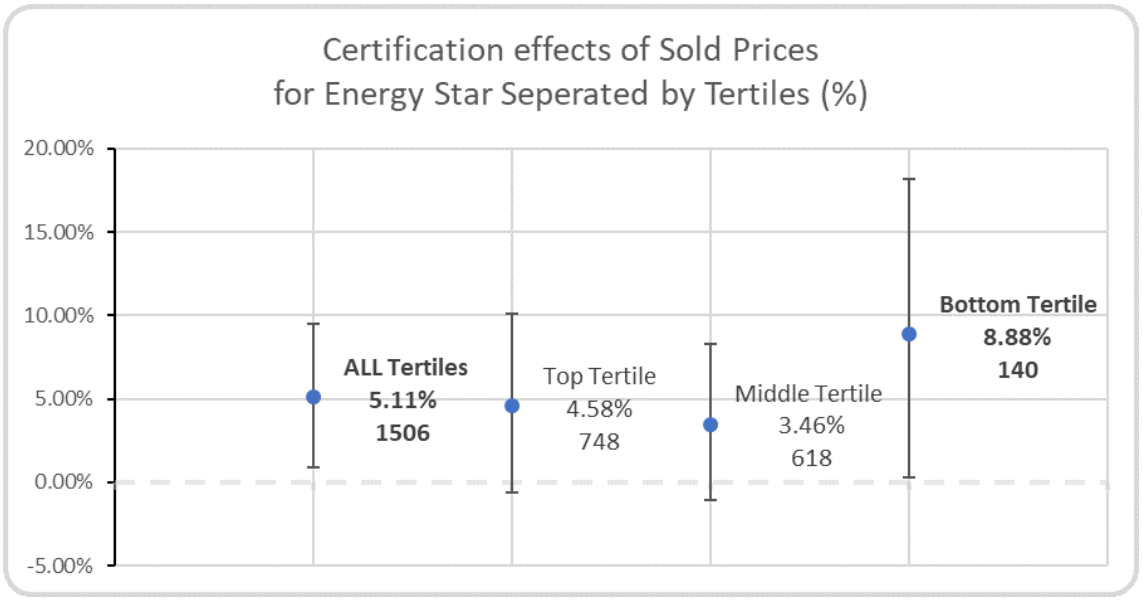

Figure 6. Energy Star premium results tertile comparison in percentage.

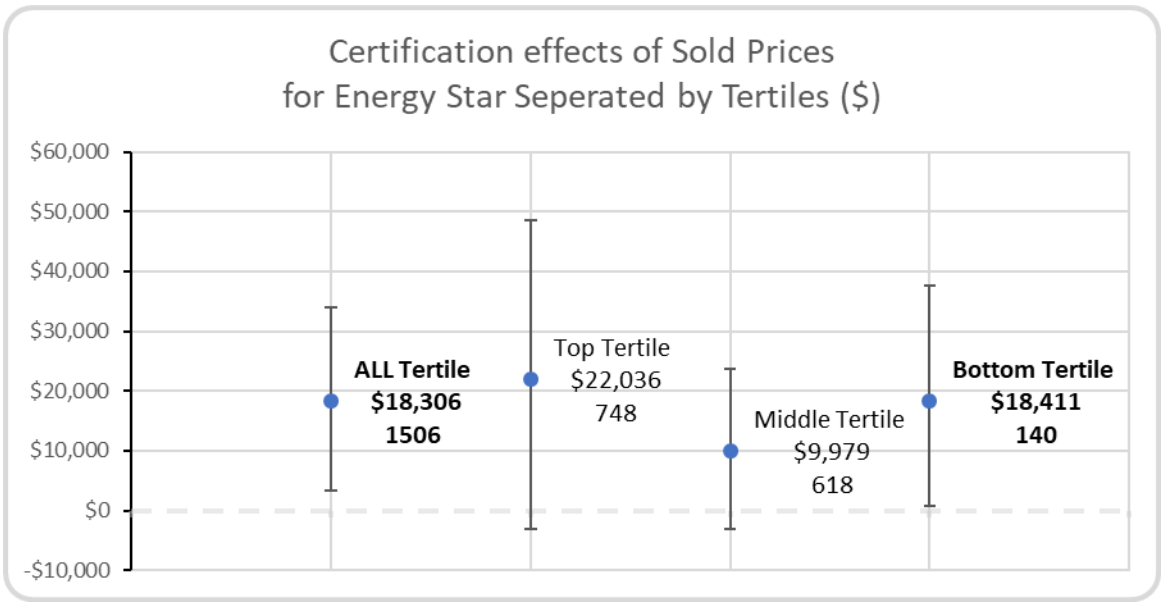

Figure 7. Energy Star premium results tertile comparison in dollars.

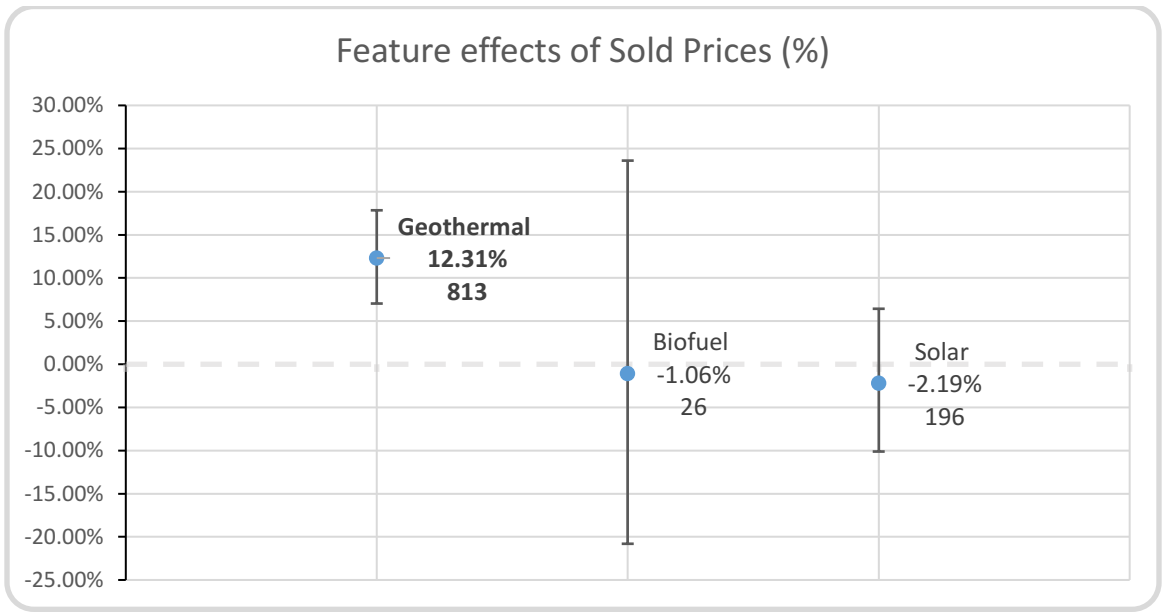

Figure 8. Sustainable heat source premium results comparison in percentages.

Additionally, heat source was analyzed with the same single family not age restricted, marketed as average or above condition data group, utilizing the same

independent variables and same statistical matching method. The initial extraction of data resulted in 38, 1162, and 293 transactions between 2009 and 2017 for bioFuel, geothermal, and solar heat sources respectively. After restriction of average or above condition the data was trimmed to 27, 930, and 227 respectively with resulting matches of 26, 813, and 196 through the analytical process.

Geothermal, otherwise known as ground source heating, had a statistically significant result of 12.31%, with a 95% confidence interval between 7.04% and 17.85% and a t-stat of 4.73 (Figure 8). Biofuel and solar heating sources did not result in statistically significant effects, with t-stats of -0.09 and -0.51 respectively (Table 5).

Table 5. Philadelphia area green feature results.

	Feature	**Premium (Δ %)**	**Significance (%)**	**t-stat**
1	**Geothermal**	**12.31**	**95**	**4.73**
2	Bio-fuel	-1.06	95	-.09
3	Solar	-2.19	95	-.51

*bold noting statistically significant

The 813 matched pairs of geothermal had an average baseline of $403,665 with a conclusion that an average amount attributed to having geothermal increased the sold price by $49,700 to $453,364 (Figure 9).

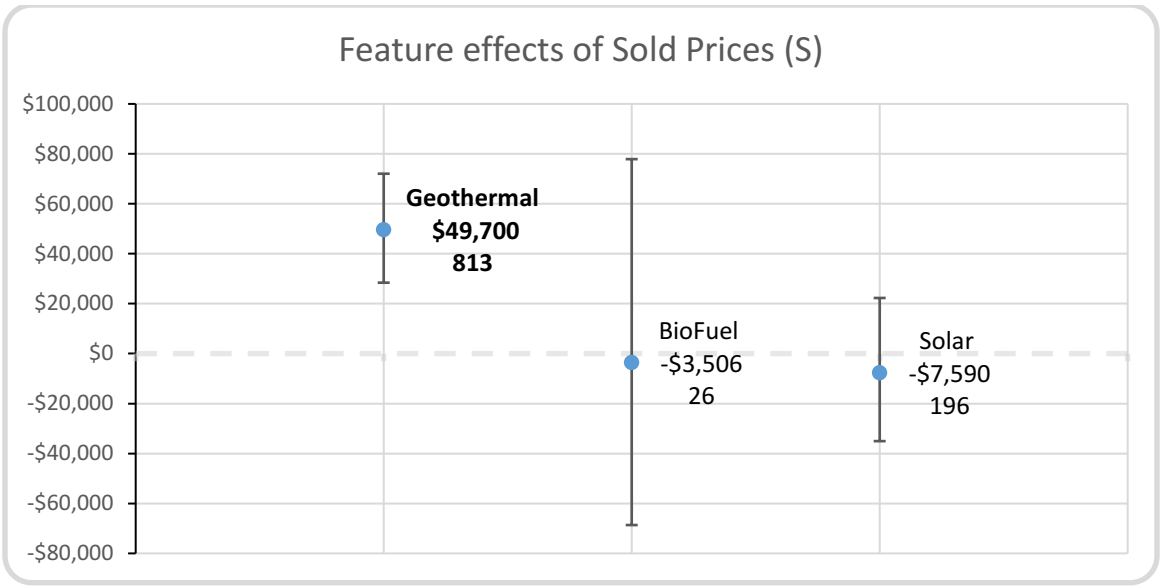

Figure 9. Sustainable heat source premium results comparison in dollars.

Premium Contribution

Mentioning the energy conservation attributes in the sales process is meaningful to the transaction, given the fact that a Realtor® has included sustainability factors in the property marketing. Showing a price premium for any certification gives an additional quantitative basis to sustainable features. Results are outlined in Table 3 for green labels and in Table 5 for green heat source features, showing the analyzed percentage of added value to the home that was obtained by having the particular label or feature. In both tables, results focus on changes in premiums. These are expressed as a percentage value, consistent with the procedure in most studies. It allows a comparison over time, over price range, and square footage of homes. The respective significance levels and t-stat values are included for each label and feature. Results are further shown with confidence intervals in percentage in table 6 and 7, and in dollars in tables 8, 9, and 10.

Table 6. Detail certification summary of results in percentages.

Certification	Matches	Lower (95%)	Mean	Upper (95%)	t-stat
Energy Star*	**1506**	**0.92%**	**5.11%**	**9.46%**	**2.40**
HERS 90	655	-9.66%	4.98%	22.00%	0.63
HERS 90-100	102	-5.70%	4.76%	16.39%	0.87
LEED	25	-28.22%	-0.12%	38.98%	-0.01
National Green	88	-13.33%	2.25%	20.63%	0.26
Other Green Certification*	**784**	**1.45%**	**8.53%**	**16.10%**	**2.38**

Table 7. Detailed heat source summary of results in percentages.

Heat Source	Matches	Lower (95%)	Mean	Upper (95%)	t-stat
Geothermal*	**813**	**7.04%**	**12.31%**	**17.85%**	**4.73**
BioFuel	26	-20.81%	-1.06%	23.60%	-0.09
Solar	196	-10.12%	-2.19%	6.43%	-0.51

Table 8. Detailed summary of certification results in dollars.

Certification	Match Baseline	Lower (95%) ($)	Difference ($)	Upper (95%) ($)	t-stat
Energy Star*	**$358,569**	**$3,314**	**$18,306**	**$33,920**	**2.40**
HERS 90	$463,485	-$44,777	$23,095	$101,969	0.63
HERS 90-100	$360,219	-$20,537	$17,152	$59,023	0.87
LEED	$447,702	-$126,327	-$532	$174,503	-0.01
National Green	$310,628	-$41,400	$6,998	$64,096	0.26
Other Green Certification*	**$375,321**	**$5,432**	**$31,997**	**$60,415**	**2.38**

Table 9. Energy Star by tertile.

Energy Star	Match Baseline	Lower (95%) ($)	Difference ($)	Upper (95%) ($)	t-stat
Top Tertile	$481,467	-$3,145	$22,036	$48,544	1.71
Middle Tertile	$288,130	-$3,192	$9,979	$23,760	1.48
Bottom Tertile*	**$207,282**	**$665**	**$18,411**	**$37,672**	**2.04**

Table 10. Detailed heat source summary of results in dollars.

Heat Source	Match Baseline	Lower (95%) ($)	Difference ($)	Upper (95%) ($)	t-stat
Geothermal*	**$403,665**	**$28,408**	**$49,700**	**$72,040**	**4.73**
BioFuel	$329,972	-$68,653	-$3,506	$77,883	-0.09
Solar	$346,420	-$35,043	-$7,590	$22,283	-0.51

Additionally, with the limited amount of data on some certifications, most notably LEED starting with only 37 identified homes sold over the time period, and the decline in the number overall of each certification in sales data of single/detached, non-age restricted, average or above condition homes, peeking in 2016 at 636 and falling off to 528 in 2017, representing about a 17% decline after years of steady increase, it might be difficult to continue this study and find sufficient matches in the foreseeable future (Figure 10 & Table 11).

Table 11. Yearly homes sold by certification.

Energy Star	**5**	**128**	**173**	**209**	**232**	**268**	**224**	**260**	**207**
HERS <90	1	4	7	15	47	123	173	164	136
HERS 90-100	0	8	15	21	16	10	17	16	11
LEED	1	3	5	5	1	0	2	2	10
National Green	0	4	11	8	11	27	17	12	12
Other Green Certification	**2**	**32**	**46**	**90**	**94**	**104**	**157**	**182**	**152**
Year	2009	2010	2011	2012	2013	2014	2015	2016	2017

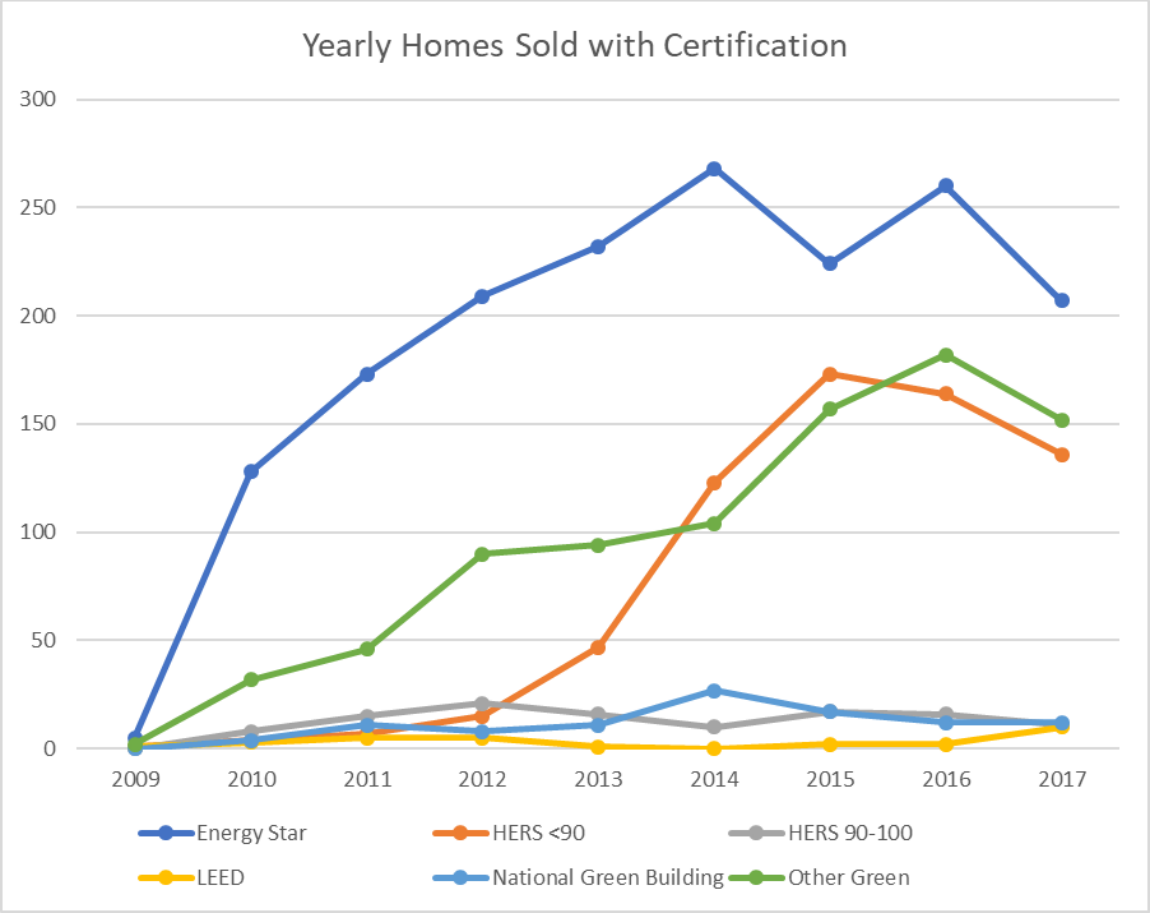

Figure 10. Yearly number of sold homes with each certification.

Chapter IV

Discussion

A substantial dataset of 250,354 of 375,598 sold single family not age restricted average or above condition real estate transactions in the Philadelphia metropolitan area was computer matched on sixteen independent variables. Robust results were obtained with the ability to make closely aligned adjustments to the independent variables upon matching. Accordingly, with this study two certifications, Energy Star and Other Green Certification, and one heat source, Geothermal, produced premiums that meet scientific threshold for significance. Concluding with 95% confidence that if the true increase percentages in a home's sold price due to Energy Star and Other Green Certification were known, the interval between 0.92% and 9.46% and 1.45% and 16.10% respectively would contain them. Also concluding with 95% confidence that if the true percentage increase in a home's sold price due to geothermal heat source were known the interval between 7.04% and 17.85% would contain it. Thus revealing, within the limitation of this study, these two categories and one sustainable feature had positive effects adding to the price a home that was sold for during the timeframe 2009 to 2017 accordingly.

The effects of premiums and popularity on market acceptance of a label are related. The Energy Star label is the most well-known and dominant label on the market, leading to its effect on premiums compared to other certifications. This may explain the statistical significance of Energy Star, though it does not explain the statistical significance of Other Green Certification. For less utilized certifications a small sample

size may have negatively influenced their validity and reliability in the statistical analysis. This consideration was one of the reasons the entire timeframe of observation in multiple years was utilized.

Single family homes are considered the staple of the American residential real estate market and were used in most other similar studies across the United States. The decision was made to limit the data to that sourced from the multiple listing service being TrendMLS, as it is most representative of the primary housing market in the Philadelphia metropolitan area. It was beyond the scope of this study to evaluate the fundamental differences in the certification or the requirement changes over time of the certifications. This study researched how having a particular certification identified in the multiple listing service marketing affected the prices that the house were sold.

Analysis Considerations

Given the low numbers of some certifications, especially LEED, HERS 90–100, and National Green Building, the decision was made not to separate the years which would result in averages across the time period. Converting the data into dichotomy or binary values, known as dummy coding, was used to separate each of the certifications and the three heat sources of this study. Numeric coding was also used to convert alphabetic values in the garage spaces field, so the difference in the number of garage spaces could be analyzed not just the fact that a house had a garage.

Initial regression with date as an exact day, which was the original format from the exported multiple listing service data, resulted in erratic correlation, which proved to be too small a timeframe. Revisions to month also proved inconclusive. Further

refinement to quarterly produced more meaningful results though still relatively little difference. Daily was too small a definitive so quarterly interaction with yearly was used.

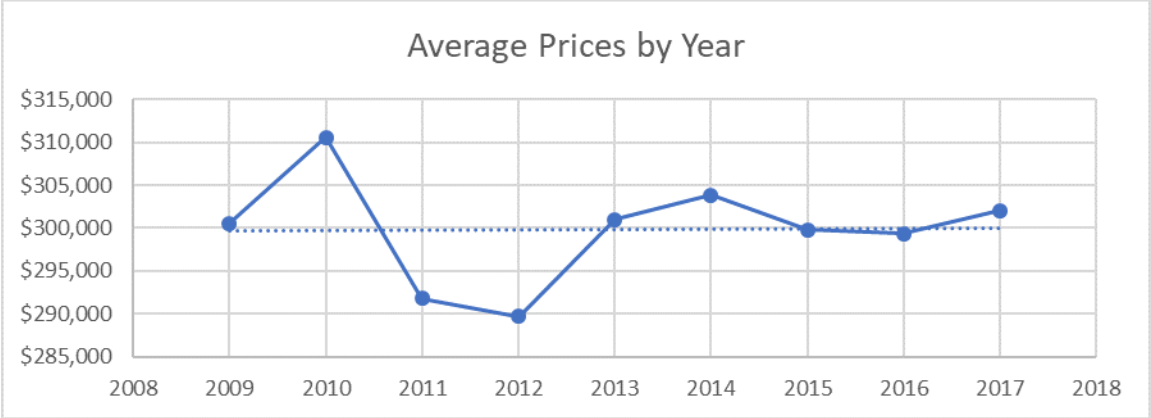

Figure 11. Volatility of real estate market during recessionary timeline.

The average prices per year was analyzed of the 375,598 transactions, and as it revealed the recessionary nature of the timeframe on house prices. The expectation was that year of a sale would be a significant correlation, with earlier years being systematically lower than more current years. It was revealed with the graph of the average sales price per year, that during this timeframe a recessionary volatility was experienced without a specific pattern (Figure 11). There was essentially a flat trend using a starting point of 2009 and 2017 as the end date. The start date of 2009 was used as that was the time the certifications initially appeared into the MLS system. Typically, it is thought that seasonal trends exist in the region, with more sales occurring and resulting higher prices in the spring between the end of winter and the start of summer. Slow periods are expected from the fall holiday season through winter and then again during the summer, which typically experience lower volume of sales and lower resulting

prices. There typically is a slight increase in sales following summer and just before the fall time period. Accordingly, quarter and year were still included in the analysis.

The certification criteria changed over the timeframe and so did the requirements of the multiple listing service, each of which was beyond the scope of this analysis. Sold pricing, converted into its natural log, was used as the dependent variable. The remaining fields from the export of the MLS data were looked at carefully to determine their importance to the dependent variable and the amount filled in within each category. A correlation matrix was generated to aid in the analysis. Initial individual regressions were done with each variable that was believed from experience to have relevancy. This revealed the need to categorize some of the fields that were continuous format. The fields of age and acreage, were initially continuous from zero to 999 for age and from zero to the hundreds for acreage. Convergence was not obtained in all certifications with these fields of the data being in the original continuous format so the data was split into relevant categories. Total acreage which was converted into: less than one fifth, one fifth below one half, one half below one acre, one acre to two acres, over two acres to five acres, over five acres to less than ten acres, and ten acres and above. Additionally, age was categorized into zero, 1-5, 6-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-99, and one hundred and over. These were chosen based on experience in the marketplace. Upon these conversions, convergence was obtained for all certifications.

Other Green Certification Evaluated

Differentiation, explaining the differences and nuisances of the certifications, has been shown to have an effect on premiums (Shewmake & Viscusi, 2015). Other Green

Certification category allowed a wide interpretation compared to all the other multiple listing service categories with definitive independent criteria for certifications that had detailed descriptions. For example, a home may have had Energy Star appliances but not be fully Energy Star certified, in which case it would not qualify to be included in the Energy Star certified home category. However, it could have been included in the Other Green Certification category. In addition, being included in the Other Green Certification category inevitably suggests an explanation on the part of the marketing: it would have served to differentiate it as it would enviable have explained the context that Other Green Certification was used for the property.

It has also shown that the level of differentiation affects adoption (Shewmake & Viscusi, 2015). Differentiation is especially useful in saturated markets as was experienced during much of the study timeframe. Additionally, identifiable markers of greenness have been shown to influence premiums (Aroul, 2009; Aroul & Hansz, 2012; Bloom et al., 2011; Cadena & Thomson, 2015; Kahn & Kok, 2013; Shewmake & Viscusi, 2015). With the flexibility of the catchall Other Green Certification category the branding and visibility may have been easier and more direct to consumer needs and desires. This may have resulted in increased consumer perception and resulting higher premiums. Consumer perception has been revealed as an important factor in these premiums. Whereas the other certifications are specific in their criteria, the Other Green Certification has no defined specifications and thus may have allowed a wide array of interpretations which might have aided differentiation in marketing efforts.

Other Green Certification was the one category that allowed extension beyond the house itself, in that a house could have been promoted in this category for being in a

neighborhood that had sustainability aspects. Anecdotally, after preliminary review of some of the properties in this category, some of the marketing was geared towards open space, both passive and active, as well as trial networks interconnecting the neighborhood. School districts are a major value consideration in real estate. Buyers, especially for single family homes, often make decisions based on children. One possible explanation could be that parents that purchased based on children's needs might have paid extra to live in a home promoted as green in the Other Green Certification category as it had trail networks and active open space which might foster child activities and socialization.

Broader Viewpoints

Among the host of factors revealed by other studies that influence these premiums is the overall economy (Cadena & Thompson, 2015; Kahn & Kok, 2013; Shewmake & Viscusi, 2015). During the timeframe of this study the overall economy was tumultuous. This included historically low interest rates and upward spikes in energy pricing. These two factors coupled with job insecurities and the unusual deflating prices in real estate certainly weighed in on buying decisions of housing consumers during most of this study's timeframe. The overall operating costs most certainly factored into the buying decision during this unprecedented economic time.

Lower priced homes typically are sold to first time buyers. The median home purchase price across the United States was $203,700 to first time buyers compared to the median of $280,000 to repeat buyers (Lautz et al., 2018). These buyers are typically immensely concerned about overall operating costs. Conversely, homes that are not the

lowest in the marketplace tend to appeal to "move up" buyers who usually experience increases in incomes that allow them to seek larger housing. Therefore, the buyers of moderate and higher priced houses may not have been as concerned with overall operating expenses as lower priced houses, especially in strained economic times as experienced during this study period. Low interest rates may have also fostered these premiums. When the overall housing costs are all factored into household economics, cost efficiencies can equate to significant dollar amounts. For example, with a typical rate during the timeframe of 4% for a 30 year mortgage, only $88 in monthly overall savings otherwise available as a mortgage payment would equate to $18,433 in principle amount. Such a cost savings may have equated to a corresponding increase in the price. This is about the mean for the statistically significant lower tertile of the Energy Star certification (Figure 7 & Table 9).

Higher premiums on lower prices of the Energy Star homes seems to reveal that those homebuyers took the overall view of their housing expenses above principle, interest, taxes, and insurance, as the Energy Star certification embodies cost savings on operating a home as its hallmark. This could help to explain the fact that Energy Star showed the highest and only statistically significance in the lowest tertile. Another consideration may have been that more expensive homes might have been expected to have more energy efficient measures and thus the incremental cost to meet Energy Star requirements might have been a smaller percentage. Conversely, lower priced homes might not have been as expected to have significant energy efficient measures and thus the incremental cost to meet Energy Star requirements might have been that larger percentage as was revealed in the results.

Geothermal and Solar Heat Source

California, where studies have shown premiums for solar photovoltaic systems (Dastrup et al., 2012), was recently reported to have an eight year payback for home solar installations compared to twelve years in Pennsylvania (Zientara, 2018). Also, it has been shown in that prominent study on solar home price premiums that without government incentives solar photovoltaic systems were not considered beneficial for homeowners (Dastrup et al., 2012). Additionally, a cluster of solar panels homes – multiple homes in the same neighborhood - was found to have a negative impact (Dastrup et al., 2012). This may be because they are perceived as a commodity as that study suggests. The lack of uniqueness or a common fixture may devalue it. Alternatively, the lack of solar panels in a region may equate to the consumer the scarcity and perceived negativities of being the one of a few to have them. Although clusters had been shown to have a slightly lower effect of a premium, as may be a norm for the area, having too few may be a detriment as well. This might have been the case in the Philadelphia region especially where it is known for its conservative and less progressive attitudes as compared to areas of the other studies such as California.

Additionally, the south and west, especially southern California, are well known for having a lot of sunny days. Conversely, the Philadelphia region is not typically known for sunny days, and more moderate all four seasons. San Diego and Sacramento have a reported 3,055 and 3,608 total hours of sunshine with 146 and 188 clear days per year compared to 2,498 total hours of sunshine and 93 clear days per year for Philadelphia (CurrentResults.com, 2018). Philadelphia region consumers might have relied more on

constant ground temperatures, which geothermal requires, rather than the sunny weather required for solar panels.

Geothermal systems are based on the ground providing constant temperatures throughout the year. These systems could have provided a reasonable payback period in areas such as Philadelphia. Perception of year round reliability from the ground temperature verses inconsistency of the sun in the area may account for the fact that geothermal was highly valued and solar heating was not in the Philadelphia region. In 2009, Pennsylvania was shipped 21,357 tons of geothermal units, compared to 6,998 tons of geothermal units shipped to California, showing Pennsylvania's great use (EIA, 2010). Valuing geothermal heating may be a market peculiarity to Philadelphia, like water conservation measures are valued in San Antonio. Geothermal and biofuel heating did not appear in other previous studies, which might be due to a lack of available data. While data on houses with these features may not be easily obtained for certain regions, this information was available for this study. Conversely, data on drought tolerant plants and low-flow commodes, which is available in other areas, was not readily accessible for the Philadelphia marketplace. This exemplifies the fact that different features are regionally important.

Environmental Consumers

The limited amount of overall green labeled homes sales, about 1% in the Philadelphia region (3,907 of 371,691 of the sold transactions from 2009 through 2017), may be accounted for by the region being less environmentally minded than places like California. Studies show that the effect of price premiums on sustainable items differs

between specific groups of buyers, based on the value they impose on climate and environmental issues in their buying decisions (Kahn & Kok, 2013). Typical variables correlated to premiums are car ownership, political party affiliation, and the tendency to donate to particular categories of causes. Areas with a high concentration of environmentally conscious Toyota Prius owners (hybrid gas-electric vehicle) correlate with sizeable premiums, while a high local concentration of pickup truck owners correlates to lower premiums, as the latter are assumed to be less environmentally conscious (Kahn & Kok, 2013). The top five cities for Prius cars for sale are all in California, with Philadelphia being the sixth in the nation and Allentown, PA, just north of the Philadelphia region, being number one for Hummer cars for sale (Dhar, 2012). Prius cars are the visible sign of green-mindedness, with Hummer vehicles being the antithesis of environmentally minded. However, to those in the Philadelphia region that are environmentally minded, the premium results are in line with studies from other parts of the country. Invariably, it would most likely be the same environmentally minded consumers that pay premiums for hybrid cars would also pay a premium for a "green" labeled house. Since there are less Prius cars for sale in the Philadelphia region, it makes sense that there are less "green" labeled houses sold as well.

The visibility aspect might be another reason why solar heating of homes did not command a premium and geothermal did in the Philadelphia marketplace. The Philadelphia region is historically and economically based on fossil fuels. Oil in the United States was first discovered in Titusville, Pennsylvania in 1859 (Wells, 2018). The Philadelphia region, with its access to water, seaports, and railroad networks, was an early site of oil refineries (Hein, 2016). To this day, the Philadelphia region's refineries

supply significant portion of East Coast gasoline (EIA, n.d.). Pennsylvania is also a coal state, with vast deposits and continued mining operations just outside the Philadelphia metropolitan area. In addition, although not in the Philadelphia area, most of Pennsylvania has Marcellus shale operations, with 40 of the state's 67 counties having drilling operations (Corbett, 2014). Having solar for heating in the Philly area might be akin to having a Hummer in Berkeley, CA; they're not in keeping with the mentality of the local tribe. It might just be that to be environmentally friendly goes against the prevailing economy and attitudes for the region. One of the reasons that solar heating, which is highly visible sign of environmental concern and popular in other regions of the county, did not result in a premium in Philadelphia is that the region is dependent upon fossil fuels.

Same City Different Results

The way housing data is analyzed makes a difference in the results. Two different studies for the same region with data from almost the same time period resulted in different premiums. The findings for a premium of about 5% for one study (Shewmake & Viscusi, 2015) and 8.7% for the other (Walls et al., 2017) could be due to the data set trimming, number of variables evaluated and considered, and methods they each chose as part of their analysis. The Philadelphia region study similarly required decisions on the treatment of the original data, which consequently resulted in trimming of data. These other studies also used propensity score matching with balance table for review of the 10% threshold for matching. Even in the same region, of Austin, different results were obtained. This reveals the need to carefully examine the decisions made in each study not

just their results, as their results are a product of those decisions. Ideally, there would be a uniform way of treating an analysis so it could be replicated anywhere. Ultimately, however, statistically significant premiums were revealed as each study, including this one, used similar statistically sound methods and processes. Similar to the Texas studies, the Philadelphia study findings showed the premium for the local label exceeded the national Energy Star label.

Upon close examination, in one study, any label (which included the local Environments for Living (EFL) and three of the five levels of the local AEGB label) resulted in a 5% premium (Shewmake & Viscusi, 2015). In that study, they decided to control for low-income housing. In particular, the AEGB label had 9,943 homes labeled of which 4,533 were affordable housing derived from a local program of Safe, Mixed-income, Accessible, Reasonably-priced, Transit-oriented (S.M.A.R.T.) homes. In addition, they controlled for a large section of new construction redeveloped area that mandated at least the third level of the AEGB rating. These criteria trimmed the data to 1,105 AEGB labeled homes and 29,416 unrated homes sold between January 2008 and April 2012. Further, homes were limited to be fifteen years old or less and resulted in a reduction from 29,416 to 15,668 homes in the control set and 1,105 to 1,079 homes in the AEGB labeled set. Available sales data allowed the final analysis with 14,589 non-rated homes and 1,079 AEGB rated homes.

Comparably, the second study used data over the 2008 to 2011 time period (Walls et al., 2017). They eliminated unrealistic and missing values. In addition, they eliminated the highest and lowest priced outliers, non-arms-length transactions, as well as restricted geographic matching to within one mile. These trimmed the data set from 91,857 to

42,600. They benchmark the threshold of 10% in the balance table of their propensity score matching. The unmatched sample had 42,582 observations and with their nearest neighbor analysis, it showed 4,064 observations and resulted in an 8.7% premium for the AEGB label. Among the 13 independent variables was an index of house quality. These variables were aligned with similar methods of the study reported here. Additionally, they evaluated the financial aspects of the energy component of the label and revealed that it only explains a portion of the premium consumers are paying for the label. The local Austin AEGB label encompasses far more than energy savings. Water usage is one of the five environmental impact topics rated with the AEGB label (Shewmake & Viscusi, 2015), which is of importance in the south Texas area as indicated by studies showing water saving features in the sale of homes commanded a sizable premium. A study in San Antonio, about eighty miles away from Austin, found a 7.7% premium for water features in homes (Cadena & Thompson, 2015). It may be that a part of the premium for the AEGB could be due to the water saving's attributes intertwined in the components to obtain that label. The higher premium for the local label may be because they address local concerns more than a national label. It might even be that the local labels were created out of the need to address these regional concerns. Energy Star is a national label which does not address local environmental concerns, which could be a reason for a lower premium observed for that label in that study as well as this one.

Of additional note, the Environments For Living (EFL) label has a two-year guarantee on energy usage and the temperature levels in the home (Shewmake & Viscusi, 2015). This added benefit may add to the premium a buyer would pay over a comparable certification, such as Energy Star, that does not have such a warranty. This may also

reveal layered components of the premium, as consumers may have added up the benefits they derived in addition to just energy savings.

Layered Components

There are numerous reasons that motivate the American consumer, particularly when purchasing homes. Internal, financial, and social norms often influence consumers of environmental items (Delgado et al., 2015). Internally buyers benefit from the "warm glow" of aligning with their belief system; doing good (purchasing a sustainable home) gives them a good feeling. Additionally, other non-financial internal benefits a buyer of homes with these labels received might include better indoor air quality and comfort. Financially, buyers may expect to receive a personal benefit, usually in the form of a cost savings over alternatives. For example, a buyer may have benefited from the certainty of future expenditures such as the warranty with the EFL label in Austin. Third, there was a benefit to the buyer for fitting in with society or "looking good" within their tribe.

The reason for the premiums from "green" labels on houses could have been due to a combination these factors and even an inferred superior quality of construction (Walls et al., 2017). This phenomenon can be supported as it was found in car sales, which can also be correlated to sustainable home features such as solar panels on a roof. Prius cars were reported to command a 4.5% premium of its value from their virtuous observability over comparable hybrid cars (Delgado, et al., 2015). Solar panels are correlated with Prius cars, in that they are visible signs of greenness (Dastrup, et al., 2012). Coincidently, homes with solar panels receive higher premiums in area with higher Prius ownership. Pickup trucks are conversely not signs of environmental

stewardship. Accordingly, areas with high ownership of pickup trucks have also been shown to have low premiums of solar panels.

The premiums may have been made up of layers of these added benefits. These benefits are not mutually exclusive and the extent varies regionally. For example, in Research Triangle it was concluded the premiums for labels equated to just the energy savings, while in Portland the premiums for labels exceeded the benefit from energy savings alone (Walls, et al., 2017). This might be that in Research Triangle buyers do not value additional components of a label whereas Portland may be a community that values the added components.

Adoption Curve Connection

The effect of price premiums has been shown in this study. A premium could offset the net investment to these items for a decision maker. This would shorten the break-even timeframe and thus increase the rate of return without changing the buyer's initial cost. For example, the average of the Energy Star homes matched in this study sold were $376,876 with a baseline of $358,569, of which a 5.11% was attributed to the label, being an $18,306 premium. This financial attribute is in addition to all other savings realized from energy conversation, as the annual cost savings are the same with or without the realization of a premium. The premium could be mathematically discounted based on the anticipated ownership time to justify offsetting the initial cost of the certification, thereby reducing the threshold for breakeven point of such an analysis. For example, if a buyer initially paid $10,000 more an Energy Star rated home and owned it for seven years and then sold that home for $18,306 more because of that additional

investment, they would have received nearly an 8% annualized return on that $10,000 investment. This is in addition to the monthly cost saving by having a more energy efficient house.

The implications are of practical use for homeowners, buyers, sellers, remodelers, and developers, regardless of their attitudes towards sustainability. The realization of premiums could be an impetus for the housing industry to consider sustainability improvements to homes, since the financial equation would be enhanced.

Purchasers of green items do not have to be socially, ethically, or environmentally conscious in order to enhance their decisions to buy these features based on premiums and not solely on payback periods. This opens up the door to a new set of adopters. If added premiums can be widely demonstrated and thus relied upon, which this study adds to that realization, that added feature may act as the improvement to push adoption to the next level past the point that cost savings alone which has been used to date. This could act as a product innovation by possible new consumer appeal and a new customer segment (Figure 12). The overall adoption of green certifications in Philadelphia on a yearly basis has peaked in the 2015-2016 timeframe and is seeing a decline (Figure 10 & Table 11). If this pattern can be explained by the technology adoption theory, that downward trend will continue without some intervening new component added. I assert that premiums could be the necessary addition to reverse that downward trend in sales of certified homes.

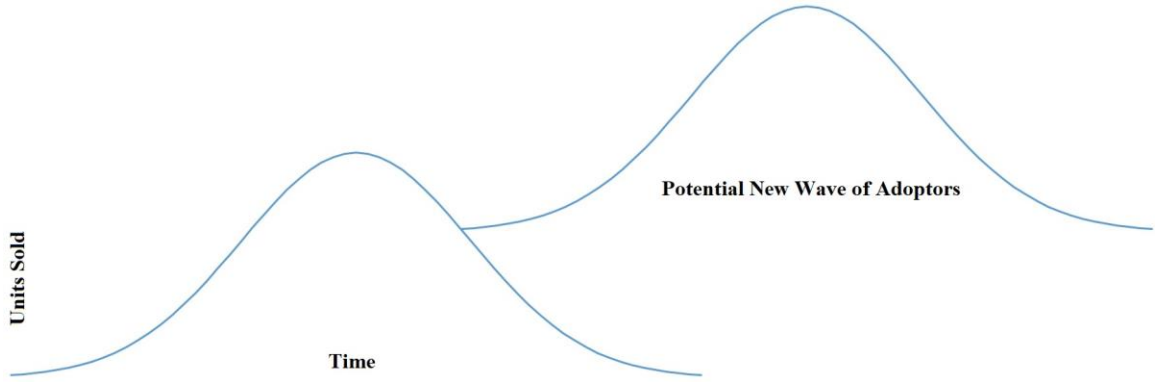

Figure 12. Technology innovation curve with proposed new adaptors' wave.

Additional studies like this one could add to understanding the financial decisions of consumers that make up these premiums.

Conclusions

In the Philadelphia region, the MLS sustainability certification category Other Green Certification had the highest percentage premiums at 8.53% equating to $31,997 on a mean price matched home of $407,319 with a baseline of $375,321, followed by Energy Star Certification at 5.11% equating to $18,306 on a mean price matched home of $376,876 with a baseline of $358,569. Results from the other certifications were not statistically significant. Additionally, analysis of geothermal heat source resulted in statistically significant premiums of 12.31% equating to $49,700 on a matched pair home with the mean price of $453,364 with a baseline of $403,665. Analysis of biofuel and solar heating sourced homes did not provide statistically significant results. The premium for Other Green Certification was similar to some studies of the effects of premiums for "green" labels on residential housing in other parts of the county. Premiums of Energy

Star certified homes in the Philadelphia area also were consistent with some studies in other areas across the country.

The study's hypothesis that Energy Star would be the highest and only certification with a 2-4% premium was shown to be invalid. It was not the highest, nor was it the only certification to show a statistically significant premium, and the premium results were higher than expected for Energy Star. Other Green Certification produced the highest premium. This may be similar to the results from the study in Austin (Shewmake & Viscusi, 2015) and Portland (Walls et al., 2017) where the local certification produced higher premiums than Energy Star. Visibility and consumer perceptions are important drivers of these premiums, and the Other Green Certification category in the Philadelphia MLS system gave the flexibility and enhanced effort with more freedom and flexibility to tailor marketing efforts to the consumer.

Additionally, the hypothesis that solar heating would be responsible for a 5-7% price increase was shown to be invalid. The data for solar was limited to it being used as a heating source. In addition, Pennsylvania did not have significant incentives for solar, unlike states like California where solar premiums have been demonstrated. Additionally, consumer perception may have been a factor as the wide use of solar in other areas has become an acceptable visual and psychologically. Whereas the relatively scarce use in the Philadelphia area, demonstrated by the limited number of sales, may be visually and psychologically a hurdle in a perception of added value.

There is a decline in the overall number of single family average or above condition not age restricted homes that are being sold in the Philadelphia metropolitan area with "green" labels (Table 11). This trend may be representative of the diffusion of

innovation theory. The shape of the yearly homes sold with certification is starting to look like a bell curve, with the end of 2017 being at the declining stage (Figure 10). This bell curve is typical and predictable for technological innovations (Rogers, 2005). It appears as though the decline in yearly homes sold with certification will continue without some intervening product innovation.

The bottom line was the uniformity and consistency of premiums demonstrated for certain green certifications with this study, thus filling in the geographic gap of the United States. This knowledge could be used for additional studies and promotional value across the country. With each addition study confirming premiums for residential green certification, especially Energy Star, the prevailing acceptance of premiums in addition to energy savings may become commonplace. This may serve to attract different consumers that heretofore have not been adopters. I contend that this could start a new wave, similar to product innovation at the current declining stage (Figure 12).

This study adds to the reliability of premiums for a certain certification, namely Energy Star. Premiums could serve as a selling feature above cost savings. If this information attracts a different set of consumers, namely those primarily motivated by financial returns rather than altruistic or philosophical concerns, the downward trend of adoption of certifications could produce a new wave similar what product expansion does on a technology adoption curve.

This analysis provided statistically reliable results for the Philadelphia housing market. By sublimation with all other relevant studies in the country that use statistical methods, the results further support the inference of that green certification premiums operate in any area of the United States. Utilizing these premiums in the decision-making

process will help the adoption of more sustainable items. If each of the independent studies throughout the United States that are based upon unbiased, random samples were correlated, this would give inference to premiums across the entire housing market in the United States. Such results are expected to be of use to appraisers, lenders, policy makers, researchers, trade associations, and advocacy groups as well as homeowners, buyers, sellers, remodelers, and developers. This study helps fill in the geographic gap of the northeast to other studies in the south, south central, west, and northwest regions of the United States. The more studies like this that reveal statistically significant premiums in the residential sector, the closer we come to having a consensus similar to the commercial sector, where it is universally acknowledged that there is an identifiable dollar value associated with obtaining and promoting green certifications.

References

Andreoni, J. (1990). Impure altruism and donations to public goods: a theory of warm-glow giving. *The Economic Journal,100*(401), 464. doi:10.2307/2234133

Aroul, R. R. (2009). *Going green-impact on residential property values (*master's thesis). Retrieved from ProQuest Dissertations Publishing. (UMI No. 1467938)

Aroul, R. R., & Hansz, J. A. (2012). The value of 'green:' evidence from the first mandatory residential green building program. *Journal of Real Estate Research*, *34(1),* 27-49.

Bloom, B., Nobe, M. C., & Nobe, M. D. (2011). Valuing green home designs: a study of ENERGY STAR® homes. *The Journal of Sustainable Real Estate, 3*(1), 109-126.

Cadena, A., & Tomson, T. A. (2015). An empirical assessment of the value of green in residential real estate. *The Appraisal Journal, 83*(1), 32.

Caliendo, M., & Kopeinig, S. (2005). Some practical guidance for the implementation of propensity score matching estimators. *Lecture Notes in Economics and Mathematical Systems Microeconometric Evaluation of Labour Market Policies, 1588* (May 2005), 1-28. doi:10.1007/3-540-28708-6_4 Provisional preliminary work

Caliendo, M., & Kopeinig, S. (31 january 2008). Some practical guidance for the implementation of propensity score matching estimators. *Lecture Notes in Economics and Mathematical Systems Microeconometric Evaluation of Labour Market Policies,* 71-96. doi:10.1007/3-540-28708-6_4

Cochran, W. G., & Chambers, S. P. (1965). The planning of observational studies of human populations. *Journal of the Royal Statistical Society. Series A (General), 128*(2), 234. doi:10.2307/2344179

Corbett, T. (2014). *Energy = Jobs* (Rep.). Harrisburg, PA: Retrieved from the Commonwealth of Pennsylvania website: *http://www.naseo.org/Data/Sites/1/documents/stateenergyplans/pa-state-energy-plan-web.pdf*

CurrentResults.com. (n.d.). Average annual sunshine in American cities. Retrieved from: *https://www.currentresults.com/Weather/US/average-annual-sunshine-by-city.php*

Dastrup, S. R., Zivin, J. G., Costa, D. L., & Kahn, M. E. (2012). Understanding the solar home price premium: electricity generation and "green" social status. *European Economic Review, 56*, 961-973.

Dehejia, R., & Wahba, S. (2002). Propensity score-matching methods for nonexperimental causal studies. *The Review of Economics and Statistics, 84*(1), 151-161. Retrieved from *http://www.jstor.org/stable/3211745*

Delaware River Basin Commission (n.d.). About DRBC. Retrieved from Delaware River Basin Commission website: *https://www.state.nj.us/drbc/about/*

Delgado, M. S., Harriger, J. L., & Khanna, N. (2015). The value of environmental status signaling. *Ecological Economics, 111*, 1-11. doi:10.1016/j.ecolecon.2014.12.021

Dhar, R. (2012, March 17). The prius/hummer index: what cities buy the smallest and biggest cars? Same Retrieved December 26, 2018, from *https://www.theatlantic.com/business/archive/2012/03/the-prius-hummer-index-what-cities-buy-the-smallest-and-biggest-cars/254638/*

Eckhardt, G. (n.d.). Regional climate and water availability. Retrieved December 26, 2018, from *https://www.edwardsaquifer.net/climate.html*

Eichholtz, P., Kok, N., & Quigley, J. M. (2013). The economics of green building. *Review of Economics and Statistics, 95*(1), 50-63. doi:10.1162/rest_a_00291

EIA. (2017). U.S. energy facts explained. Retrieved from the U.S. Energy Information Administration website: *http://www.eia.gov/energyexplained/?page=us_energy_home*

EIA. (2010). *Geothermal heat pump manufacturing activities 2009* (p. 12, Rep.). Washington, DC: Retrieved from U.S. Energy Information Administration website:https://www.eia.gov/renewable/annual/geothermal/archive/geothermalrpt09.pdf

EIA, (n.d.) U.S. energy information administration - EIA - independent statistics and analysis. Retrieved from the U.S. Energy Information Administration website: *https://www.eia.gov/state/analysis.php?sid=PA*

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (4th ed.). Thousand Oaks, CA: Sage.

Gerarden, T. D., Newell, R. G., & Stavins, R. N. (2015). *Assessing the energy-efficiency gap* (NBER Working Paper No. 20904). Cambridge: Harvard.

Hein, C. (2016). Refineries (oil). Retrieved from The Encyclopedia of Philadelphia *website: https://philadelphiaencyclopedia.org/archive/refineries-oil/*

Henry, T. (2011, November 29). A history of drought and extreme weather in Texas. Retrieved from *https://stateimpact.npr.org/texas/2011/11/29/a-history-of-drought-and-extreme-weather-in-texas/*

Kahn, M. E., & Kok, N. (2013). The capitalization of green labels in the California housing market. *Regional Science and Urban Economics, 47*, 25-34. *http://dx.doi.org/10.1016/j.regsciurbeco.2013.07.001*

Lautz, J., Dunn, M., Snowden, B., Riggs, A., Horowitz, B., & Schnerre, A. (2018). *2018 National association of REALTORS® profile of home buyers and sellers* (Rep.). Washington, DC: National Association of Realtors. NATIONAL ASSOCIATION OF REALTORS®. All rights reserved. Reprinted with permission.

Miller, N., Spivey, J., & Florance, A. (2008). Does green pay off? *The Journal of Real Estate Portfolio Management, 14*(4), 385-400.

Miller, R., Choate, A., Wong, A., Snow, C., Snyder, J., Jaglom, W., Biggar, S., Schultz, P. (2014). *Useful climate information for Philadelphia: past and future* (pp. 1-28, Rep.). Philadelphia, PA: ICF Incorporated, L.L.C. doi: *https://www.phila.gov/media/20160505145605/Useful-Climate-Science-for-Philadelphia.pdf*

Rogers, E. M. (2005). *Diffusion of Innovations*. New York, NY: Free Press.

Rosen, S. (1974). Hedonic prices and implicit markets: product differentiation in pure competition, *Journal of Political Economy*, *82*, 34-55.

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika, 70*(1), 41. doi:10.2307/2335942

Rubin, D. B. (1973). Matching to remove bias in observational studies. *Biometrics, 29(1)*, 159. Doi:10.2307/2529684

Rubin, D. B. (2001). *Health services and outcomes research methodology, 2*(3/4), 169-188. doi:10.1023/a:1020363010465

Salari, M, & Javid, R. J. (2016). Residential energy demand in the United States: analysis using static and dynamic approaches. *Energy Policy*, *98*, 637-649.

Shewmake, S., & Viscusi, W. K. (2015). Producer and consumer response to green housing labels. *Economic Inquiry, 53*(1), 681-699.

Stuart, E. A. (2010). Matching methods for causal inference: a review and a look forward. *Statistical Science, 25*(1), 1-21. doi:10.1214/09-sts313

Thavaneswaran, A., & Lix, L. (2008). *Propensity score matching in observational studies.* Retrieved from University of Manitoba, Faculty of Health Sciences, Manitoba Centre for Health Policy website: *http://umanitoba.ca/faculties/health_sciences/medicine/units/chs/departmental_units/mchp/protocol/media/propensity_score_matching.pdf*

TREND. (n.d.). TrendMLS. Retrieved from *http://www.trendmls.com/*

TREND. (2018). TrendMLS. "*InfoCenter*" Retrieved from Trend Multiple Listing Service website: *http://www.trendmls.com/InfoCenter/ShowLinkDoc.aspx?linked=86*

TREND. (2018). TrendMLS. "*News*" Retrieved from Trend Multiple Listing Service website: *http://www.trendmls.com/Guest/News/ShowDoc.aspx?id=9218*

TREND. (2018). TrendMLS. Retrieved from *http://www.trendmls.com/Guest/News/ShowDoc.aspx?id=9218#.XAGiT-hKiUk*

TREND. (2018). *Definitions: help topic 11008.* Retrieved from Trend Multiple Listing Service website: *http://www.trendmls.com/Support/11008.htm*

TREND. (2018). *Definitions: help topic 11044.* Retrieved from Trend Multiple Listing Service website: *https://www.trendmls.com/help/4083.htm*

TREND. (2018). *Definitions: help topic 11093.* Retrieved from Trend Multiple Listing Service website: *https://www.trendmls.com/Support/11093_3.htm*

TREND. (2018). *Definitions: help topic 11096.* Retrieved from Trend Multiple Listing Service website: *https://www.trendmls.com/Support/11096_5.htm*

Walls, M., Gerarden, T., Palmer, K., & Bak, X. F. (2017). Is energy efficiency capitalized into home prices? evidence from three U.S. cities. *Journal of Environmental Economics and Management, 82*, 104-124.

Wells, B. (2018). First oil discoveries. Retrieved from The American Oil and Gas Historical Society website: *https://aoghs.org/petroleum-discoveries/*

Zientara, B. (n.d.). 2018 State solar power rankings. Retrieved from Solar Power Rocks a Wave Solar Company website: *https://www.solarpowerrocks.com/2018-state-solar-power-rankings/*