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Building Performance and Energy Star Ratings in Commercial Office Space

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While writing this thesis, I have not witnessed any wrongdoing, nor have I personally violated any conditions of the Skidmore College Honor Code.

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Abstract

Literature surrounding the topic of environmental certification programs has consistently shown that green buildings financially outperform non-green buildings. Financial performance and energy performance go hand-in-hand when studying commercial real estate, as markets are dominated by institutional and private investors seeking the highest financial returns. Financial performance is the single greatest motivator for firms to implement sustainable initiatives as profit generation takes utmost priority. However, many indications suggest that environmental certification programs are simply branding techniques that do not meet expectations for energy performance. This study examines over 783 million ft^2 of office space across four major metropolitan markets to understand greenhouse gas intensity levels as they relate to Energy Star ratings. This study finds that buildings ranked at the highest level by Energy Star underperform those with slightly lower scores, suggesting there is an underlying issue not captured by Energy Star performance measurement. Two main explanations for the results were rating inflation and over consumption of product. The paper argues that the current Energy Star rating system lacks a complete understanding of building performance and highlights the issues that can arise as they relate to financial performance.

1. Introduction

As climate change is making its impact felt around the world, corporations are trying to find ways to improve corporate social responsibility by implementing sustainable business practices. That includes making decisions as to where to physically locate a business that makes the most sense from a social responsibility and financial standpoint. Commercial real estate is an important industry to study due to the global economy's reliance on physical space to conduct business. Moreover, the level of liquitidy and investment involved requires researchers to ensure the market is operating optimally. It is nearly impossible not to interact with some element of commercial real estate on a daily basis. The built environment shapes our cities and can change the way a community operates by way of interactions. Commercial real estate is integral to our daily lives therefore understanding its performance will leave us all better off. Traditional built environment, however, poses a great deal of challenges for climate change. The immense use of raw materials, massive consumption of natural resources including water and natural gas, release of various carbon emissions, waste disposal and light pollution are just a few examples of ways buildings threaten the environment. In 2015, buildings emitted 40% of all greenhouse gasses in the (highest sector in the economy) and used 74% of all electricity produced in the United States, and consumed over 40% of all raw materials globally (Hunter et al, 2018, pg. 97). The industry for environmentally friendly design and upgrades is growing rapidly, projected to increase to over $125 billion globally by 2020. However, in order to meet standards set out in the Paris Climate Accord, it is estimated that $215 billion must be spent on efficiency upgrades by 2020 (Hunter et al. 2018, pg. 98). It is no surprise then that government policy, corporate social responsibility and long-term cost reduction schemes have driven this industry towards a focus on environmental sustainability. To make an impact on overall greenhouse gas emissions of commercial real estate would make enormous contributions to public and environmental well-being.

Over the past decade, corporate responsibility has become a driver for firms who aim to cultivate a positive image and use their influence to create positive change. As tastes and preferences alter value creation over time, investors have been quick to follow suit and incorporate efficient and sustainable practices to benefit their investment strategies. Ultimately, the physical space a company occupies has become ever more important to its image and mission statement. Furthermore, environmentally friendly real estate decisions are used as a way to offset other areas of a business with large carbon footprints. This is especially true regarding oil and mining companies, as they are some of the most likely tenants of environmentally certified buildings (Eichholtz, Kok and Quigley, 2015). These findings should not come as a grand surprise in the sphere of environmental investment. As investors demand more emphasis on corporate social responsibility, stakeholders in the commercial real estate industry are more informed than ever on how to create value through social causes. It is now common to see leading real estate investment firms create entire divisions with sole focus on ways to improve and implement sustainable initiatives within their assets. Providing a product demanded by consumers is the principle priority of any supplier. The emphasis on sustainability injected itself into operating practices across the industry. This study aims to build on the topic of sustainability in commercial real estate and to shed light on the efficacy of major sustainable initiatives, particularly environmental certification programs in order to contribute to the on-going, rapidly growing literature surrounding green building practices. As the single largest contributor of greenhouse gasses by sector, commercial real estate should be studied to ensure its carbon footprint is as low as possible.

An overwhelming amount of academic research ties sustainable real estate with increased financial returns. In a sense, sustainability has become a luxury item as tastes and preferences over the last decade have shifted toward environmental conscientiousness and minimal carbon footprint. These premiums are due to limited supply of green office space combined with an ever growing demand. Consumers' willingness to pay for green features and certification titles has made a significant impact towards firms' risk reduction, tenant satisfaction, asset prices and rent roll. What remains unclear is the effectiveness of certification programs on greenhouse gas emissions and energy consumption. Proponents of environmental certification argue that these programs act as providers of information to consumers to make more informed decisions. However, critics of certification programs have shown that the efficacy of the programs remains unclear, and that highly certified buildings do not significantly outperform non-certified counterparts. Based on a review of the literature, the way in which researchers select data produce differing outcomes on emissions and energy reduction figures. The variety of different ways to measure energy consumption and emissions rates also creates differing results. Furthermore, the type of certification studied also creates differing results, eluding to whether some certifications are more accurate than others. Nonetheless, certifications are impactful in commercial real estate and it is important to understand their efficacy as they relate to greenhouse gas emissions. Understanding these programs in greater detail will support the progress towards a cleaner future.

Understanding the impact of certification programs on building performance is important due to financial benefits associated with green buildings. In a competitive market like commercial office space, differentiators are essential to attracting consumers. It is important to completely understand emissions output to ensure that premium product actually provides optimal performance, otherwise, consumers will be paying for products that do not meet expectations.

This study aims to answer the following questions: How does the level of environmental certification effect greenhouse gas emission intensity in the commercial office buildings? How accurately does Energy Star measure building performance? Are there any explanations for the nature of the relationship between Energy Star and building performance? Building off prior research, this study aims to add to the on-going discussion relating to certification levels and their efficacy in commercial real estate.

2. Literature Review

Real estate economic research has widely agreed that sustainable development is a positive trend beneficial to stakeholders. It is no surprise then that government policy, corporate social responsibility and long-term cost reduction schemes have driven this industry towards a focus on environmental sustainability.

Environmental certification programs are a key tool aimed at reducing information asymmetry for stakeholders. They provide context to help make more informed decisions based on general environmental performance of a particular building. Holtermans and Kok (2017) found that in 2014, 40% of all commercial real estate space in the 30 largest US metropolitan areas achieved some level of environmental certification, compared to 5% in in 2005. It has become evident that over the last two decades, environmental conscientious investment decisions have proved to take hold in the minds of tenants, investors and property managers. Conscientious decision making has speared innovation in construction technology and changed the way investors value sustainable development. When making investment decisions, firms incorporate every cost into their models, including the expected savings from certain technologies. Furthermore, incorporating green features into building designs has become almost standard in new buildings. There is no question that green features are essential in the design and development process to stay competitive in this market.

When discussing efficient building performance in the context of environmental certification, financial performance must be highlighted due to the abundance of liquidity and investment in this industry. As profit generating entities, commercial real estate firms make decisions regarding their assets with a primary focus on the bottom line. Darryl Neate, Director of Sustainability at the Toronto-based pension fund Oxford Properties Group, noted in an interview that the single most important factor when deciding to implement a new sustainable initiative was the financial payoff brought forth to the firm. Whether it be implementing technologies to decrease utility use, developing green common space, or incorporating natural light into design plans, every dollar spent on sustainable initiatives must have a return on equity. With this in mind, financial implications and building performance go hand-in-hand, as the movement towards a sustainable commercial real estate market would not be driven forward without financial viability.

Despite being a relatively recent field of study, financial performance of green buildings has become a popular topic with a specific focus towards a positive outcome on investors, property managers and tenants. Using a proprietary data set from the real estate investment firm Bentall Kennedy, Devine and Kok (2015) used a logarithmic regression model to determine tangible and intangible benefits of green certification. After analyzing rental rates, tenant satisfaction surveys, utilities use and level of green certification, Devine and Kok (2015) found that environmentally certified office buildings experience higher tenant satisfaction, increased probability of lease renewal and decreased tenant rent concessions compared to their non-certified counterparts.[1] With regards to building performance, Devine and Kok (2015) analyzed utility consumption by buildings certified under three different programs. Their findings were somewhat counterintuitive as they found buildings certified by the EPA's Energy Star rating system actually consumed more power than the average non-certified counterpart. Yet these certified buildings achieved a 2.7% premium on rent prices and 9.5% higher occupancy rate. It is important to note that the proprietary data set used in the study does not give a random sample

[1] Concessions are incentives provided to tenants to encourage them to choose a building. They may include free or discounted rent for an agreed amount of time. Concessions are a cost for property owners and/or investors thus reducing them creates value and increases returns.

from the entire market, rather it is a collection of assets determined by Bentall Kennedy's investment strategy. If Bentall Kennedy has a particular interest in green office buildings, their portfolio will reflect those interests. Despite the limitations of the data, the findings suggested that in some cases, certified buildings produced higher overall value despite underperforming in energy consumption.

Fuerst and McAllister (2011) suggest similar findings relating to financial performance. In their study on Energy Star buildings, they found that buildings certified by the EPA achieve a 4% rental premium and a 26% sale price premium. Despite not focusing on efficiency performance, these findings reinforce the notion that high levels of certification correlate with financial benefits. One would naturally assume that the driver of such substantial financial returns would be building performance as it directly relates to its certification level. Combining these findings point towards a claim that suggests highly rated Energy Star buildings are more valuable yet less efficient.

This trend is not only unique to office space as Bond and Devine (2015) showed in their study of over 25,000 LEED certified single and multi-family properties across the United States. Their findings show that LEED certified apartments generally procure a 8.9% premium compared to non-certified counterparts. Despite the differential in asset class and certification program, this study reinforces the theme that green buildings outperform and generate more value than non-green buildings. Unfortunately, no analysis was conducted on energy reduction or greenhouse gas emissions. Similar findings for non-office assets by Freybote, Sun and Yang (2015) studying neighborhood certification and condo prices in Portland, Oregon found that certified condos achieve a 3.8% sale price premium. This is additional evidence in favor of green buildings being stronger investments with greater financial performance. However, Freybote, Sun and Yang (2015) found no correlation between neighborhood certification and condo prices nor any significant results in reducing harmful emissions. This suggests that building certification adds more value to individual buildings rather than entire neighborhoods or areas. Findings on single family and multifamily buildings suggest that not only is sustainability a focal point in the decision making process for large firms finding office space, but also to individuals and families who are prepared to pay a premium on homes that include green features.

It is important to recognize consumer habits when studying environmental certification in commercial real estate to understand demand drivers for these products. Sexton and Sexton

(2014) describe the phenomenon as "conspicuous consumption," after finding results that suggest consumers' were willing to pay a premium for a Toyota Prius as it is a suggestion of environmental conscientiousness. Green certification programs provide information to tenants (consumers) to make such decisions when it comes to office space. In many ways, society relies on awards and certifications to ensure a product or service is credible and/or reliable. For instance, labelling a food product organic serves to inform the consumer that the product has been handled throughout its life cycle without pesticides or other unnatural chemicals. Certifications are an integral aspect of our economy as they serve as the background check that most consumers are incapable of completing. In relation to commercial real estate, most businesses do not have the capabilities to understand building performance thus rely on certifications like Energy Star to inform them. Robinson et al. (2016) build on consumer value for Energy Star certification and analyze consumers' willingness to pay for this product. In their survey of 703 random individuals in office spaces across 17 geographical areas, they found that 58% of respondents considered Energy Star to add value to a building. However, the survey was prominently completed by those without a leadership position, suggesting minimal influence on their firms' decisions to select office space. Nevertheless, this consumption trend highlights that price and quality play important roles in consumer decision making; however personal values and beliefs also make significant impacts. Firms with large amounts of disposable income and individuals with tighter budgets both seem to place high value on efficient buildings. Consumer habits like these develop a further understanding of why environmental certification creates salience in commercial real estate.

As previously mentioned, it would be a logical hypothesis for one to believe that financial benefits are derived from the level of certification achieved by a building. This may be due to the cost reductions associated with lower utility and the augmented value placed on sustainable goods. Eichholtz et al. (2013) investigated the direct correlation between financial and energy performance of buildings to determine the correlation between lower costs and higher rents. The authors found that the energy efficiency of Energy Star certified buildings significantly contributed to rents commanded by landlords as well as transaction prices in the open market. They found that when buildings saved $1 on energy, rent premiums and sale prices increased by 3.5% and 4.9%, respectively. In another words, as energy efficiency increases, financial performance increases. This study, however, does not address a fundamental question associated with their hypothesis: Does the rent and price premium come from the certification level or the reduction in energy? The lack of substantial control group prevents a robust analysis between efficiency and price for non-certified buildings. It seems as though in this study, efficiency provides a premium to rent but without addressing individual building performance and exact rating level relative to non-certified buildings. Despite concerns, this study presents empirical evidence for previously unconfirmed suspicions.

Unlike the general consensus on financial performance of certified buildings, researchers have provided mixed conclusions on the efficacy of certification programs with regard to energy efficiency. Even certain researchers have found contradicting evidence within their own work, which creates uncertainty that needs to be further examined and developed. Newsham et al. (2009) provided an interesting perspective into the clouded nature of this topic. By studying energy use intensity[2] of certified buildings across North America, Newsham et al. (2009) found that on average, certified buildings use 18-39% less energy per floor than their equivalent counterparts. However, their study also concludes that 28-35% of certified buildings actually consume more energy than buildings of equivalent characteristics. This paper was an early indication of the limitations of building performance supposedly highlighted by certification. The wide range of their conclusion, however, creates uncertainty within the result as the sample size only consisted of 100 certified buildings. The lack of robustness in the sample size in conjunction with the age of the study likely produced stale results as access to information and rapid advancements in technology over the past decade could alter the outcome today. Nevertheless, these results disrupt conventional beliefs that certified buildings outperform their counterparts and propose the need for continued research.

More recent research on building performance confirms Newsham et al. (2009) findings, providing further insight in to why some buildings with high certification levels underperform their counterparts. Scofield (2013) used 973 New York City office buildings to examine differences in Energy Star ratings and energy performance of LEED certified and non-certified buildings. Scofield (2013) was the first to examine whether buildings were actually deserving of their Energy Star ratings based on their energy usage and greenhouse gas emissions. As a physicist, Scofield (2013) took an alternative approach to analyzing this issue. He gathered individual buildings' source EUI, representing the total raw fuel used to operate on a per square

[2] Energy Use Intensity (EUI) is a measurement of consumed energy per ft^2. EUI will be revisited later in the study.

foot level, and compared them to their Energy Star ratings. What he found was that buildings at the *Certified* and *Silver* levels of LEED produced relatively higher source EUI and greenhouse gas emissions levels compared to conventional buildings yet maintained a mean Energy Star rating 10-points greater. Though, of the 973 buildings studied, only 21 of them were LEED certified, possibly biasing results as the control sample is minimal. His findings highlight that a handful of large LEED certified buildings had the highest discrepancy and worst performance in comparison to their counterparts. Smaller LEED buildings tended to outperform those with similar characteristics. These findings are in line with Newsham et al. (2009) outlining that only a portion of highly certified buildings experience underperformance. This may occur because large buildings are not managed properly to fully incorporate efficient practices. A building may have certain features that satisfy certification schemes, yet daily operation are not being managed suitably to achieve optimal levels of performance. Despite witnessing only a portion of buildings experience underperformance, the credibility of the Energy Star rating is called into question. The subgroup of underperformers should have an Energy Star rating reflective of their performance.

These differences in Energy Star scores have consequences with regards to financial performance as previously stated. Buildings with LEED certification and high Energy Star ratings will achieve greater returns in the name of efficiency, despite using more energy and producing greater levels of greenhouse gasses. The results of financial performance and energy performance with regard to certification programs are inconsistent with one another providing the need to further study emissions levels and Energy Star ratings. This is an early indications of a market inefficiency that can affect the returns achieved throughout the marketplace.

Despite evidence that supports the claim that highly rated buildings use more energy and emit higher levels of greenhouse gases, there is ample evidence to suggest certification programs provide major benefits to public health as a result of their cumulative performance. Multiple public health articles examine the benefits of improved air quality associated with the reduction of air pollutants released by the burning of fossil fuels on site. Through a study on the exposure to carbon dioxide and volatile organic compounds, Allen et al. (2016) found that the tenants of green certified office buildings scored higher on cognitive tests and experienced higher productivity due to improvements in ventilation and air quality. However, survey data can be limited in quality as tenants with large amount of disposable income tend to locate in green buildings. Large amounts of disposable income would allow firms to provide competitive wages and hire more productive employees with higher rates of education. Therefore, cognitive tests in survey form could be subject to non-random sampling as those surveyed in green buildings would likely score higher on cognitive tests regardless of the building they are located in. However, Colton et al. (2015) found complementary results with their study on asthma morbidity and building-related symptoms. They confirmed that green public housing developments experienced fewer asthma related symptoms and overall sick building symptoms. These findings are hopeful for certification programs as a whole. Though a portion of certified buildings underperform their expectations, cumulatively, certification programs provide a net benefit to public health.

A recent study conducted by researchers at Harvard's T.H. Chan School of Public Health aimed to quantify these cumulative effects. Studying over 335 million m^2 of LEED certified buildings between 2000-2016, they were able to determine the economic value and public health benefits derived from a large collection of certified buildings. They aimed to study carbon emissions such as particulate matter, sulfur dioxide and nitrogen oxides – chemicals commonly known to be released from the burning of fossil fuels. Predominantly, the study focused on the health co-benefits associated with efficient design and were able to quantify the results through the EPA's Social Cost of Carbon (SCC). They found that in the United States, LEED certified buildings amassed $1.28 billion in climate-related benefits and $2.68 billion in direct health benefits from the reduction of air pollutants (MacNaughton et al., 2018). Researchers were also able to use their findings on air pollutant reductions to estimate that the overall benefits of LEED certified buildings in the US has come in the form of 288 averted premature deaths, 171 hospital admissions, 11,000 asthma hospitalizations, 54,000 respiratory symptoms, 21,000 lost days of work and 16,000 lost days of school. These findings are extremely important to the study of environmental construction and design because they are the first to directly correlate and quantify greenhouse gas reduction as economic variables and measurements. One critique, however, is the fact that these researchers focused on total buildings already certified while not focusing on the individual breakdown of change in emissions with a change in certification level. Nonetheless, it is an important addition to the literature as it is the first of its kind to quantify certification benefits on a major scale.

Results from past literature involving the underperformance of highly rated buildings clouds the general consensus on the benefit of certification. Copiello (2016) attempted to provide theoretical insights and context to these results in his paper on efficient building markets. His primary argument stems from the work of late nineteenth-century economist William Stanley Jevons. Copiello (2016) applied Jevons' paradox to the sustainability trend in commercial real estate. Jevons' paradox suggests that reductions in energy consumption due to technological advancements and manufacturing techniques would create a countertrend. As energy consumption decreases due to do efficient practices, economic actors would be motivated to consume more, ultimately counteracting original energy savings. Applied to the commercial real estate industry, Copiello (2016) argues that the chase for self-sufficient buildings counteracts previous reductions in energy consumption as marginal costs begin to outweigh marginal benefits at a certain threshold. The non-linear models in his study show that as the efficiency of a building improves so too does energy consumption, however, a rebound effect occurs and energy consumption increases beyond the optimal point. This work can be used to explain the counterintuitive findings between financial performance and energy performance. As a building increases its efficiency, its consumption also increases. This could come in the form of higher density and occupancy as well as longer hours of operation, thus increasing its overall energy needs. The economic theory used in Copiello's study provides an explanation to these findings, however, more empirical research must be conducted to unearth the drivers behind this trend and assess the magnitude of the issue.

To summarize, we understand that environmental certification programs are intended to reduce information asymmetry in commercial real estate by providing third-party due diligence and making information publicly understandable. Environmentally certified buildings achieve significant financial benefits including rent and asset price premium, higher occupancy rates, higher levels of tenant satisfaction, and increased likelihood of rent renewal. These rewards are important to investors as they aspire to achieve the highest returns possible. However, many studies how found that Energy Star ratings do not accurately represent emissions release and energy requirements. This is a suggestion that there are potential issues within Energy Star that might be uncovered by way of further analysis.

This study aims to build on the relationship between Energy Star ratings and greenhouse gas emission intensity at the building level in order to provide more insight into the suspicious trend seen in the literature. It incorporates aspects from Newsham et al. (2009), Scofield (2013) and MacNaughton et al. (2018) to assess greenhouse gas emissions as they relate to Energy Star. Furthermore, this study applies Jevons' paradox to attempt to further understand consumption habits in commercial real estate office space and their implications on financial rewards.

2.1 Energy Star Rating System

Developed by the Environmental Protection Agency (EPA) in 1992, the Energy Star rating system was the first voluntary certification program offered to promote energy efficiency and reduce greenhouse gas emissions. As a government-backed program, Energy Star is intended to be a non-biased way to nationally benchmark energy performance. Using a sophisticated benchmarking system, Energy Star accounts for a variety of differing factors such as size, occupancy and density to provide a clear efficiency score across the country particular to each asset class. Moreover, it is the industry leader in certification, as 40% of all commercial building space in the US uses Energy Star benchmarking systems to reduce information asymmetry and promote sustainable building design. As local by-laws have been introduced across metropolitans, data availability has increased substantially. Access to emissions reports and extensive data has allowed researchers to further their comprehension on this topic.

Energy Star uses an important metric called Energy Use Intensity (EUI). EUI is expressed as energy use per square foot. This value is important because it creates an energy benchmark at the per square foot level, allowing for buildings to be cross-compared despite size. EUI is associated in the measurement of total water, electricity, natural gas use as well as total greenhouse gas emissions in a set year. The decision to focus on Energy Star rating was due to the fact it is a fluid and specific variable ranked from 1-100 and re-administered yearly in order to maintain relevance to a given year.

3. Methods

The data employed in this study was a cross-section taken from public benchmarking reports for the year 2017 from New York City, Seattle, Boston, and Chicago. As early as 2009, local initiatives in all four cities have made it mandatory for commercial real estate owners to report on building characteristics and energy usage through the EPA's online Energy Star reporting system (EPA, 2019). Policy has made it possible to gather and analyze data in a uniform fashion.

The selected metropolitan cities were chosen because each resides in the northern half of the United States providing similar climate conditions. Similarities in geography help reduce bias that can be associated with warmer climates thus improving the accuracy of the study. The sample used in the regression analysis consists of 2,012 office buildings across these cities with a gross square footage of over 783 million ft^2 and an average building floorplan of 297,624 ft^2. Originally, 145 additional buildings were studied although due to the absence of reported total greenhouse gas emissions required them to be omitted. Office buildings were chosen to be the focal sample in this study because they are the single largest asset class (by asset value) and most active principle building activity with green certification (Scofield, 2009) (NCREIF, 2018). Furthermore, office buildings are the only asset class that firms view as a statement of their image. This is important to highlight because it helps understand motivations for locating in particular buildings.

The dependent variable in this study is *GHGIntensity* as it relates to $ENERGYSTAR_i$. *GHGIntensity* is a measure of the amount of greenhouse gasses emitted by the i^{th} building divided by its total square footage ($kgCO_2e/ft^2$). A similar study on the efficacy of LEED-certified office buildings in New York City emphasised the relevance of greenhouse gas intensity as a measurement of individual building performance as it relates to energy efficiency (Scofield, 2013). This is the dependent variable of the study because it is the overall representation of greenhouse gas emissions from a building, that can be studied in a regression to determine in what way it changes with respect to $ENERGYSTAR_i$. It is quantifiable and allows for a more accurate comparison across buildings as it baselines emissions output on a per square foot basis, preventing distortion that could potentially arise due to differences in building size. Furthermore, *GHGIntensity* can be used in post-regression analysis to determine economic impact using the Social Cost of Carbon calculator and provide policy recommendations.

The independent variable of interest in this study is $ENERGYSTAR_i$. The goal is to uncover how $ENERGYSTAR_i$ interacts with *GHGIntensity*. $ENERGYSTAR_i$ represents the Energy Star rating given to the i^{th} building in the data set ranging from 1-100. The wide range of the scores allows for a more comprehensive analysis of the relationship between the two variables. Energy Star ratings were used as a comparable measurement for overall building performance in a comparative study on large green-certified New York City office buildings and their non-green counterparts (Scofield, 2013). The interesting aspect of using Energy Star rating as an independent variable is that the process the EPA uses to determine each building's score factors in characteristics such as size and age of building. It is true that older and larger buildings will produce higher greenhouse gas emission levels due to outdated construction methods, however, the EPA has taken steps to benchmark those factors in the development of their rating system. Therefore our model has withheld size and age as control variables to prevent confounding variable bias from occurring. Furthermore, withholding these variables will provide more insight into Energy Star's accuracy. If all performance factors are considered in the Energy Star rating, then age and size should be accounted for and reflected in each unique rating.

A key control variable incorporated in the study is $lnSourceEUI_i$ which represents the i^{th} building's total energy consumed on a per square foot basis ($kBtu/ft^2$) which naturally controls for the variation of size of each building in the data set. Source EUI, or source energy use intensity, is considered by the EPA to be the most accurate determinant of a building's total energy usage. It represents the total amount of raw fuel required to operate a building, controlling for size differences. Using EUI as a control variable has been used in various studies in order to create a baseline energy measurement for conventional buildings as they compare to LEED certified buildings in a panel data study (Scofield, 2009) (Scofield, 2013) (MacNaughton et al., 2018). Some studies have used site EUI to represent energy consumption, however, this measurement does not completely capture total energy (Newsham et al., 2009). Similarly, Devine and Kok (2015) used source EUI to control for power consumption in their analysis of building utility consumption of environmentally certified buildings in Canada and the United States. Due to the fluidity of the $ENERGYSTAR_i$ variable, $SourceEUI_i$ was used rather than a baseline EUI because it was intended to control for each individual building's energy consumption rather than the general market energy consumption. Using $lnSourceEUI_i$ as a control variable in this study was important because it is a key component that explains the dependent variable *GHGIntensity* due to the natural outcome on emissions that result from the increase or decrease in energy consumed.

The three other control variables used in this study are $lnNatGasPC_n$, $lnPetroPC_n$, $lnCoalPC_n$. Each of these control variables represent the three main types of fuels used to generate electricity in a given state, benchmarked at a per capita level to allow for unbiased cross-comparison related to differences in population. Values on fuel type involved in electricity generation in New York State, Illinois, Washington, and Massachusetts were taken from the US

Energy Information Administration website for the year 2017 (US EIA, 2019). The first represents millions of ft^3 of natural gas consumed per capita of the n^{th} state where the i^{th} building resides. The second represents thousands of barrels of petroleum used per capita of the n^{th} state where the i^{th} building resides. The third represents thousands of tons of coal per capita in the n^{th} state where the i^{th} building resides. State populations for the year 2017 were used to create a per capita metric, allowing for comparison between states without suffering bias from differences in overall population. A larger population would create greater demand for energy resulting in increased greenhouse gas emissions and energy consumption. The decision to use the variable in ln form was to avoid distortion of final results due to the magnitude of the values. This study aims to focus on ratings as they relate to performance therefor it is necessary to baseline this figure to per capita values. Moreover, across each state, the types of fuels used in the production of electricity varies due to factors like policy implementation, government spending, infrastructure, access to fuel sources, and overall demand for electricity. Past literature has also taken this approach when controlling for greenhouse gas emissions. MacNaughton et al., (2018) used a similar strategy by subdividing national power grids to achieve regional reductions in electricity and air pollutants allowing them to calculate mass of greenhouse gases emitted per amount of fuel burned in each region. The intent in using types of fossil fuels for electricity generation is to provide more clarity to explain *GHGIntensity* across different geographical areas. Analyzing particulate matter release by each fossil fuel shows differences in quantity and quality of air pollutants emitted into the atmosphere (MacNaughton et al., 2018). Two buildings that are entirely identical yet reside in different geographical areas may experience differing greenhouse gas intensity levels due to differentiation in the production of electricity at its source. Each of these variables are necessary to the study because they act as control variables for the 'cleanliness' of a given state's power grid. For instance, this allows us to compare buildings that operate on a predominantly coal based power grid in Chicago versus a natural gas based grid in Massachusetts.

A factor that must be addressed when cross comparing cities on greenhouse gas emissions is income level. Higher income cities tend emit more greenhouse gasses than lower income cities because geographical areas with high income levels tend to consume more, thus produce higher greenhouse gas emissions (Girod and De Haan, 2010). However, due to the fact that this study solely focuses on office buildings where firms tend to be consumers rather than individuals, income level has been withheld as a control variable. Variation among firm expenditure on office energy in each city would be low and would not provide significant variability in the model.

4. Discussion

Three non-linear functions were used in this study, each with a varying fuel type acting as a unique control variable. Rather than running all variables in the same model, separating the fuel type control variables allows for a more comprehensive analysis on the relationship between $ENERGYSTAR_i$ and *GHGIntensity* with respect to the differences in power grid cleanliness. A quadratic model was determined best suitable to accurately define the *GHGIntensity* variable.

The following three regressions were used in this study to determine the relationship between *GHGIntensity* and $ENERGYSTAR_i$:

(1) $$(GHGIntensity_i) = \beta_0 + \beta_1 energystar_i + \beta_2 energystar_i{}^2 + \beta_3 \ln(SourceEUI)_i + \beta_4 \ln(NatGasPC_n) + \varepsilon_i$$

(2) $$(GHGIntensity_i) = \beta_0 + \beta_1 energystar_i + \beta_2 energystar_i{}^2 + \beta_3 \ln(SourceEUI)_i + \beta_4 \ln(PetroPC_n) + \varepsilon_i$$

(3) $$(GHGIntensity_i) = \beta_0 + \beta_1 energystar_i + \beta_2 energystar_i{}^2 + \beta_3 \ln(SourceEUI)_i + \beta_4 ln(CoalPC_n) + \varepsilon_i$$

Preliminary hypotheses of β_1 is thought to be negative, meaning *GHGIntensity* and $ENERGYSTAR_i$ experience a negative linear relationship. Estimates for β_2 are expected to be positive, creating a upward opening parabola. Understanding where the inflexion point occurs will be essential to the discussion of results. This hypothesis is derived from past research concluding that achieving a higher environmental certification level decreases greenhouse gas emissions and intensity. Many researchers have found a negative correlation with greenhouse gas emissions and environmental certification programs thus a general negative relationship is a logical estimate (MacNaughton et al., 2018) (Newsham et al, 2009). In relation to previous studies, the relationship is estimated to be non-linear, opening upward.

The estimated values of β_3 are expected to be lowest in equation (1) when controlling for natural gas, followed by petroleum in equation (2) and coal in equation (3). All β_3 estimates are expected to hold positive values. These estimates are due to the fact that while controlling for natural gas use, greenhouse gas emissions release after an increase in source EUI would be least drastic as natural gas is a cleaner alternative to petroleum and coal. Petroleum follows because it ranks second in terms of its harmful environmental release. Coal is expected to be greatest due to the fact it is considered to be the dirtiest power source, thus having the largest impact of *GHGIntensity* after its consumption (MacNaughton et al. 2018). These estimates, however, are not completely indicative of the relationship as *GHGIntensity* is a presented as a function of $ENERGYSTAR_i^2$.

With regards to β_4 in equation (1), it is estimated that the value will be lowest and will be least impactful on *GHGIntensity* for reasons stated earlier on cleanliness of the fossil fuel. In equation (2), it is estimated that β_4 will be positive and have a marginally larger effect on *GHGIntensity*. In equation (3), β_4 is expected to have the largest positive impact on *GHGIntensity* due to the magnitude of greenhouse gas emissions released by coal when burned.

Following the results of the regression models, $\hat{Y}$ as a function of $ENERGYSTAR_i$ was graphically represented to analyze the quadratic relationship in each case. This function is used to estimate *GHGIntensity* as a function of $ENERGYSTAR_i^2$. The following equation was used to graph the estimate for *GHGIntensity*:

$$(4) \qquad \hat{Y} = b_o + b_1 energystar_i + b_2 energystar_i{}^2$$

4.1 Discussion of Results

Table 1 of the Appendix lists the results of the non-linear regressions after correcting for heteroscedasticity. Results of the relationship between $lnSourceEUI_i$ were as expected, as the effect on *GHGIntensity* is lowest when controlling for natural gas use at 2.922, followed by petroleum at 3.682 and coal at 4.819. Natural gas is considered to be a cleaner fossil fuel as it releases less particulate matter and GHG emissions when burned thus producing the lowest effect on *GHGIntensity.* As coal is considered to be the 'dirtiest' fossil fuel in the study, it is logical that is has the greatest effect of *GHGIntensity.* This is due to the fact that increasing the amount of energy required to operate a particular building in a coal based power grid will cause the greatest change in GHG emissions and intensity. All three results for $lnSourceEUI_i$ are statistically significant at the 1% level. The results from the control variables of fuel types were as expected for two of the three estimates.

In equation (1), $lnNatGasPC_n$ holds a value of -3.056 having the most negative influence on *GHGIntensity*. The variable $lnPetroPC_n$ generated a positive value of 0.860 as expected due to its more harmful nature. However, $lnCoalPC_n$ generated a value of -0.556, meaning an increase in a particular state's use of coal per capita to produce electricity would decrease *GHGIntensity*. This unexpected results could be due to the fact that the state of Massachusetts uses very minimal coal in their production of electricity, potentially withholding its complete effect in the model. However, despite the unexpected result, the value remains small. All β_4 values are statistically significant at the 1% level.

Table 2 presents results from the variance inflation factor check that ensures no multicollinearity was present in the model. VIF checks are important to this study due to the fact that multiple variables relating to emissions and energy consumption are present in the model. VIF checks quantify the magnitude of multicollinearity to ensure no variables interact with one another. In each model, mean VIF remains under the threshold of 5 therefor no multicollinearity was present between variables.

Figure 1 presents the graphical relationship between *GHGIntensity* as a function of $ENERGYSTAR_i^{\,2}$ while controlling for $lnNatGasPC_n$. The mean Energy Star rating in the data set of 72.5 is represented by the red line in Figure 1, Figure 2, and Figure 3. The blue line represents the point of inflexion at 86.4. It can be concluded that as Energy Star increases, GHG intensity decreases until achieving a score of 87 (Energy Star ratings cannot be given in decimal points) and begins to increase slightly as ratings approach 100. Despite the increase as Energy Star approaches 100, the graph is a predominantly negative trend. This suggests that those with low ratings can achieve a much greater magnitude of decline compared to those with higher ratings. Relative greenhouse gas reduction for the top rated buildings are more difficult to achieve than for those with lower scores. Furthermore, the findings suggests that it is only possible to reduce greenhouse gas emissions to a certain extent. Emissions eventually plateau and reductions are more difficult to come by.

Figure 2 presents a similar relationship while controlling for $lnPetroPC_n$, however, experiences a more drastic increase upon surpassing its inflexion point of 74.3. In this case, the increase in Energy Star rating decreases expected GHG intensity levels and provides social benefits until achieving a score of 75. Between the ratings of 75 and 100, GHG intensity levels are expected to rise. The trend seen when controlling for petroleum use is a greater increase than that of natural gas.

Figure 3 is the graphical representation of *GHGIntensity* as a function of $ENERGYSTAR_i^2$ while controlling for $lnCoalPC_n$. Figure 3 shows the inflexion point to be at 67.2, the only inflexion point that resides below the mean Energy Star rating in the data set. The results suggest that there are social benefits of achieving a higher Energy Star rating until reaching the score of 68 when the primary fuel source for electricity is coal. Between the score 68 and 100, greenhouse gas intensity levels begin to rise, similar to the estimates found in the two previous figures. This relationship experiences the most drastic increase in greenhouse gas intensity beyond its inflexion point. The result falls in line with original estimates, confirming that coal use has the greatest impact on emissions release.

Each graph is subjected to negative constant values which is why the values on the y-axis are negative. This is the result of using an estimated quadratic function to model the relationship. In reality, greenhouse gas intensity cannot have negative values. For the purpose of this study, we analyze the shape and relationship of the line rather than the estimated values.

The findings shown in each graph present similar results as each line maintains a generally similar shape. The inflexion points in each graph present the most interesting results that can provide more context into the validity of the algorithm used in the EPA's ranking of building performance. Logically, one would assume that properties ranked between 80 and 100 would achieve the highest building performance as Energy Star rating is an evaluation of greenhouse gas emissions and overall energy efficiency. However, these findings suggest that buildings with the highest rankings do not experience reductions in greenhouse gas intensity nor overall emissions levels as formerly expected. These results beg the questions: is the EPA's ranking system for buildings somehow flawed? Do environmental certification programs provide an adequate representation of energy efficiency? How do these findings influence tangible and intangible characteristics at the firm level?

Findings like these are not exclusive to this study as Scofield (2013) found that in his research on certified office space in New York. LEED *Certified* and *Silver* status buildings actually consumed more source energy (higher source EUI) and experienced relatively higher greenhouse gas emissions when compared to non-LEED certified office buildings of similar characteristics. Scofield's most similar finding was that LEED-buildings experienced an average Energy Star rating 10 points higher than non-LEED certified buildings (Scofield, 2013). The results found in this study mimic those found by Scofield (2013) as buildings with higher Energy Star ratings emit more greenhouse gasses and consume more energy.

Key assumptions regarding the backbone of the Energy Star rating need to be assessed to further understand how and why a certain ranking is given to a building. Primarily, the median score for all US buildings is thought to be 50 as Energy Star acts as a national benchmarking scheme. This means unique building ratings are derived from national comparison within each asset class rather than simple criteria met. However, no study reviewed in this research paper possessed a data set with a median Energy Star rating of 50. The sample used in this study showed to have a median score of 79 and a mean score of 72.5, significantly higher than 50. The first explanation for the differing median scores is that office buildings in Boston, New York City, Seattle, and Chicago are some of the most efficient office markets nationally. This would be statistically improbable as the sample size was large and geographically separated. The second explanation is that the method the EPA uses in calculating Energy Star is experiencing some sort of score inflation (Scofield, 2013). As Energy Star is a comparative measurement from historical performance given yearly, the advancements in efficiency could outpace the accuracy of its measurement system. Ratings are a reflection of improvements in past performance compared to national averages. If technology is improving rapidly across the sector, then most buildings will outperform their historical levels. It will seem as though great improvements were met resulting in higher individual scores that inflate ratings across the industry. Rating inflation is likely an issue only a portion of buildings experience that skew median results. Generally, green certified buildings have had exceptional effects on greenhouse gas reduction and public health improvements (Colton et al., 2015) (Allen et al., 2016) (MacNaughton et al., 2018). I cannot conclude what portion of buildings experience rating inflation, however, based on Newsham et al. (2009) estimates, roughly one third of highly rated buildings underperform their counterparts. Nonetheless, rating inflation poses a threat to the credibility and accuracy of the EPA's rating system.

An alternative lens to explain the results is to look into the uses and consumption habits for highly rated buildings. A possible justification for underperformance is that buildings ranked between 80-100 are more productive than those with lower scores. This means they could have higher occupancy density (number of occupants per ft^2), higher number of personal computers drawing greater levels of energy, or operate longer hours requiring more energy to continue normal operations (Scofield, 2013). In the age of rapid technological advancement, particularly in the construction industry, new commercial buildings require more source energy to meet demand required for the use of new technologies. This framework strongly relates to that of Copiello (2016) and his work with Jevons' paradox. As this industry becomes more efficient and incorporates new technologies to buildings, demand for these new products increases. As seen in Exhibit A of the Appendix, Copiello's results show a strikingly similar relationship to that of this study. When buildings become more efficient, energy requirements and costs decrease until an inflexion point and begin to rebound. Buildings ranked at the top of the spectrum for Energy Star become sought after due to various consumption drivers like conspicuous consumption, corporate social responsibility, and cost-savings schemes as shown by individuals' willingness to pay for green products (Robinson et al., 2016). Due to these tastes and preferences, demand for that space begins to increase along with consumption, overall energy use and GHG intensity. Essentially, buildings that achieve high performance and high ratings are overburdened by increases in consumption, creating a rebound effect and nullifying previous energy reductions.

Technological innovations in newly designed and constructed buildings have also been a duel edge sword. For the most part, technology has proven to provide ample benefits to sustainability through advancement in diesel generators, HVAC systems and LED lighting. However, technology has also been problematic in the sense that in some instances, it does not perform to the standard it was originally intended to meet (Scofield, 2013). For example, a diesel power generator that provides site energy to the building can be expected to operate at an efficient level throughout the day. However, if certain times of day are more demanding than others, the generator will experience inefficient fuel consumption and atmospheric release. The generator may be considered to be a sustainable product in the eyes of certification schemes, however, if it is not used properly it will not deliver the results that are expected. On the other hand, sustainable technologies can be entirely new sources of energy or utility consumption. For example, installing electric car power stations in the parking lot of a building becomes a burden that otherwise would not exist. Despite the fresh power pull, popular opinion would agree electric car power stations have a net benefit to the environment. The rebound effect of greenhouse gas intensity at the highest rated Energy Star buildings could be due to inefficient uses of otherwise sustainable technologies and nominal increase in overall power dependent features. Upon inspection by certification programs, it may seem as though initiatives were in place to achieve a higher rating, however, in actual practice the buildings underperform and release higher levels of greenhouse gasses.

The implication of these results as they relate to the broader commercial real estate market point to a market inefficiency. A consensus on this topic is that environmental certified real estate assets experience a variety of different tangible and intangible benefits that pertain to overall asset performance. Whether it be rent and asset price premiums, tenant satisfaction, or reduction of risk in rent roll, environmental certifications bring financially rewarding outcomes that should be paid attention to (Eichholtz, et al., 2013) (Devine and Kok, 2015) (Freybote, Sun and Yang, 2015) (Robinson, et al., 2016). The first reason why there is market inefficiency is due to disproportionate monetary rewards from rent and asset price premiums being earned by those underserving of them. Consumers (tenants) are paying premiums for a product they deem to be of higher value, yet in reality, energy consumption and emissions levels are non-optimal. This is a confusing and unexpected outcome that tenants face, which leads to the second reason for market inefficiency. Certification programs pose as a threat to free and complete information within the market as there is clear distortion in performance results. A main argument for certification programs was to reduce information asymmetry, however, results show that the standard assumption on energy performance and rating level has been disproven to an extent. Sustainable initiatives implemented by property managers and owners require significant financial analysis to determine whether it is viable. Without complete information, tenants, investors, and property managers will have less ability to make informed decisions when it comes to commercial office space. Furthermore, the lack of complete information clouds the understanding of the effects of the built environment on pollution and energy consumption. The increases in greenhouse gas intensity as shown in Figures 1, 2 and 3 are indications that the commercial real estate industry is not performing optimally. When controlling for coal use in a power grid, buildings at the top tier experience the worst underperformance, confirming that coal emits the most harmful air pollutants and particulate matter. While the industry is taking strong steps towards reducing its environmental impact, more information must be obtained to reach its full potential. It is clear that Energy Star rating does not provide a complete summary of a building's overall performance, merely an aesthetic that reduces credibility of the EPA and other certification programs.

Admittedly, the results of this research come with limitations that can be improved upon in future studies. Data limitations from public benchmarking reports are such that individual property managers are responsible for self-reporting, posing a problem that can arise from human error in data reports. Furthermore, the method of controlling for differences in power grids could be narrowed down to a more accurate measurement. Data collection on city power grids is limited, therefor state power grids were used a proxy source energy cleanliness. Furthermore, population figures used were also based on the entire state rather than specific city. To narrow down population and electricity production measurements would provide a clearer picture of this relationship. Controls for age, size and density were purposely omitted in this study as Energy Star rating is supposed to take into account these factors in their rating. Including such variables could uncover more distinct flaws of the EPA's methods and build a more comprehensive solution moving forward. Another limitation of the study is the negative constant values used to graph the each non-linear relationship. In reality, greenhouse gas emissions levels cannot be negative, therefor the estimates of the line cannot be taken at face value. A problem with regression analysis is likely the cause of this issue.

5. Summary and Conclusion

Public energy benchmarking data from Boston, New York City, Chicago and Seattle office buildings for the year 2017 has shown us the relationship between the EPA's Energy Star rating system and greenhouse gas intensity levels. The results of this study conclude that an increase in Energy Star rating decreases greenhouse gas intensity levels. However, top rated buildings perform sub-optimally compared to those with slightly lower scores, proposing an issue with the EPA's methodology when collecting data and providing rankings. Buildings performing at optimal levels achieve scores between 67 and 85. Beyond those scores in either direction, greenhouse gas intensity increases. As a measurement of performance, Energy Star is intended to improve information for stakeholders in the US commercial real estate industry, however, falls short of doing so as expectations do not meet reality. Consumers are being subjected to financial premiums for products that do not match up to their marketability. This is an issue for the commercial real estate market as it creates market inefficiencies, limiting the industry from performing at its optimal level.

The results presented in this study are likely the outcome of two main issues: rating inflation and over consumption of sustainable office space. Rating inflation is derived from rapid advancements in technology along with stale data that over praises reduction efforts, creating an illusion of significant energy reduction. In combination with past findings, this study showed that Energy Star does not accurately represent sustainability. In order to alleviate this issue, the EPA must use the most recent data results of emissions levels to continuously account for industry wide improvements as well as individual ones. Utilizing their resources, the EPA should be able to more accurately compare asset classes across the industry, without compromising the validity of their rating system. An essential next step on this issue is a deeper look into the median levels of Energy Star ratings nationwide in order to understand the distribution of scores. Incorporating more data by adding additional cities into the study will produce a more accurate result. It will be interesting to see what the median levels of Energy Star ratings are when a larger data set is used. This is key to their methodology in order to maintain national benchmarking standards. These results may be most troubling to those concerned about a sustainable future because financial rewards are being allocated to those with more harmful emissions releases. This is likely not an issue for the entire market, simply a subset of buildings that alter the final outcome. Nonetheless, certifications must be an accurate representation of the performance in order to maintain credibility and reliability for those incapable of investigating themselves. If a portion of buildings achieve overly inflated scores, then the program essentially becomes a marketing gimmick because it no longer provides accurate, industry wide benchmarking. Despite the nature of the rebound effect at the highest level, the general trend shows a significant decrease in greenhouse gas intensity as Energy Star rating increases. If the problem is not alleviated, then financial rewards will continue to be achieved by those who are underperforming. Firm motivation as it relates to sustainability is driven by the bottom line, therefor financial performance and energy performance must resemble one another to optimize the market. It is of utmost importance that industry regulators pay attention to reoccurring literature showing inefficiencies in Energy Star ratings in order to implement practices that accurately define a building’s performance.

In contrast, over consumption of office space could be a burden on the performance of a building. When applied to commercial real estate, Jevons’ paradox acts as an explanation of why the most highly rated buildings underperform. Tastes and preferences have altered consumers habits toward conspicuous consumption, creating an ever growing demand for green office space to satisfy corporate social responsibility initiatives. A few examples of consequences from high demand are greater levels of occupancy, greater number of personal computers drawing power, more water and utility utilization, and longer hours of operation. As buildings aim to be as sustainable as possible while attracting the most business, the sheer volume of inhabitants within a building offset previous steps taken to reduce greenhouse gases. Over consumption of office space, however, must be recognized when assessing a building's performance. In order to alleviate the stresses placed on buildings under high demand, owners and operators must understand the way in which their building functions and execute that strategy on a daily basis.

To understand how and why Jevons' paradox is possibly occurring in the commercial office market, we could limit the range of observations to only those in the top half of Energy Star ratings. By doing so, we would be able to further dissect productivity and density rates to capture a measurement of consumption. Analyzing different features such as number of personal computers or electric car power stations could unveil their impact on overall building performance. However, data collection for such an undertaking would require immense amounts of time since large office buildings have many different facets of sustainability.

Refining the regression model used in this study to obtain positive estimations of greenhouse gas intensity would be valuable moving forward. Being able to estimate a building's greenhouse gas intensity levels would allow for the use of Social Cost of Carbon calculator to put a price on how efficient a building operates. Furthermore, using Harvard's Co-benefits of the Built Environment calculator would also become possible. We would be able to quantify the differences between quartiles of Energy Star ratings as they relate to public health and economic value. Using a similar method that MacNaughton et al. (2018) incorporated in their study on public health, it would be possible to price on the improvements in Energy Star rating.

Reductions in commercial real estate greenhouse gases emissions must be a priority for the industry and for government regulators. The built environment remains one of the single largest contributors to air pollution, raw material and electricity consumption in the United States. Despite the current administration's skepticism on climate change, consumers of office space have a growing emphasis on sustainability due to financial bonuses that come with it. United States' real estate practices must remain at the forefront of the industry and continue making progress towards achieving a sustainable future. It will be important to see if the results of this study can be duplicated when analyzing different markets.

Appendix

Table 1: Regression Model Results of *ENERGYSTAR*$_i$ on *GHGIntensity*

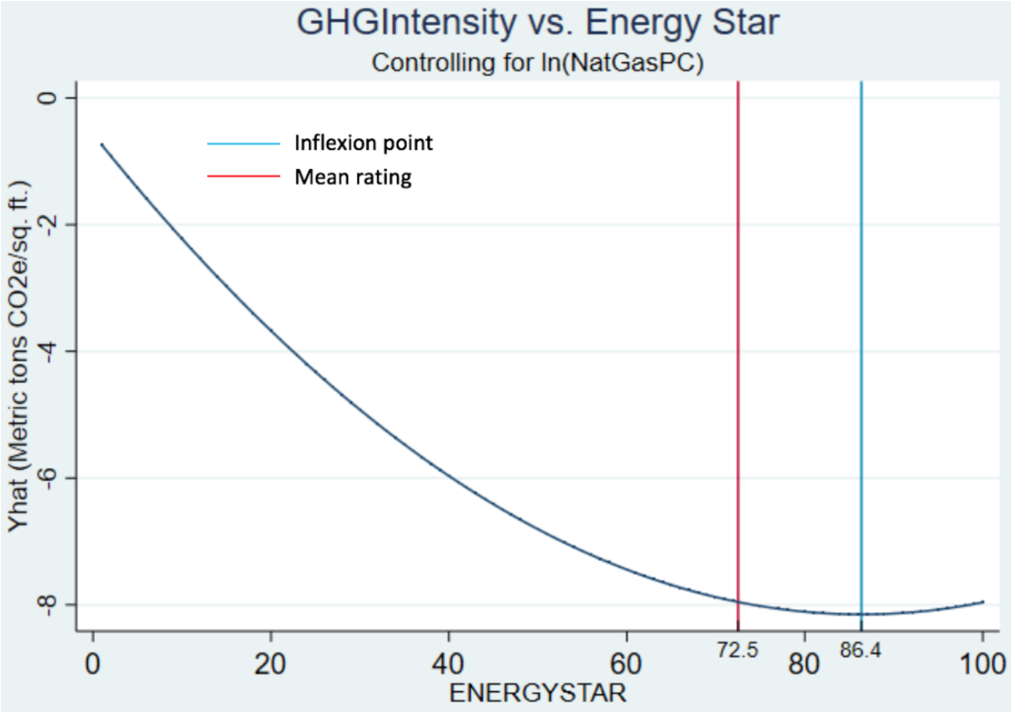
	Model (1)	**Model (2)**	**Model (3)**
Dep var *GHGIntensity*			
ENERGYSTAR	-0.176*** (0.048)	-0.189*** (0.046)	-0.171*** (0.046)
ENERGYSTAR2	0.001** (0.000)	0.001*** (0.000)	0.001*** (0.000)
lnSourceEUI	2.922*** (0.657)	3.682*** (0.626)	4.819*** (0.883)
lnNatGasPC	-3.056*** (0.918)		
lnPetroPC		0.860*** (0.057)	
lnCoalPC			-0.556*** (0.077)
Constant	-0.568 (3.260)	-1.886 (2.865)	-16.011*** (4.965)
Observations	2,012	2,012	2,012
R-squared	31.2%	40.7%	36.7%

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: VIF Test for Heteroscedasticity

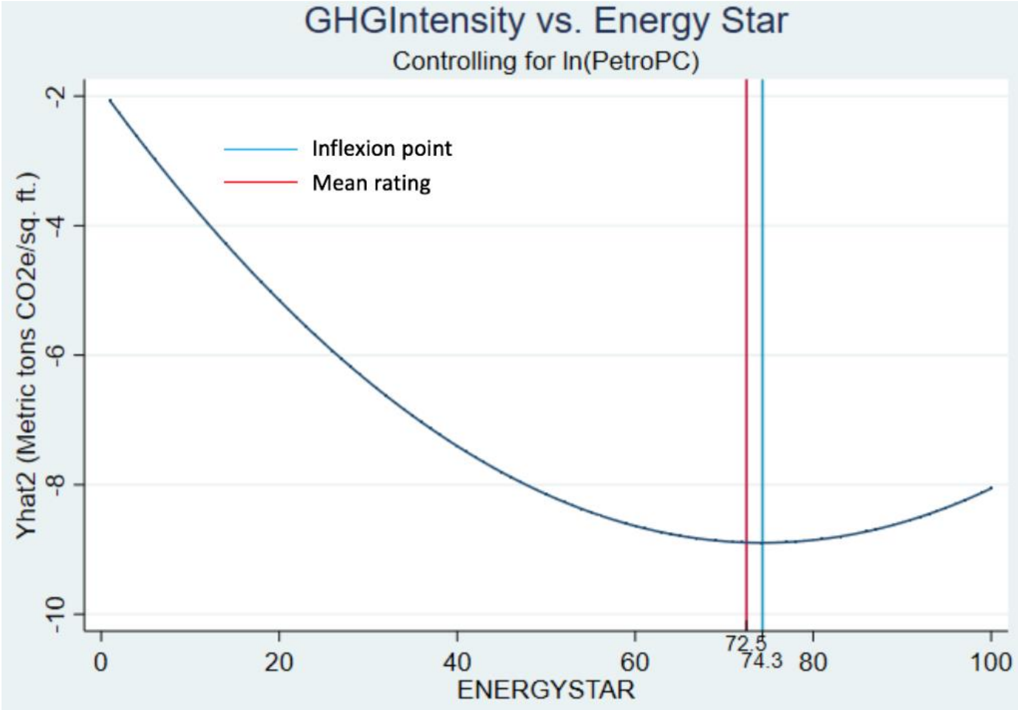
	Model (1)		**Model (2)**		**Model (3)**	
Variable	VIF	1/VIF	VIF	1/VIF	VIF	1/VIF
ENERGYSTAR	1.38	0.723	1.36	0.737	1.36	0.735
Source EUI	1.37	0.731	1.36	0.737	1.36	0.735
NatGasPC	1.02	0.98				
PetroPC			1.00	0.999		
CoalPC					1.00	0.996
Mean VIF	1.26		1.24		1.24	

Figure 1: GHG Intensity vs. Energy Star (controlling for Natural Gas)



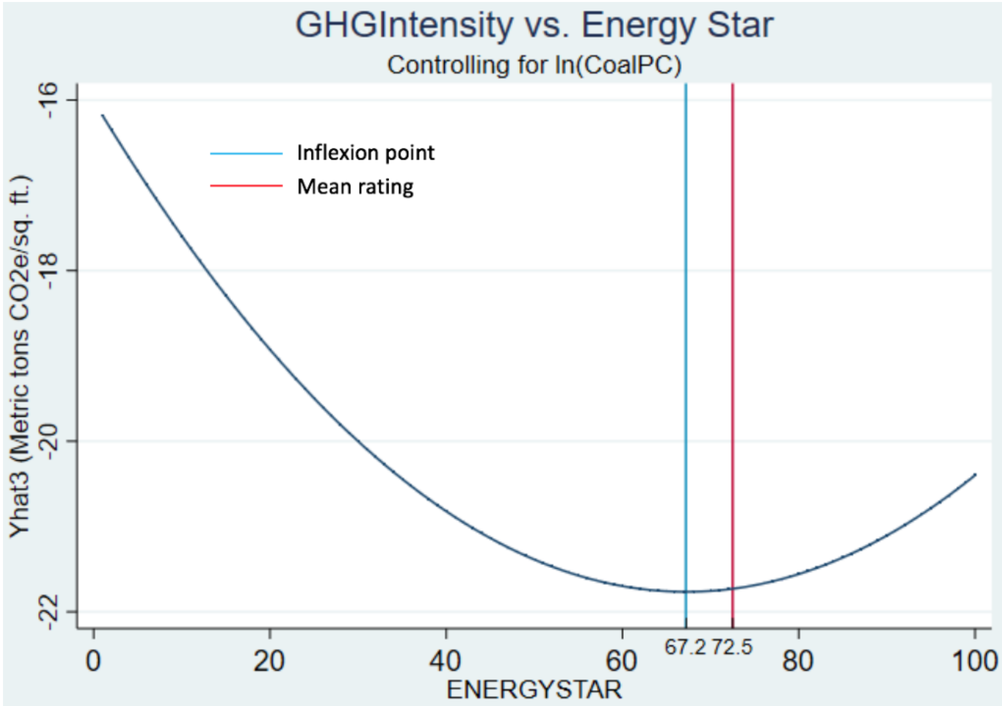
Note: Prediction intervals were withheld from the graph because their magnitudes were too small

Figure 2: GHG Intensity vs. Energy Star (controlling for Petroleum)



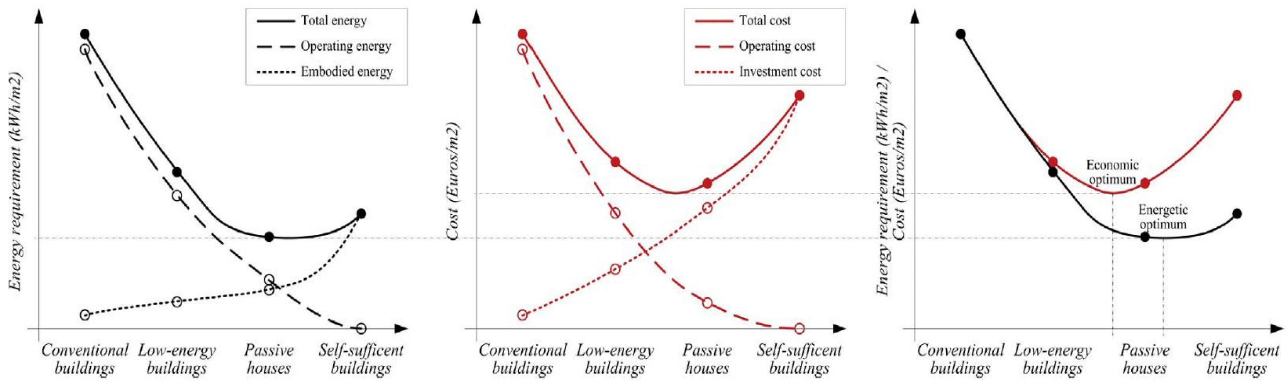
Note: Prediction intervals were withheld from the graph because their magnitudes were too small

Figure 3: GHG Intensity vs. Energy Star (controlling for Coal)



Note: Prediction intervals were withheld from the graph because their magnitudes were too small

Exhibit A. Visual representation of Jevons' paradox



Source: Copiello (2016)

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