Occasional Studies

The Effect of LEED Certification on Residential and Commercial Office Buildings in the District of Columbia in 2018

and the Implications of Residential LEED Buildings for Low-income Households

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1 Introduction

Home to approximately 54 percent of the world's population, urban areas are significant contributors to greenhouse gas emissions (United Nations, 2014). Cities and their populations are also quite vulnerable to climate change impacts. Tackling climate change and environmental sustainability is a challenge that is emerging as a key urban policy issue by an increasing number of U. S. cities and national organizations. One response to this challenge has been the introduction of the United States Green Building Council's (USGBC) Leadership in Energy and Environment Design (LEED) green building rating system in 2000. LEED is a leading design standard for green buildings across the country.

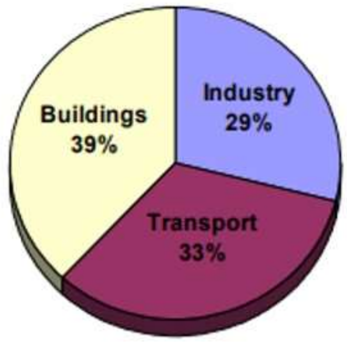
This study uses District of Columbia government administrative property tax data to assess the effects of LEED-certification on the rents, operating expenses and utility expenses of large multi-family residential buildings and large commercial office buildings. For 2018, we find that both LEED commercial office and multi-family residential buildings incurred lower operating and utility expenses than comparable non-LEED buildings. However, only the multi-family residential buildings in the study experienced a rent premium attributable to LEED certification. This research is the first - to the best of the author's knowledge - to investigate the impact of green-building certification on residential buildings in one jurisdiction using an econometric model. Consequently, we also find there is a notable interrelationship between the city's sustainability and affordable housing policies. In 2018, we estimate that the city ensured at least 900 low-income households were partaking in sustainable living in some of the city's newest, trendiest LEED buildings via subsidized rents.

The remainder of this section discusses the buildings sector, LEED certification and the District of Columbia's environmental sustainability policy. Section two describes the data used in this analysis while section three explains both the residential and commercial building models. Section four presents the results of the model. Section five provides a discussion on the findings including the policy interaction between the city's sustainability policy and affordable housing policy. The final section presents the study's conclusions.

1.1 Environmental Sustainability and Climate Change – the Buildings Sector

The buildings sector is an important factor in environmental sustainability. According to the International Panel on Climate Change (IPCC) (a United Nations organization), buildings accounted for 31 percent of total global final energy use, 8 percent of energy-related CO_2 emissions and 54 percent of final electricity demand in 2014. More specifically, the U.S. Energy Information Administration estimates that in 2018 the residential and commercial sectors[1] accounted for 40 percent of total energy consumption in the United States. Moreover, the USGBC claims that together these two sectors account for 39 percent of total CO_2 emissions per year (Figure 1) in the U.S. and are responsible for more emissions than any other country in the world, with the exception of China.

Figure 1: CO_2 Emissions from Fossil Fuels in the United States, 2016



Source: USGBC

Over the last decade, global building construction has been booming. Experts suggest that emissions from buildings could more than double by mid-century due to population growth, extensive in-migration to cities, and lifestyles changes that contribute to building energy use (Broadwater, 2016). The IPCC has called for "rapid and far-reaching" changes across major sectors of the global economy to limit further increases to the earth's temperature. Thus, the buildings sector has been identified as a key sector to be reformed if any of the climate change mitigation goals are to be achieved. Consequently, there has been a call for minimum building efficiency standards to be implemented on a broad scale.

1.2 LEED-Certification

The LEED green building rating system, established in 2000 by the USGBC, has emerged as the nation's leading green building rating system. The program rates buildings on how their design and systems affect energy and water efficiency, carbon dioxide emissions and other green performance measures. The rating system consists of four certification levels: "certified", "silver", "gold", and "platinum". These ratings are awarded to buildings of varying types depending on the number of points they earn for their designs, interior fit outs, core and shell, operations, and maintenance. John Scofield, a professor at Oberlin College and major critic of the USGBC system, posits that the program focuses heavily on points achieved

[1] The commercial sector also includes street and other outdoor lighting energy consumption, and for water and sewage treatment; however, their contribution to the commercial sector's total energy consumption is miniscule.

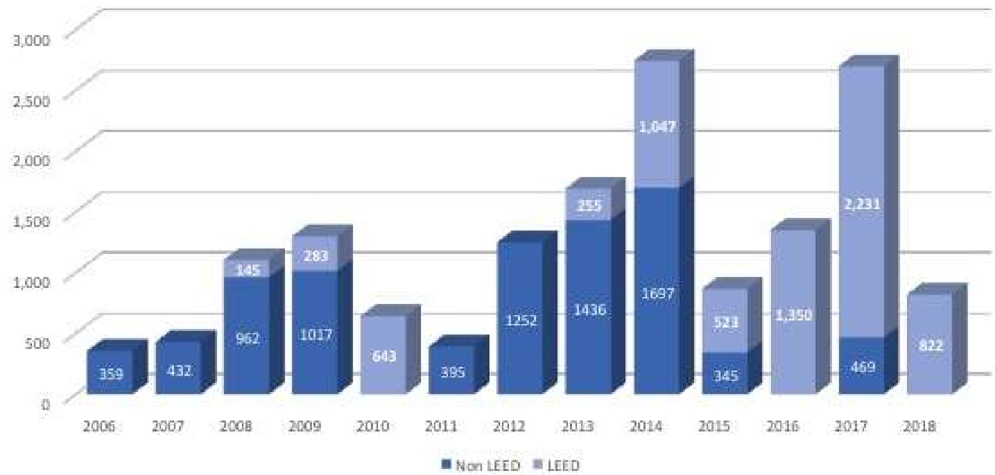
through a checklist of items without giving proper recognition to actual energy performance (Scofield, 2017). In response to criticism and recognizing the need for actual performance data, the USGBC beginning in 2009 required all certified buildings to measure and report annual energy consumption data to the USGBC for five years after certification. However, the data is not available for independent analysis nor has the USGBC published any comprehensive analysis of said data.

1.3 The District of Columbia's Call to Action and Private Sector Response

The District was the first city in the nation to pass major sustainability legislation. In 2006, the District of Columbia Government enacted the Green Building Act (GBA). The city law requires all new privately-owned "nonresidential" (hereafter, commercial) buildings with 50,000 or more square feet of gross floor area meet the USGBC's LEED certification standards.[2] Subsequently, the city has consistently led the nation in the number of LEED-certifications and was designated the world's first LEED Platinum city in 2017. In 2018, the District had 145 certified building projects with 37.1 million LEED-certified gross square feet (Sazegar, 2019). Due to the legislative mandate, it is currently presumed that nearly all large commercial buildings built after 2009 when the law was fully enacted are substantially green in certain respects.[3] Surprisingly however, an increasing number of new large residential buildings have obtained LEED certification. Seventy-one percent of all new apartment units in large multi-family residential buildings delivered in the city since 2014 are LEED-certified (Figure 2). This designation allows owners and management companies for these buildings to rightfully claim, environmental sustainability, increased efficiency, and reduced costs in varying degrees. Concurrently, there has been a tendency for these same residential projects to charge slightly higher lease rates (Alpin Limited, 2016). This suggests that some residential developers have discovered considerable additional economic value (e.g. profits) and marketing opportunities of being LEED-certified. Figure 2 shows that the city had 7,299 residential LEED units in large multi-family buildings in 2018.

[2] In the legislation, the term "nonresidential" is meant to include buildings intended for, but not limited to, public service, educational, not-for-profit, religious, and medical uses. This study uses the term "commercial" instead since all "nonresidential" buildings under investigation are large commercial office buildings.
[3] To smooth the transition for building developers into our current sustainability & regulatory regimes, the law was gradually phased in between years 2006 and 2009.

Figure 2: Units in Multi-family Residential Buildings Delivered by Year in The District of Columbia



Source: CoStar

2 Data Description

This is a cross-sectional study that attempts to measure two sets of effects. The first is the effect of LEED-certification standards on the rents, utility expenses[4] (the portion borne by building owners for common areas and all other management functions) and all other building operating expenses on large commercial office buildings in the District of Columbia in 2018. The second is the effect of LEED-certification on the three aforementioned variables for large multi-family residential buildings.[5] Data for this study were collected from several sources. Property characteristic data including year built, average monthly rent, number of units and number of stories were obtained from CoStar –(the largest real estate database in the United States). This study also uses several types of microlevel administrative data from the District of Columbia Office of Tax and Revenue (OTR), including the 2018 Building Income and Expense data, 2018 Real Property Assessment data, and 2016 Individual Income Tax (IIT) data. The IIT data was used to analyze annual income for tenants of residential buildings.

2.1 Commercial Office Buildings

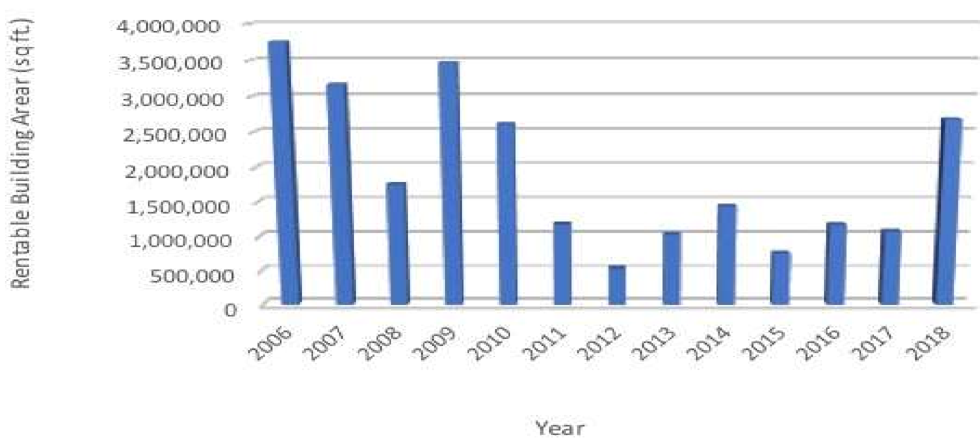
The city's GBA mandates all new private commercial development projects that are 50,000 square feet or larger meet, at minimum, the "Certified" level of LEED certification

[4] Water, fuel and electric expenses.

[5] In this study, operating expenses are non-utility expenses such as maintenance, payroll, janitorial, landscaping, roof repairs, pool, trash etc.

standards. Therefore, all commercial buildings built after 2009 presumably meet LEED-certified standards (per city regulations). To discern between the office buildings that meet LEED-certified standards and those that do not, this study analyzes the 2018 rents, utility expenses and operating expenses for both older and newer buildings. The treatment group consists of 30 large commercial office buildings built between 2009 and 2018. These buildings are presumed to meet LEED-certified standards and will be referred to as the "newer" buildings. The year 2009 was selected as the starting point for newer buildings because it encompasses the end of the Great Recession and full implementation of GBA. The control group consists of 35 large commercial office buildings built between 1990 and 1997. These buildings will be referred to as "older" buildings and are presumed to not meet LEED-certified standards. Figure 3 shows that annual new rentable building area in large commercial office buildings grew from 0.5 million square feet in 2012 to 2.7 million in 2018, an average annual growth rate of 30.9 percent.

Figure 3: Commercial Office Space in the District of Columbia Delivered by Year



Source: CoStar

Table 1 provides summary statistics of selected variables for commercial office buildings in 2018. It appears that operating expenses, utility expenses and rents per square foot (psf), as well as the size of the newer buildings (the treatment group) are less than the older buildings (the control group). Nonetheless, the overall mean assessment values psf tend to be higher. The next section focuses on determining if these differences are statistically significant.

Table 1: Summary Statistics of Selected Variables for 2018 Data

	Newer Buildings N = 30		Older Buildings N = 35	
	Mean	Median	Mean	Median
Total Operating Expenses psf ($)	7.78	7.80	9.60	9.75
Total Utilities Expenses psf ($)	2.15	2.40	2.88	2.86
Average Monthly Rent psf ($)	4.20	4.30	4.32	4.35
Assessment Value psf ($)	652.60	552.23	545.69	518.69
Rentable Building Area (sf)	285,669	258,351	289,637	258,000

2.1.1 T-test Results: Commercial Office Buildings

Two-sample t-tests were used to assess whether differences in respective averages of the older buildings (treatment group) and newer buildings (control group) are statistically significant. Table 2 presents the results of the t-tests for commercial office buildings. On average, 2018 operating and utility expenses psf for newer buildings are lower (and statistically significant) than older buildings by 18.9 percent and 25.3 percent, respectively. However, there is no statistical evidence of a significant difference between a newer and older building in terms of average monthly rent and the other variables.

Table 2: Results of T-tests Based on 2018 Data

	Older Buildings	Newer Buildings	Difference
Operating Expenses psf ($)	$9.59	$7.78	-$1.81**
	(0.5945)	(0.6121)	(0.8565)
Utilities Expenses psf ($)	$2.88	$2.15	-$0.73***
	(0.1361)	(0.1691)	(0.2147)
Average Monthly Rent psf ($)	$4.32	$4.20	-$0.12
	(0.1910)	(0.1631)	(0.2557)
Assessment Value psf ($)	$545.70	$652.60	$106.90
	(36.3551)	(56.7632)	(65.5739)
Typical Floor Size (sf)	28,220.6	27,133.6	-1,087.0
	(2,440.4)	(1,686.2)	(3,065.0)
No. of Commercial Buildings	35	30	

Note: Standard errors are shown in parentheses and statistical significance indicated at the 1%(***), 5%(**), and 100%(*) level.

2.2 Multi-family Residential Buildings

There are 36 LEED-certified large multi-family residential buildings in the District. Only 27 of those buildings matched to both the Building Income and Expense and Real Property Assessment datasets. Twenty-six non-LEED certified buildings of similar size, age and submarket locations were identified for the control group. The treatment and control groups comprise a total of 15,663 residential units in the District.[6] Between 2016 and 2018, developers added over 5,500 LEED residential units in the city without a government mandate, which is approximately 40 percent of all Class A and B units added during that time. Table 3 shows that on average, LEED-certified buildings have lower utility expenses and higher rents psf than non-LEED buildings.

Table 3: Summary Statistics of Selected Variables

	LEED Buildings N = 27		Non-LEED Buildings N = 26	
	Mean	Median	Mean	Median
Total Operating Expenses psf ($)	8.24	7.68	8.16	7.18
Total Utilities Expenses psf ($)	1.02	0.79	1.21	1.06
Average Monthly Rent psf ($)	3.58	3.61	3.20	3.15
Assessment Value psf ($)	319.42	329.50	307.92	353.02
Rentable Building Area (sf)	274,787	271,528	295,337	270,000
Number of Units	270	281	322	291
Vacancy Rate (%)	5.66	5.41	4.77	3.83

2.2.1 T-test Results: Large Residential Buildings

Two-sample t-tests were used to test the statistical significance of the differences in averages of the treatment and control groups. Focusing on the key expense and rent variables, Table 4 shows that the operating and utility expenses for LEED buildings (treatment group) and non-LEED buildings (control group) are statistically insignificant. That is, there is no meaningful difference between the means of the two groups. On the other hand, the average rents for LEED buildings are meaningfully 11 percent higher than non-LEED buildings.

Interestingly however, the table shows that renters in LEED buildings had higher income that was on average $5,979 (7.2 percent) higher, but this was found to be statistically

[6] 7,299 LEED units and 8,364 non-LEED units.

insignificant. Additionally, renters in these same buildings were on average 1.9 years older but statistically insignificant than those in non-LEED buildings.

Table 4: Results of T-tests Based on 2018 Building Income and Expense and 2016 Individual Income Tax Data

	LEED Buildings	Non-LEED Buildings	Difference
Operating Expenses psf ($)	$8.24	$8.16	$0.08
	(0.631)	(0.547)	(0.839)
Utilities Expenses psf ($)	$1.02	$1.21	-$0.19
	(0.194)	(0.155)	(0.249)
Average Effective Rent psf ($)	$3.54	$3.19	$0.35***
	(0.011)	(0.007)	(0.013)
Assessment Value psf ($)	$319.40	$307.90	$11.50
	(36.369)	(34.862)	(50.438)
Average Square Feet per unit	773.00	800.20	-27.20***
	(2.190)	(2.000)	(3.220)
Vacancy Rate (%)	5.20	4.10	1.10**
	(0.074)	(0.045)	(0.082)
Mean Tenant Income	$88,987.30	$83,008.70	$5,978.60
	(4,611.40)	(1,197.50)	(3,675.50)
Mean Age of Tenants	32.47	30.58	1.89***
	(0.259)	(0.142)	(0.272)
No. of Residential Buildings	27	26	

Note: Standard errors are shown in parentheses and statistical significance indicated at the 1%(***), 5%(**), and 100%(*) level.

In summary, the operating expenses and utility expenses were statistically the same for both LEED and non-LEED residential buildings, while the rents for LEED residential buildings were 11 percent higher than non-LEED residential buildings.

2.2.2 Additional T-test Results for Residential Buildings: Income by Filer Type

In 2016, the city's individual income tax single filers accounted for 67 percent of the over 300,000 tax filers, but only 45 percent of the income of all filers. In contrast, married filers accounted for just 17 percent of all tax filers yet 48 percent of the personal income in the city. With married filers tending to be higher income than single filers, the composition of tax filers in the study's LEED and non-LEED buildings may play a significant role in the income dynamics and statistics.[7] That is, given that Table 4 shows that LEED buildings have higher rents and slightly older tenants with higher incomes on average, LEED buildings may simply have more

[7] According to the income tax data for tax year 2016, the average (median) income for all single filers was $67,236 ($46,950). The average (median) income for all married filers was $272,303 ($160,958).

married couples as tenants, which may be a key driver in the higher income statistics in the table.

Of the 4,108 tax filers (i.e. tenants) in the study's non-LEED buildings, 89 percent were single filers and 9 percent were married filers. Similarly, 86 percent of the tax filers in LEED buildings were single filers, and 8 percent were married filers. Consistent with Table 4, Table 5 shows that on average single filers in LEED buildings earned $6,885 (9.1 percent) more than single filers in non-LEED buildings, while married filers earned $25,763 (16.4 percent) more than their counterparts in non-LEED buildings. Notably, the confounding result centers on head of household filers in both types of buildings.[8] The tax data indicates 2 percent of the tax filers in non-LEED buildings were head of household filers, but 6 percent of the tax filers in LEED buildings were head of household filers. When we pair these statistics with the head of household statistics in Table 5, which state that these filers in the more expensive LEED buildings earned on average $25,538 (39.1 percent) less than their counterparts in non-LEED buildings, this is perplexing and warrants closer examination and investigation.[9]

Table 5: Results of T-Tests Based on 2016 Individual Income Tax Data

	Non-LEED Buildings	LEED Buildings	Difference
Single Filers	$75,532	$82,417	$6,885**
	(939.8)	(2,771.5)	(2,543.0)
Married Filers	$157,545	$183,308	$25,763**
	(5,270.3)	(10,878.8)	(11,023.2)
Head of Household Filers	$65,390	$39,852	-$25,538***
	(5,774.3)	(2,867.1)	(5,768.8)
No. of Tax Filers	4,108	2,869	

Note: Standard errors are shown in parentheses and statistical significance indicated at the 1%(***), 5%(**), and 100%(*) level.

3 The Models

3.1 Commercial Office Buildings

OLS linear regression models were used to analyze the effect of being a newer office building on (i) operating expenses; (ii) utility expenses; and (iii) average monthly rent (all psf).

[8] Head of household tax filers are adult unmarried income earners with at least one dependent. These filers are generally considered to be single low wage earners with children. For example, of all city income tax filers 59 percent of all head of households are EITC claimants. Of the 438 EITC claimants in this study, 61 percent were tenants in LEED buildings and 39 percent were in non-LEED buildings.

[9] The average (median) income for all head of household filers in the city in 2016 was $42,764 ($29,847).

The model specifications are as follows:

$$Opexpenses_i = \beta + \delta New_i + \mu Assessment_i + \sigma Logfloorsize_i + \theta Renovated_i + \gamma ClassA_i + \epsilon_i \quad (1)$$

$$Utexpenses_i = \beta + \delta New_i + \mu Assessment_i + \sigma Logfloorsize_i + \theta Renovated_i + \gamma ClassA_i + \epsilon_i \quad (2)$$

$$Rent_i = \beta + \delta New_i + \mu Assessment_i + \sigma Logfloorsize_i + \theta Renovated_i + \gamma ClassA_i + \epsilon_i \quad (3)$$

where: $Opexpenses_i$ represent operating expenses psf in equation 1; $Utexpenses_i$ represent utility expenses psf in equation 2; and $Rent_i$ is average monthly rent psf in equation 3. New_i is a dummy variable which takes the value 1 if the building was built between 2009 and 2018 and 0 if built between 1990 and 1997; $Assessment_i$ is the assessment value psf; $Logfloorsize_i$ is the natural log of building floor size; $Renovated_i$ is an indicator variable taking the value 1 if the building was renovated and 0 otherwise; $ClassA_i$ is a binary variable taking the value 1 if the building is a class A building and 0 if it is Class B; and *i* is individual building.

3.2 Multi-family Residential Buildings

Again, OLS regression models were used to estimate the impact of being LEED-certified on (i) operating expenses; (ii) utility expenses; and (iii) average monthly effective rent income all psf. The model specifications are:

$$Opexpenses_i = \beta + \delta LEED_i + \mu Assessment_i + \sigma Age_i + \theta Age_i^2 + \epsilon_i \quad (4)$$

$$Utexpenses_i = \beta + \delta LEED_i + \mu LogRBA_i + \sigma Pool_i + \theta HighRise_i + \gamma Vacancy_i + \epsilon_i \quad (5)$$

$$Rent_i = \beta + \delta LEED_i + \theta_1 MidRise_i + \theta_2 HighRise_i + \gamma ClassA_i + \sigma Units_i + \epsilon_i \quad (6)$$

where: in equation (4) $Opexpenses_i$ is the total operating expenses psf; $LEED_i$ is a binary variable which takes the value 1 if a building is LEED-certified and 0 otherwise; $Assessment_i$ is the assessment value psf; *Age* is the age of the building; and $Age^2{}_i$ is the age of the building squared. In equation (5) $Utexpenses_i$ is the total utility expenses psf paid by the building owner or management company; $LogRBA_i$ is the natural log of rentable building area; $Pool_i$ is a dichotomous variable which takes the value 1 if a building has a pool and 0 otherwise; $HighRise_i$ is a dummy variable which takes the value 1 if the building has 13 or more stories and 0 if it has less than 13 stories; and $Vacancy_i$ is the vacancy rate. In equation (6) $Rentf_i$ is the average effective rent psf; $MidRise_i$ is a dummy variable which takes the value 1 if the building has 7 - 12 stories and 0 otherwise; $HighRise_i$ remains the same as in equation (5); $ClassA_i$ is a binary variable taking the value 1 if the building is a class A building and 0 if it is Class B; $Units_i$ is the number of units in a building; and *i* is an individual building.

4 Results

4.1 Commercial Office Buildings

The effect of being a new building on owner operating expenses, utility expenses and average monthly rents were estimated using OLS models. The results in Table 6 show that, ceterus paribus, newer buildings' operating and utility expenses are $2.53 psf (7.43 percent) and $0.80 psf (9.44 percent) lower than older buildings, respectively. These results align with those of Reichardt (2014) who found that LEED-certified buildings have operating expenses that are 5.4 to 8.6 percent lower than conventional buildings. The rent coefficient is statistically insignificant suggesting that the average rents for the two populations are essentially the same.

Table 6: OLS Regression Results on the Impact on Operating Expenses, Utilities Expenses and Rent Income for Newer Commercial Office Buildings

	Operating Expenses psf (1)	Utilities Expenses psf (2)	Average Monthly Rent (3)
Constant	34.061***	8.444***	5.407*
	(9.625)	(0.553)	(17.583)
Newer	-2.534***	-0.797***	-0.446
	(1.559)	(0.215)	(8.382)
Assesment Value psf	0.008***	0.0003	-0.001**
	(2.796)	(0.431)	(18.068)
Log Floor Size	-2.781***	-0.538**	-0.221
	(2.845)	(0.452)	(18.062)
Renovated	-0.368	-0.362	-0.069
	(0.946)	(0.877)	(0.958)
Class A	-0.510	-0.218	0.749*
	(0.001)	(0.0004)	(0.0003)

Note: Standard errors are shown in parentheses and statistical significance indicated at the 1%(***), 5%(**), and 100%(*) level.

The commercial office regression results confirm the t-test results, but the regression coefficients depict a more precise picture than those of the t-tests. A t-test is commonly used to determine whether the mean of a population significantly differs from the mean of another but similar population. When the difference is statistically significant, the amount of the difference is not explained. A regression allows us to include explanatory variables that might contribute to the total change in the dependent variable (via the coefficients of the explanatory variables). In this study, for example, the t-test results indicate that utility expenses for newer office buildings were 25.3 percent lower than for older office buildings. However, there are, undoubtedly, numerous reasons for this relatively large percent change. The regression model helps in this regard. Equation 2 explicitly identifies newer buildings as one of the explanations for the changes in utility expenses. Building assessment value, floor size of buildings, building class, and whether the building was renovated are the other explanations for changes in utility expenses among the buildings included in the model.

For this research, we are focused on estimating the impact of being a newer office building on utility expenses. Table 6 shows that while building assessment value, floor size, whether it was renovated and its class exert varying degrees of influence on changes in utility expenses, being a new building (while controlling the other factors) is estimated to only account for 8 percent of the total change in utility expenses of the buildings in the dataset. Conceptually, this suggests that while the total difference in the average utility expenses psf between newer an older building is 25.3 percent (per the t-test) only 8 percent can be attributed to solely being a newer building. Other factors account for the remaining 17.3 percent.

4.2 Multi-family Residential Buildings

Table 7 show that LEED-certified multi-family residential buildings' operating expenses is reduced by $1.39 psf (17.3 percent), while utility expenses were $0.45 psf (7.82 percent) lower than non-LEED buildings. Additionally, LEED buildings command rental rates that are roughly 10.2 percent ($0.30 psf) higher than non-LEED buildings.[10] [11]

[10] This finding is consistent with (Sazegar, 2019) who found that "certified" and "silver" LEED residential buildings in the city had rents that were 9.7 percent higher than comparable non-LEED buildings. "Gold" and "platinum" LEED residential buildings were found to have 11.4 percent higher rents than comparable non-LEED buildings. https://districtmeasured.com/2019/06/03/some-effects-of-leed-buildings-in-the-district-of-columbia/

[11] When examining the effect of LEED certification on operating and utility expenses of residential buildings, we observed that the models were statistically insignificant for the entire sample (53 observations: 27 LEED and 26 non-LEED). Subsequently, LEED buildings with less than 112,000 square feet of rentable building area were eliminated to determine if there is a size effect when studying the impact of LEED-certification on expenses. This resulted in a sample size of 49 (23 LEED and 26 non-LEED) for those two models. However, the entire sample (consisting of 53 observations) was maintained when estimating the impact of certification on average effective monthly rent.

Table 7: OLS Regression Results on the Impact on Operating Expenses, Utilities Expenses and Rent Income for LEED-Certified Residential Buildings

	Operating Expenses psf (4)	Utilities Expenses psf (5)	Average Monthly Rent (6)
Constant	8.020***	5.801*	2.903***
	(1.642)	(2.887)	(0.269)
LEED	-1.392*	-0.454**	0.297**
	(0.803)	(0.214)	(0.126)
Assesment Value psf	0.006***		
	(0.002)		
Building Age	-0.195		
	(0.458)		
Building Age^2	-0.003		
	(0.033)		
Log Rentable Building Area		-0.392*	
		(0.233)	
Pool		-0.076	
		(0.252)	
Vacancy Rate		0.093**	
		(0.038)	
High-Rise		-0.292	0.481**
		(0.283)	(0.196)
Mid-Rise			0.659***
			(0.157)
Class A			0.144
			(0.291)
Number of Units			-0.0008*
			(0.0005)

Note: Standard errors are shown in parentheses and statistical significance indicated at the 1%(***), 5%(**), and 100%(*) level.

While the t-test results showed that operating and utility expenses for residential LEED and non-LEED buildings were statistically the same, the regression results indicate that the operating and utility expenses for LEED buildings were lower psf than non-LEED buildings by 17.3 percent and 7.8 percent, respectively. It is possible that the t-tests, either by being a generally less refined type of inferential statistic or more simply having less variation among the two populations, had difficulty discerning meaningful differences in the means. However, once the regression controlled for other factors beyond whether it was a LEED building, many of the coefficients were found to be statistically significant. Equation 6, however, confirms that rents tend to be higher for LEED buildings than for non-LEED buildings.

5. Discussion

5.1 Policy Interactions

This analysis finds statistical evidence that a majority of tenants in residential LEED-buildings tend to have higher incomes than tenants in non-LEED but otherwise comparable buildings. This suggests that the households in LEED buildings have a greater ability and willingness to pay not only for a high degree of sustainable living, but for other key amenities the current rental market demands. This study also finds that these residential LEED buildings appear to charge higher rents on the order of 10.2 percent for their units (which also tend to be 27.2 square feet (3.4 percent) smaller). This rent effect could preclude lower income households as tenants.

However, based on a closer review of the OTR's 2018 Building Income and Expense data for all income earning properties in the city, we found that at least 500 affordable housing units were Inclusionary Zoning (IZ) units in LEED-certified residential buildings.[12] The city's IZ program was enacted into law in 2006 and is one of many policy tools used by the city government to help provide more affordable housing units to low-income residents. The program requires a minimum of 8 –10 percent of the residential floor area of all new residential projects (including LEED projects) be set aside as units for low-income households. This closer review of the data also revealed that at least 400 additional LEED units (exclusive of the above mentioned 500 IZ units) are subject to some type of other affordable housing program (i.e. subsidized rent). In total, this means that in 2018 at least 900 low-income households were afforded housing in some of the city's newest, more expensive LEED residential developments, thus sharing in the city's sustainable living movement. This is consistent with the analysis of income tax data that indicates that not only were 6 percent of tenants in LEED buildings head of householders (compared to only 2 percent of the tenants in non-LEED buildings), but also the head of households in the more expensive LEED buildings earned on average $25,538 (39.1 percent) less than their counterparts in non-LEED buildings (Table 5).[13]

[12] The data include detailed income and expense data for all income earning properties (for the Income Approach to valuation) and also contain information on how many units in respective buildings were subsidized and via which housing program. This is needed documentation provided by building owners/property managers to help explain the constrained income for some units in affected buildings.

[13] Of the 438 EITC claimants in this study, 61 percent were tenants in LEED buildings. Also, 9.2 percent of all tax filers in the LEED buildings were EITC claimants.

5.2 Identifying Particular Beneficiaries of the City's GBA

The growing number of LEED-certified buildings are just one of the ways the city is accelerating sustainable development and delivering a better standard of living for its citizens. These buildings reduce the city's carbon emissions, energy and waste, conserve water, prioritize safer building materials and lower the population's exposure to toxins. However, there are a few other particular beneficiaries from this policy beyond the city in general with its lower carbon footprint.

First, there are renters in LEED buildings who might derive possible psychological benefits from knowing they are appreciably contributing to a lower carbon footprint as well as economic benefits via paying lower utility expenses. (Even though, lower utility expenses may be offset to some degree given that this study finds that renters in respective residential buildings tend to pay slightly higher rents.) Second, it appears that developers, owners, and management companies of residential LEED buildings are the greatest pecuniary beneficiaries. We found that these buildings have lower (owner/management company-borne) utility and other operating expenses while simultaneously charging their residential tenants higher rents (approximately 10 percent). This could have considerable positive implications on the level of profits these residential buildings earn.

Third and most interestingly, we highlight select low-income households that live in LEED buildings via the city's affordable housing programs. While LEED buildings help the city achieve its environmental sustainability goals, another one of the city's paramount social policy goals involves increasing the number of affordable housing units for low-income residents. Apparently, there is a notable interrelationship between the city's sustainability and affordable housing policies. In addition to the city encouraging more new LEED residential buildings, the city is simultaneously ensuring (via its affordable housing programs) that a portion of all new (including LEED) apartment units are set aside for low-income households. Thus in 2018, we estimate the city has ensured at least 900 low-income households were partaking in sustainable living in some of the city's newest, trendiest LEED buildings via subsidized rents. More specifically, it appears that that low-income households living in LEED buildings may be spending a little less on their utility expenses while simultaneously paying below market rents for premium living space. These 900 low-income households appear to be direct and significant beneficiaries of the interaction of the city's key sustainability and affordable housing programs.

5.3 Future Outlook

The District Columbia intends to continue being a national leader and pioneer in sustainability. This is evidenced by the city's Clean Energy District of Columbia Omnibus Amendment Act of 2018, which mandates that the District be 100 percent dependent on renewable energy by 2032. The new law requires that new single-family or multi-family residential buildings be at net-zero energy consumption starting in 2020, and that all commercial or large multi-family buildings achieve net-zero energy consumption by 2026. This law is one of the country's most aggressive and impactful clean energy actions to-date and will likely bolster the District of Columbia as a global leader in the fight against climate change.

6 Conclusion

This study investigates the effect of LEED standards on the rents, utility expenses and other operating expenses on both large multi-family residential and large commercial office buildings in the District of Columbia in 2018. We find that utility expenses and operating expense for residential LEED buildings were 7.8 percent and 17.3 percent lower, respectively, than non-LEED residential buildings. We also find that apartment rents in residential LEED buildings were 10.2 percent higher on average than comparable non-LEED residential buildings.

In terms of commercial office buildings in the city in 2018, we find that office buildings that meet LEED-certification standards experienced 7.4 percent lower operating expenses and 9.4 percent lower utility expenses than the control group. We did not find statistical evidence that suggests these newer large office buildings that met the standards experienced higher rents (e.g. rent premiums).

While the District of Columbia's Green Building Act of 2006 explicitly targeted only commercial buildings in the city, it appears that the increasing number of residential LEED buildings supports the notion that LEED-certified buildings are not only socially and environmentally necessary but also economically and financially viable in today's housing market (even with designating about 12 percent of the city's 7,300 LEED units as rent-subsidized housing units). The growing number of not only commercial buildings but also residential buildings that meet LEED-certification standards will continue to help the District of Columbia lower its carbon footprint more rapidly than anticipated at the enactment of the GBA in 2006.

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