Environmental Performance of Commercial Real Estate: *New Insights into Energy Efficiency Improvements*

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KEY FINDINGS

- Real estate investors and lenders have started to consider environmental certification and/or energy efficiency in financing and underwriting decisions.
- We find that green building certification and investments in energy efficiency lead to significant reductions in building energy consumption.
- The median energy consumption of commercial real estate decreased by 42% over the past decade.

ABSTRACT: *This article provides new insights into the performance of commercial real estate, focusing on the environmental performance of institutional assets. The authors employ a proprietary dataset of energy consumption data that includes more than 26,000 buildings between 2009 and 2018. They document that, in their sample of commercial real estate, the median energy intensity decreased by more than 40% over the decade. Using a difference-in-difference analysis, the authors find that adoption of environmental building certification (Leadership in Energy and Environmental Design) is associated with significantly lower energy consumption and that there is substantial variation in these effects, depending on certification level and program, and label tenure. Moreover, specific interventions aimed at improving the energy efficiency of buildings considerably reduce ex post energy consumption, with effects varying based on local climatic conditions.*

TOPICS: ***Real estate, ESG investing****

Over the past decade, businesses and investors have advanced markedly in their consideration of sustainability issues. Indeed, the integration of environmental, social, and governance (ESG) factors into investments is rapidly becoming mainstream. Led by European institutional investors and moving from exclusion to engagement, ESG integration is now regarded as a mainstream risk-management tool, rather than a tactic used primarily by activist investors.

When it comes to the considerations of ESG factors, the real estate sector is of particular interest. The Energy Information Administration (EIA) documents that the real estate sector is responsible for 38% of total annual US energy consumption, of which half is consumed by commercial real estate. Importantly, the EIA predicts that energy consumption in commercial real estate will increase by 19.5% until 2050, despite energy efficiency improvements. In contrast, the

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predicted growth in energy consumption to 2050 for the residential sector is just 5.7%. The increase in commercial buildings' energy consumption is largely due to growing floor space and increasing technology needs, which offset efficiency gains in lighting and appliances.[1]

This study aims to provide a deeper understanding of the environmental performance dynamics of commercial buildings. The economic literature provides some evidence that environmentally certified, green commercial real estate has better financial performance—measured by rent, occupancy, and value—as compared to noncertified real assets.[2] However, not much is known about the actual environmental performance of commercial buildings beyond case studies and anecdotes. How does the sector fare when it comes to reducing its energy consumption? In addition, the environmental performance effects of specific building interventions—for example, capital expenditures designed to reduce energy efficiency, such as improved lighting or heating, ventilation, and air conditioning (HVAC) systems, or soft interventions, such as attempting to influence tenant behavior through engagement programs—are largely undocumented, and that also holds for the relationship between environmental performance and environmental certification. Both types of initiatives (i.e., capital expenditures and environmental certification programs) are typically part of public policy efforts and investor engagement with real estate investment trusts (REITs) and private equity real estate investments. Understanding their efficacy is thus important to ensure appropriate allocation of resources to improve the energy efficiency of buildings.

The study by Kahn, Kok, and Quigley (2014) is among the few to assess energy consumption determinants for commercial real estate. Employing a panel of commercial buildings from one utility provider to investigate the determinants of energy consumption, the authors documented that, surprisingly, newer and higher-quality commercial buildings consume more energy than older-vintage buildings. However, the results also show that newer buildings are more resilient to changes in local climatic conditions than older buildings. Moreover, tenants for whom utilities are bundled with rent consume more energy and respond less to temperature shocks as opposed to tenants who are responsible for their own utility bill. In related work, Kahn, Kok, and Liu (2016) exploited a large set of data on hotels that belong to a global hotel chain to investigate spatial and temporal differences in energy consumption. The authors documented that, after controlling for local climatic conditions, occupancy rates, and electricity prices, California is the most energy-efficient state, closely followed by Ohio and Arizona. Furthermore, hotels located in California made the most progress in improving energy efficiency between 2007 and 2013, reducing consumption by 35% over the seven-year period.

The literature on energy consumption in real estate mostly involves single-family housing, where consumption is determined both by physical building characteristics and heterogeneous occupants. For example, Brounen, Kok, and Quigley (2012) investigated household energy consumption and documented that natural gas consumption is largely explained by dwelling characteristics. In contrast, residential electricity consumption is strongly related to a household's income and composition: its size and the number of children and elderly.

The impact of energy efficiency improvements on residential energy consumption is the subject of quite a few recent studies.[3] Jacobsen and Kotchen (2013) showed that stricter building codes improve energy outcomes and that reductions in energy consumption are persistent. However, Levinson (2016) countered that such effects are merely due to the newness of construction and that efficiency gains from more recent building codes disappear over time. Fowlie, Greenstone, and Wolfram (2018) developed a large field experiment in Michigan and documented much smaller treatment effects following energy retrofits than what engineering estimates would suggest, perhaps due to the often-cited rebound effect (Aydin, Brounen, and Kok 2017).

The current research lacuna on the economics of commercial building energy consumption, both in the cross section and over time, is mostly due to information on energy consumption in commercial buildings being notoriously hard to obtain, in contrast to widespread

[1] EIA Annual Energy Outlook 2019. Retrieved from: https://www.eia.gov/outlooks/aeo/.

[2] See, for example, Devine and Kok (2015), Eichholtz, Kok, and Quigley (2010, 2013), and Holtermans and Kok (2019).

[3] Beyond improvements in building structure, the literature shows that behavioral interventions can lead to economically significant reductions in energy consumption (Alcott and Rogers 2014; Aydin, Brounen, and Kok 2018).

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access to consumer energy data.[4] An often-used source of commercial building energy data is the Environmental Protection Agency (EPA), but information from its Energy Star certification system is available for high-performing buildings only (i.e., those buildings the EPA rates 75 or above), significantly skewing the sample. An alternative could be the Commercial Building Energy Consumption Survey, but data from this survey are available on an irregular basis, with information on just a small set of buildings to represent the US commercial building universe.

To circumvent this data issue, we partner with Measurabl, a software platform that is used to collect, manage, and report on environmental data in commercial real estate and provides access to a proprietary set of longitudinal data on some 26,000 buildings. These buildings are owned and managed by major institutional real estate investors, thus providing deep insight into the environmental management practices of large real estate portfolio owners. Beyond information on energy consumption, the software platform also records information on interventions aimed specifically at improving the environmental performance of the building. We exploit this unique dataset to study the contemporaneous energy performance of the commercial real estate sector, as well as the temporal effects of energy efficiency interventions and environmental certification on energy consumption, covering the 2009–2018 period.

The nonparametric statistics show that although energy intensity (i.e., energy consumption per square foot of space) varies widely both within and across property types, the median energy consumption of commercial real estate decreased by 42% over the past decade. This increase in energy efficiency took place against the backdrop of a strong increase in economic activity and corresponding activity within commercial real estate assets. Analyzing the effect of building certification, using the popular Leadership in Energy and Environmental Design (LEED) label that is used by many landlords as a signaling device for green building practices, we document that the energy consumption of a building after certification decreases by 8%, on average. However, the level of certification matters for the extent of energy savings, and although the effects increase four years after certification, the efficiency gains start to slowly dissipate after that point. The results on the effect of energy interventions—investments in lighting, HVAC, building controls, and so on—show that such investments are associated with significant reductions in ex post energy consumption. Not surprisingly, the effect of energy efficiency interventions varies with local climatic conditions: In warmer climates, energy consumption decreases more strongly after investments in efficiency. Soft behavioral interventions in particular (e.g., tenant engagement programs) lead to significant reductions in energy consumption in warmer climates.

This study is important for multiple reasons. First, we address energy efficiency in the commercial real estate sector, which has been mostly overlooked hitherto. Second, we investigate the environmental performance effects of specific building interventions, and to date such evaluations have been scant. Third, although the diffusion of green building certification has taken flight over the past years, with some 20% of the US office stock being LEED-certified, building certification is typically based on ex ante, assessed energy performance rather than actual performance.[5] Evaluating the extent to which environmental building certification and actual energy use in buildings are related provides important insights into the extent to which those buildings are indeed more efficient in their use.

METHODOLOGY

Our main interest is threefold: (1) to understand the general determinants and dynamics of the energy performance of commercial real estate, (2) to understand how environmental building certification is related to commercial buildings' energy consumption (i.e., are these labels reflective of actual energy efficiency), and (3) to understand how specific energy efficiency investments affect commercial buildings' energy consumption. We address the first research question in a nonparametric, descriptive analysis. We then empirically assess the second and third research questions, estimating the following regression equations designed to control for

[4] Although there is a large engineering literature on the topic, these studies typically employ small samples or present case studies of single buildings.

[5] See https://www.cbre.com/about/corporate-responsibility/pillars/environmental-sustainability/green%20building%20adoption%20index.

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the effects of unobservable factors that also determine energy consumption trajectories:

$$lnY_{i,m,t} = \beta_{i,m,t} GREEN + \alpha_i + \delta_m + DD_{i,m,t} + \epsilon_{i,m,t} \quad (1)$$

$$lnY_{i,m,t} = \beta_{i,m,t} INT + \alpha_i + \delta_m + DD_{i,m,t} + \epsilon_{i,m,t} \quad (2)$$

$$lnY_{i,m,t} = \beta_{i,m,t} INT * CDD_{i,m,t} + \alpha_i + \delta_m + HDD_{i,m,t} + \epsilon_{i,m,t} \quad (3)$$

where $lnY_{i,m,t}$ measures the natural log of energy consumption per square foot of building *i* in month *m* and year *t*. The GREEN indicator changes from zero to one after a building is certified by LEED. *INT* is an indicator variable that takes a value of one after the intervention in a building's energy performance is complete and zero otherwise.

The equation includes building-fixed effects, α_i, to account for permanent differences in buildings' energy consumption. The model also includes month-fixed effects, δ_m, to adjust for the average effects of time-varying factors (e.g., summer and winter temperature) that generate changes in average energy consumption across all buildings. To account for differences in energy consumption resulting from local weather conditions, the model includes monthly cooling and heating degree days, $DD_{i,m,t}$. Subsequently, in Equation 3, we interact monthly cooling degree days with energy efficiency interventions to assess potential heterogeneity in the efficacy of the interventions relative to local climate conditions. The main parameter of interest is β, which measures the average difference in energy consumption subsequent to (1) LEED certification (GREEN) and (2) the completion of energy efficiency interventions (INT), after adjustment for the fixed effects. Both represent difference-in-difference estimators that compare energy consumption after certification and energy retrofits to energy consumption before the intervention, relative to consumption among buildings that have either not yet invested in energy efficiency through projects visible to the energy management platform or never did so during our sample period.

DATA

We source data through a partnership with Measurabl, a leading platform that focuses on the collection of environmental performance data for commercial real estate and provides extensive coverage of more than 26,000 commercial buildings, representing more than 5.2 billion square feet. The Measurabl platform is used by a large number of institutional real estate investors but, of course, not by all. This may lead to selection bias (e.g., in the types of buildings that are included in the platform). However, given that the impetus for the collection of environmental data is often an explicit request by limited partners (LPs), reporting is not necessarily voluntary, taking away some of the concerns about managers cherry-picking their best assets for reporting.[6]

Of the total set of buildings in the Measurabl platform, some 8,880 buildings are in the United States, the focus of this study; 7,273 buildings have detailed information on energy consumption, environmental building certification, and specific interventions aimed at improving energy efficiency, with office buildings representing the largest category.[7] All these buildings are tracked over time, with an average of 58 months of available energy consumption data over the 2009 to 2018 period.[8] To account for variation in energy consumption due to (local) weather conditions, we append information on cooling and heating degree days from the weather station that is located nearest to each building.

Exhibit 1 provides the descriptive statistics. The average building in the dataset has a monthly consumption of 335 MWh of energy (or 1.27 kWh per square foot), corresponding to some 4 GWh per year (or 15.27 kWh per square foot). We observe quite some heterogeneity in energy consumption across the four different property types included in the dataset. Monthly energy consumption per square foot ranges from 0.58 kWh for industrial buildings to 1.68 kWh

[6] One of the main drivers for the use of Measurabl is reporting of environmental performance data to GRESB, an ESG benchmark for the private equity and REIT market. A large number of LPs use GRESB to monitor their REIT and fund investments on ESG performance, making reporting mandatory at the time of investment. See www.gresb.com.

[7] Building energy consumption includes a variety of sources: electricity, natural gas, district cooling and heating, and fuels.

[8] We ensure that the sample includes at least six months of energy consumption information before and after each certification activity or energy efficiency improvement. Nontreated buildings have at least two months of available energy consumption information.

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Exhibit 1
Descriptive Statistics

	Total	Office	Residential	Industrial	Retail
Monthly Energy Consumption (kWh/sq. ft.)	1.27	1.68	0.69	0.58	0.89
	(1.02)	(0.82)	(0.85)	(1.10)	(1.07)
Cooling Degree Days (monthly)	137.25	130.02	145.97	137.84	170.90
	(170.45)	(167.13)	(175.05)	(167.31)	(185.31)
Heating Degree Days (monthly)	301.46	321.70	275.53	276.02	258.92
	(326.83)	(332.90)	(311.08)	(319.40)	(318.58)
Building Size (thousand sq. ft.)	254.60	253.43	276.79	217.2	286.15
	(293.64)	(312.62)	(177.42)	(335.49)	(260.01)
Construction Period (%)[a]					
Before 1950	4.96	5.40	6.38	1.38	5.23
1950–1959	1.53	1.71	1.05	1.35	1.62
1960–1969	4.28	5.05	2.51	3.59	3.79
1970–1979	8.67	9.80	4.87	9.86	5.77
1980–1989	24.49	31.74	6.15	23.55	8.93
1990–1999	17.88	19.11	10.40	19.09	26.86
2000–2009	30.37	23.86	43.42	37.33	38.88
2010 or After	7.82	3.34	25.23	3.86	8.90
LEED Certifications (no.)	988	907	72	3	6
LEED Level (no.)					
Certified	60	50	6	1	3
Silver	281	246	33	2	–
Gold	559	527	29	–	3
Platinum	88	84	4	–	–
LEED Program (no.)					
EBOM	768	755	8	1	4
BDC	104	57	47	–	–
CS	103	95	4	2	2
Homes	13	–	13	–	–
Interventions (no.)					
CDP–Energy-Efficiency: Building Services[b]	1,074	489	222	114	249
GRESB–Installation of HE Equipment and Appliances[c]	789	282	155	110	242
Lighting	628	208	132	109	179
HVAC	223	144	6	1	72
Building Controls	140	110	18	4	8
Occupier Engagement	86	25	53	2	6
No. of Building-Months	421,537	247,813	75,614	65,535	32,575
No. of Buildings	7,273	3,542	1,637	1,577	517

Notes: Standard deviations in parentheses.

[a]*Year of construction is not known for the entire sample. This information is available for 320,582 observations, pertaining to 5,077 buildings.*

[b]*Includes building controls, HVAC, lighting, boiler system, fan systems, high-efficiency appliances, high-efficiency equipment, load reductions, occupier engagement heating and cooling, occupier engagement technology, smart grid/smart building technologies, and systems retrocommissioning.*

[c]*Includes HVAC, lighting, boiler system, and high-efficiency appliances.*

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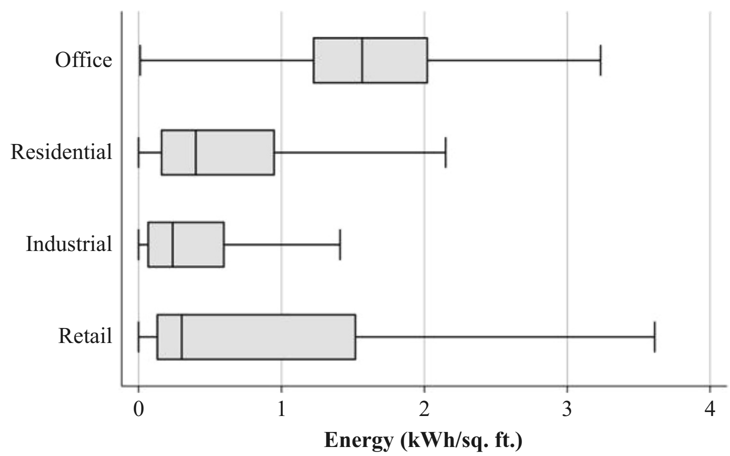
for the average office building in our sample—almost triple the consumption. Exhibit 2 visualizes the median energy consumption across all 7,273 buildings for different building categories and across time. Panel A of Exhibit 2 corroborates the differences in energy consumption across property types documented in Exhibit 1. Office buildings consume the most energy per square foot, followed by residential, retail, and industrial buildings, respectively. These differences likely stem from the relative use intensity of different property types. We observe the largest variation in energy consumption for retail, which may in part be explained by the large heterogeneity in type of retail assets (e.g., strip malls, enclosed shopping malls, supermarkets).

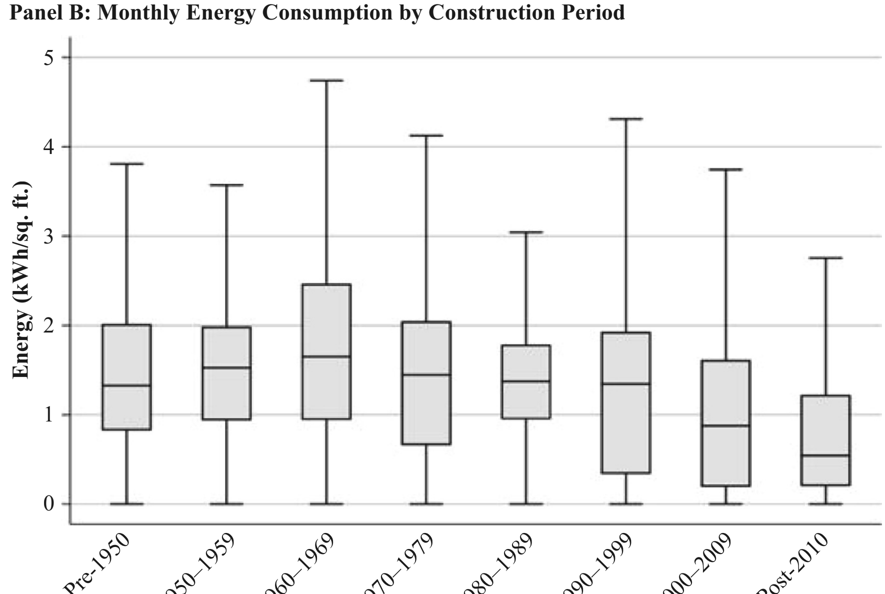
Exhibit 2

Energy Consumption across Building Categories and Time

Panel A: Monthly Energy Consumption by Property Type



Panel B: Monthly Energy Consumption by Construction Period



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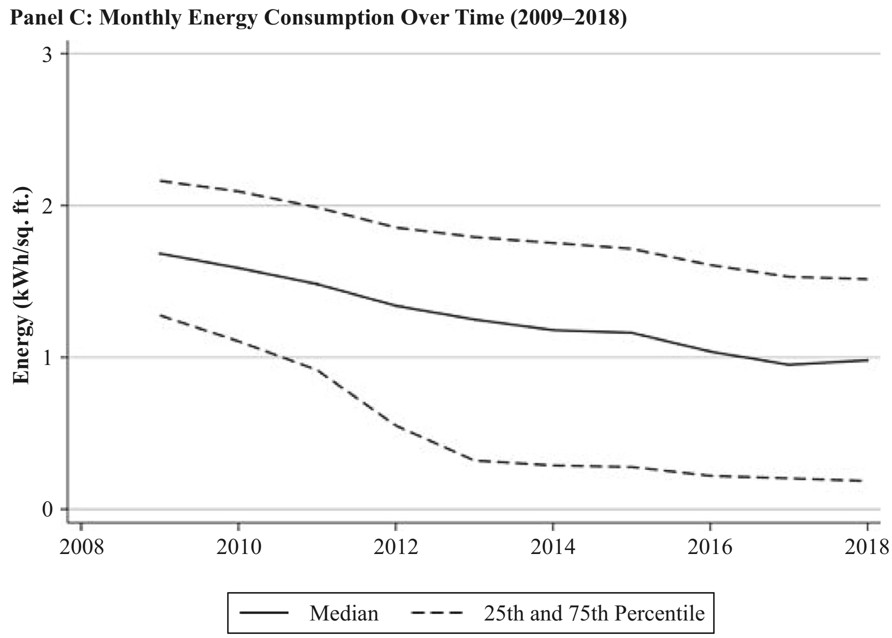
E X H I B I T   2 *(continued)*

Energy Consumption across Building Categories and Time



Notes: Panel A presents boxplots of energy consumption per property type. Panel B indicates differences in energy consumption by construction period. Panel C displays the energy consumption trajectory for the sample over time; the solid line depicts the 50th percentile, and the dashed lines represent the 25th and 75th percentiles.

Exhibit 2, Panel B shows the relationship between construction period and energy consumption, with buildings constructed before the 1970s being the least energy efficient at a monthly median consumption of 1.5 kWh per square foot. The exhibit also shows a clear trend toward improved energy efficiency, with higher energy efficiency especially for the post-2000 cohorts. The youngest buildings are most efficient: 0.5 kWh per square foot. These (simple) statistics are in contrast to the findings of Kahn, Kok, and Quigley (2014) and provide some evidence of increased efficiency in new buildings (of course, this could also be a newness effect, in line with Levinson 2016). The graph shows large variation within these age cohorts, and the differences in average energy consumption are statistically significant.[9]

The time trend of the monthly median energy consumption during the 2009–2018 sample period is illustrated in Exhibit 2, Panel C, indicating a decrease from some 1.7 kWh per square foot in 2009 to 1.0 kWh per square foot in 2018, a reduction of approximately 42%. This is likely due to the increased energy efficiency of newer buildings that are added to the sample but also to interventions aimed to improve building energy efficiency.

The main environmental certification system that we consider in this article is LEED. LEED is among the holistic certification systems, not only providing information about buildings' ex ante assessed energy consumption—based on building engineering criteria—but also about location, accessibility to public transportation, and so on. On the other hand, LEED does not focus on verifying actual energy consumption, which is the result of occupant behavior as well as a building's technical characteristics.[10]

[9] Significance verified based on a two-sample *t*-test comparing each construction period to the other construction periods.

[10] Within the different LEED programs, credit is awarded for Advanced Energy Metering—the implementation of monitoring equipment; however, the extent to which such equipment is used to reduce any discrepancy between estimated and actual energy consumption is not clear. See https://www.usgbc.org/credits/ for a detailed overview of the different credits that are awarded under different rating programs and versions.

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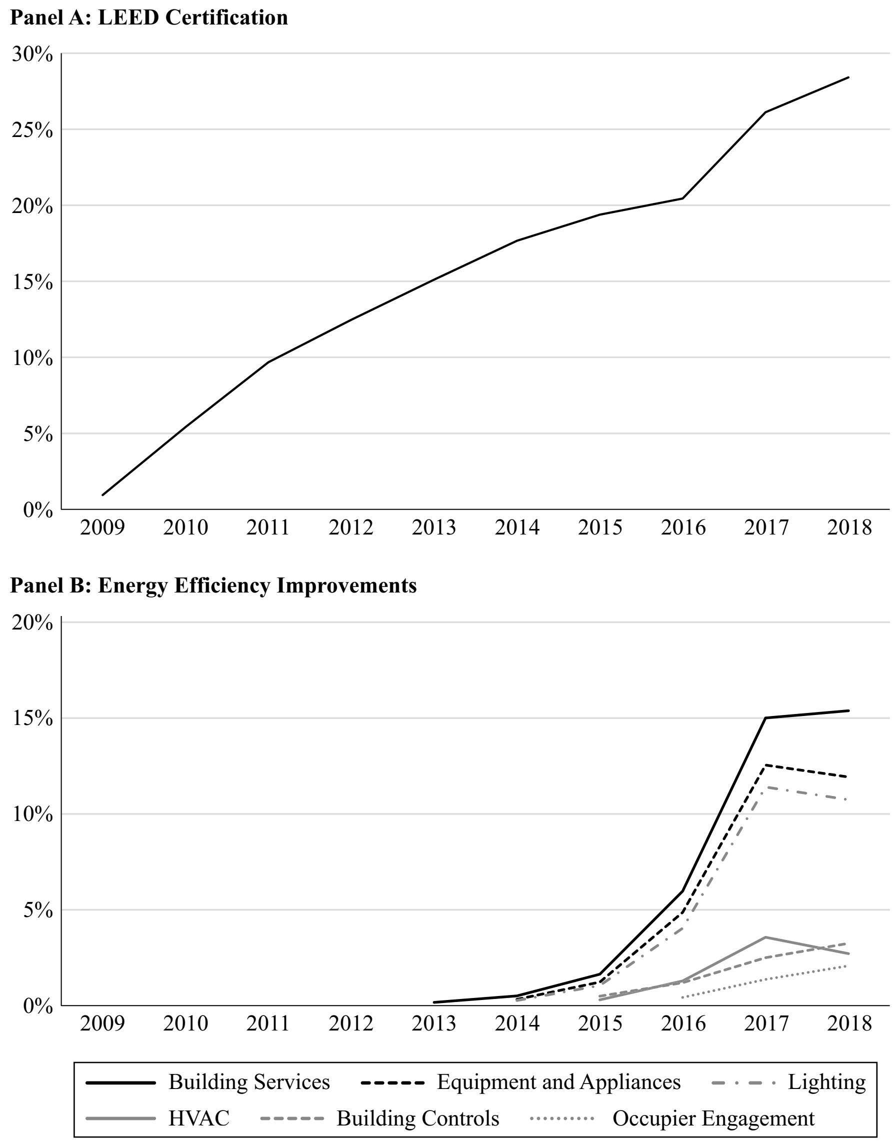
Exhibit 3
Uptake of LEED Certification and Energy Efficiency Improvements, 2009–2018



Note: The graphs in Panels A and B illustrate the adoption of LEED certification and various energy efficiency improvements in our sample over time.

Exhibit 3, Panel A provides insight into the temporal adoption of green building certification in our sample. Comparable to the CBRE/UM Green Building Adoption Index, which analyzes the broader universe of commercial buildings, we document a significant increase in the extent of green building certification over time, reaching almost 30% in 2018.

Exhibit 1 provides further insight into green certification in our sample. We observe the most certification activity in office buildings: 92% of all LEED certifications are related to office properties. We also observe that mere certification is relatively rare in the sample and that the large majority of assets are awarded a Silver, Gold, or Platinum label. Overall, 57% of the building certifications levels are LEED Gold, followed by LEED Silver at 28%. We also have information about the adoption of specific LEED programs: Operations and Maintenance (EBOM), Building Design and Construction (BDC),

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and Core and Shell (CS).[11] The EBOM and BDC programs aim to address design and construction activities for both new buildings and major renovations of existing buildings. This includes major HVAC improvements, significant building envelope modifications, and major interior rehabilitation. The CS program is for projects in which the developer controls the design and construction of the entire mechanical, electrical, plumbing, and fire protection system—called the core and shell—but not the design and construction of the tenant fit-out.

The information in our dataset on interventions allows us to differentiate among various types of energy efficiency programs implemented by building owners. We have information on energy efficiency interventions as defined and measured by CDP and GRESB, both corporate sustainability reporting schemes.[12] The interventions may partially overlap. For example, we have information about the general energy efficiency improvements related to Building Services from CDP, which encompasses lighting, HVAC, and occupier engagement interventions, and we have specific information about these individual interventions. Five of the six interventions we observe are technical, and one is of a more behavioral nature.

Exhibit 1 and Panel B of Exhibit 3 provide sample statistics on building interventions. Of the specific interventions, lighting retrofits are the most popular in the sample, with 628 occurrences. Two other popular interventions are HVAC improvements and building control systems. The behavioral intervention is tenant engagement, which aims to improve energy efficiency through the behavior of a building's users.

EMPIRICAL RESULTS

The Effect of Certification on Energy Efficiency

We first investigate the association between the LEED environmental building certification program and commercial building energy consumption.[13] It is important to note that we do not assume or infer a causal relationship between these two issues—certification is endogenous, and certain types of building owners may be more likely than others to both certify their assets and implement other energy efficiency measures.

Exhibit 4 provides the results from the estimation of Equation 1 using environmental building certification to explain commercial buildings' energy consumption. We include building-fixed effects to capture any structural variation in consumption across buildings and month-fixed effects to account for seasonality in energy consumption, and we include monthly cooling and heating degree days to control for differences in local climate. As expected, monthly cooling and heating degree days have a significantly positive impact on energy consumption.

Columns 1 and 2 of Exhibit 4 present the association between LEED certification and monthly energy consumption per square foot. The average building in our sample consumes 8.2% less energy after obtaining a LEED certification. There is significant heterogeneity across the different LEED certification levels, as documented in column 2. The lowest tier of certification, LEED Certified, although infrequently observed, is associated with a 10.5% reduction in (average) monthly energy consumption. The most frequently observed certification levels, LEED Silver and Gold, both significantly affect energy consumption. The effect ranges from 6.1% for LEED Gold to 11.1% for LEED Silver. The reduction in energy consumption for a LEED Platinum label, the designation that signals the highest level of sustainability, is largest, at 12.3%.

Column 3 of Exhibit 4 documents the results for different LEED programs. EBOM and BDC are both associated with increased energy efficiency, whereas the CS program is not. This may be explained by the fact that the LEED BDC and LEED EBOM programs can also be applied to major renovations of existing buildings, addressing the fit-out of the building. The LEED CS program is strictly reserved for new construction and employed in situations in which the developer has control over just the design and construction of the mechanical, electrical, plumbing, and fire protection system, called the core and shell. Tenant fit-out is not

[11] LEED for Commercial Interiors (CI) is deemed a tenant initiative, strictly pertaining to the fit-out of the space, and often does not cover the entire asset. Therefore, any building that is certified under the LEED CI program is excluded from the analysis.

[12] CDP, formerly known as the Carbon Disclosure Project, runs a nonprofit global carbon disclosure system. CDP works with investors, companies, and cities to measure and understand their environmental impact through self-reported data (https://www.cdp.net/en).

[13] This part of the analysis is focused on the subsample of office buildings, given that 92% of the certified buildings are offices.

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EXHIBIT 4

LEED Certification and Energy Consumption—Office (dependent variable: natural log of energy consumption per square foot)

	(1)	(2)	(3)	(4)
LEED (1 = yes)	–0.082***			
	[0.014]			
LEED Level (1 = yes)				
Certified		–0.105***		
		[0.023]		
Silver		–0.111***		
		[0.019]		
Gold		–0.061***		
		[0.017]		
Platinum		–0.123*		
		[0.072]		
LEED Program (1 = yes)				
EBOM			–0.097***	
			[0.013]	
BDC			–0.133***	
			[0.042]	
CS			0.111**	
			[0.054]	
LEED Certification Tenure (1 = yes)				
Upto 6 months				–0.048***
				[0.013]
7 to 12 months				–0.068***
				[0.013]
13 to 18 months				–0.081***
				[0.014]
19 to 24 months				–0.089***
				[0.014]
25 to 30 months				–0.083***
				[0.015]
31 to 36 months				–0.080***
				[0.017]
37 to 42 months				–0.095***
				[0.021]
43 to 48 months				–0.122***
				[0.025]
49 to 54 months				–0.132***
				[0.023]
55 to 60 months				–0.147***
				[0.034]
61 to 66 months				–0.108***
				[0.031]
67 to 72 months				–0.100*
				[0.057]
More than 72 months				–0.131***
				[0.040]
Cooling Degree Days (monthly in thousands)	0.430***	0.430***	0.431***	0.431***
	[0.019]	[0.019]	[0.019]	[0.019]
Heating Degree Days (monthly in thousands)	0.405***	0.405***	0.405***	0.404***
	[0.012]	[0.012]	[0.012]	[0.012]
Month-Fixed Effects	Yes	Yes	Yes	Yes
Building-Fixed Effects	Yes	Yes	Yes	Yes
Constant	0.215***	0.215***	0.214***	0.216***
	[0.009]	[0.009]	[0.009]	[0.009]
Building-Months	230,314	230,314	230,314	230,314
Number of Buildings	3,238	3,238	3,238	3,238
Adj. R^2	0.729	0.729	0.729	0.729

*Notes: Standard errors, clustered at the building level, are in brackets. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.*

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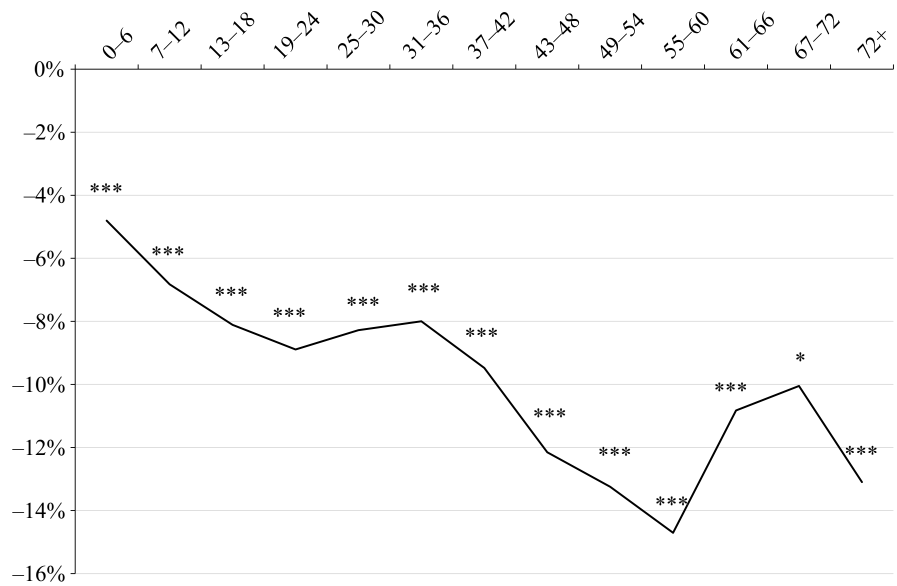
EXHIBIT 5
LEED Certification Tenure (months)



Notes: Exhibit 4 displays the decrease in energy consumption as a function of LEED certification age, based on the point estimates documented in Exhibit 3.
** and *** indicate significance of the point estimates at the 0.10 and 0.01 levels, respectively.*

included in the program, and this arguably has a significant effect on energy performance.

The fourth column provides the estimation results when LEED certification is obtained and interacted with tenure of the certification, or the time period that lapsed since the award of the certification. The results show that the energy efficiency of the building gradually improves during the first 60 months after the certification is acquired but stabilizes afterward. To illustrate this certification aging effect more clearly, Exhibit 5 presents the results of column 4. The relationship between LEED certification tenure and energy consumption is U-shaped: We observe a decrease in energy consumption that gets stronger up to some five years after certification and then stabilizes. Thereafter, the reduction in energy consumption starts to dissipate.

The Effect of Interventions on Energy Efficiency

Exhibit 6 shows the median energy consumption per square foot before and after LEED certification or particular energy efficiency investments. The sample for each graph is restricted to those assets that undergo the mentioned treatment. Therefore, the figures display a true pre–post comparison. On average, the delta between pre- and postintervention is 20%. This is largest for the occupier engagement intervention and smallest for the building controls intervention. Of course, these are just nonparametric comparisons that do not control for confounding factors influencing energy consumption.

Exhibit 7 presents the results from the estimation of Equation 2, relating various energy efficiency interventions to monthly energy consumption.[14] Similar to our earlier estimation, all models include building-fixed and month-fixed effects, absorbing systematic variation in energy consumption across buildings (e.g., building size and construction period) and over time (e.g., weather). Also similar to our previous estimations, we recognize that energy efficiency interventions are endogenous, and we cannot rule out that some landlords or buildings are more likely to consider energy

[14] We also perform these regressions with the inclusion of the LEED certification dummy, and results for the different interventions are almost identical to the results presented here. The coefficient for the LEED dummy varies between 5.7% and 6.1%, which is very similar to what we report in Exhibit 4.

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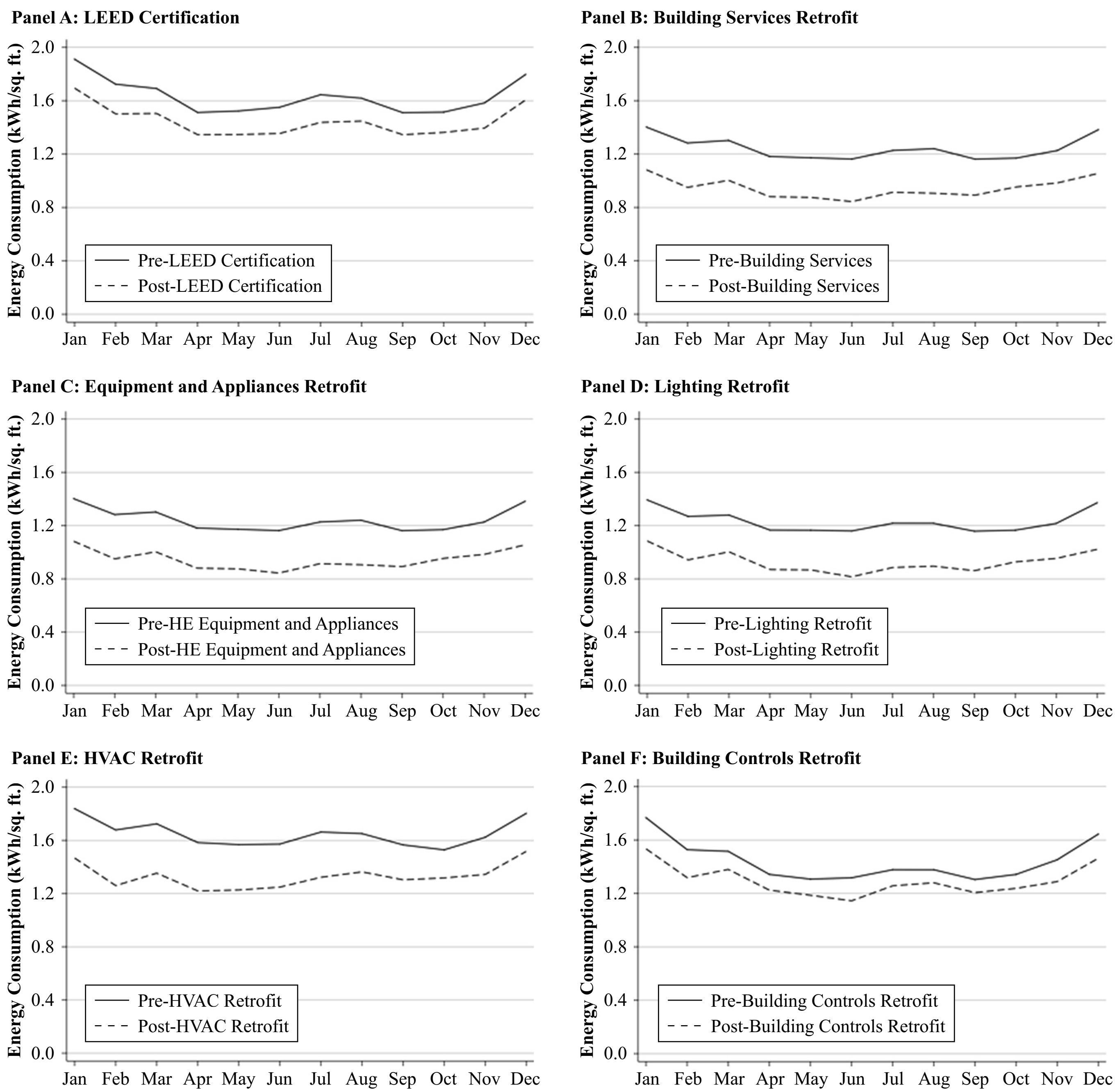
efficiency than others. Our results may thus be slightly biased, upward or downward.

The first two columns of Exhibit 7 focus on two broader intervention categories, as measured by CDP and GRESB categories, and the remaining columns focus on specific interventions aimed at improving energy efficiency. The results in Column 1, pertaining to a broad range of building services interventions, indicate that these interventions, on average, reduce energy consumption by 8.1%. This category encompasses 12

EXHIBIT 6

Energy Consumption before and after Certification and Energy Efficiency Improvements



(continued)

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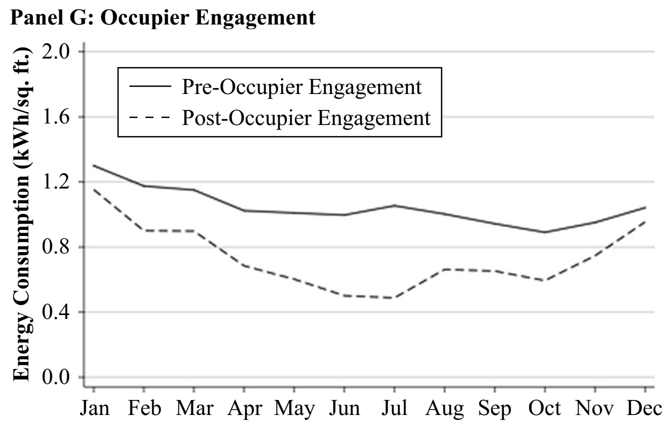
EXHIBIT 6 *(continued)*

Energy Consumption before and after Certification and Energy Efficiency Improvements



Notes: Panels A through G present the median energy consumption per square foot before and after LEED certification or particular energy efficiency improvements. The sample for each graph is restricted to those assets that undergo the mentioned treatment. Therefore, the figures display a true pre–post comparison.

different interventions, such as retrofitting the HVAC, lighting, boiler system, and fan system; installing high-efficiency appliances and equipment; and initiating occupier engagement. The second intervention category—installing different high-efficiency appliances and equipment—documented in column 2 reduces average energy consumption by 8.4%. In total, four interventions are captured by this category: retrofitting the HVAC, lighting, and boiler system and installing high-efficiency appliances.

Columns 3 to 7 disentangle the impact of four specific energy efficiency interventions. Most of them lower energy use significantly. Average energy consumption decreases by 8.7% after a lighting retrofit, as displayed in Column 3. Similarly, retrofitting the HVAC system reduces energy consumption, on average, by 9.5%. Addressing building controls reduces the average energy consumption by 11.4%. For the average office building in the sample, these effects translate into a decrease in annual energy expenditure of $566,000 to $742,000.[15] Interestingly, engaging the occupiers of a building does not significantly reduce energy consumption. This is in contrast to the literature on behavioral programs in residential real estate (e.g., the information provided by OPOWER on consumption relative to neighbors; see Alcott and Mullainathan 2010), and the latter finding calls into question whether there is a salient behavioral component in commercial building energy consumption as well.[16]

In the final column of Exhibit 7, we combine these four interventions into one estimation. Two of the results are robust to this combination, and the magnitude of individual interventions is somewhat muted. Interestingly, if one were to combine all interventions, the combined energy reduction result would be over 15%.

Exhibit 8 investigates the heterogeneity of the observed effects relative to local weather conditions. We focus on the extent of cooling degree days in an area and thus the energy needed to manage cooling load. For all interventions but HVAC improvements, we document significant heterogeneity in the effect relative to local weather conditions. Column 1 shows that, at the point of means, the effect of the broad set of interventions under the CDP Building Services category reduces energy consumption by 8.1%. However, a one standard

[15] Based on the average utility expenditure per square foot reported in BOMA International's 2018 Office Experience Exchange Report (https://www.boma.org/BOMA/Research-Resources/3-BOMA-Spaces/Newsroom/PR91818.aspx).

[16] We also estimated the effects of the energy efficiency interventions for each property type separately. In these estimations, the occupier engagement indicator is negative and significant for office buildings but not for the other property types.

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Exhibit 7

Interventions and Energy Consumption (dependent variable: natural log of energy consumption per square foot)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intervention Category (1 = yes)							
CDP—Energy Efficiency: Building Services	–0.081***						
	[0.017]						
GRESB—Installation of High-Efficiency Equipment and Appliances		–0.084***					
		[0.018]					
Lighting			–0.087***				–0.074***
			[0.020]				[0.022]
HVAC				–0.095***			–0.034
				[0.021]			[0.025]
Building Controls					–0.114***		–0.083**
					[0.038]		[0.039]
Occupier Engagement						–0.036	0.005
						[0.045]	[0.045]
Cooling Degree Days (monthly in thousands)	0.419***	0.419***	0.419***	0.418***	0.418***	0.417***	0.419***
	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]
Heating Degree Days (monthly in thousands)	0.497***	0.497***	0.497***	0.497***	0.498***	0.498***	0.497***
	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]
Month-Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Building-Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	–0.494***	–0.494***	–0.494***	–0.496***	–0.496***	–0.497***	–0.494***
	[0.009]	[0.009]	[0.009]	[0.009]	[0.009]	[0.009]	[0.009]
No. of Building-Months	421,519	421,519	421,519	421,517	421,455	421,519	421,519
No. of Buildings	7,255	7,255	7,255	7,255	7,254	7,255	7,255
Adj. R^2	0.860	0.860	0.860	0.860	0.860	0.860	0.860

Notes: Standard errors, clustered at the building level, are in brackets.

, **, and * indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.*

deviation increase in the number of cooling degree days leads to a total decrease in energy consumption of 11%. A two standard deviation increase in the number of cooling degree days reduces energy consumption by 13.9%, following interventions in the Building Services category. Effects are quite similar for the GRESB energy intervention category.

For lighting retrofits, results are even stronger. Although one may not directly relate lighting systems to cooling requirements, it is important to note that the immediate byproduct of lighting is heat. More efficient lighting thus has an effect on energy consumption not just through the lighting channel but also through the cooling channel. Interestingly, we do not find significant heterogeneity in the effect of HVAC interventions as it relates to cooling degree days. The interaction effects between building controls and weather are again very strong, with effects increasing by 3.3% when the number of cooling degree days increases by one standard deviation. Behavioral programs seem effective only in hotter climates—this makes intuitive sense, as many such programs rely on normative demand-management interventions, such as lobby signage, to reduce energy consumption on hot days.

SUMMARY AND IMPLICATIONS

An extensive literature documents the relationship between environmental certification programs and the economic and financial performance of buildings, showing that environmentally certified buildings achieve higher rents, higher and more stable occupancy

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EXHIBIT 8

Energy Efficiency Improvements and Warmer Local Climates (dependent variable: natural log of energy consumption per square foot)

	(1)	(2)	(3)	(4)	(5)	(6)
CDP—Energy Efficiency: Building Services (1 = yes)	–0.057***					
	[0.019]					
CDP—Energy Efficiency: Building Services × Cooling Degree Days	–0.171***					
	[0.050]					
GRESB—Installation of High-Efficiency Equipment and Appliances (1 = yes)		–0.063***				
		[0.021]				
GRESB—Installation of High-Efficiency Equipment and Appliances × Cooling Degree Days		–0.154***				
		[0.055]				
Lighting (1 = yes)			–0.060***			
			[0.023]			
Lighting × Cooling Degree Days			–0.197***			
			[0.062]			
HVAC (1 = yes)				–0.107***		
				[0.023]		
HVAC × Cooling Degree Days				0.090		
				[0.074]		
Building Controls (1 = yes)					–0.091**	
					[0.039]	
Building Controls × Cooling Degree Days					–0.191*	
					[0.114]	
Occupier Engagement (1 = yes)						0.043
						[0.047]
Occupier Engagement × Cooling Degree Days						–0.573***
						[0.167]
Cooling Degree Days (monthly in thousands)	0.423***	0.422***	0.422***	0.417***	0.418***	0.419***
	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]
Heating Degree Days (monthly in thousands)	0.497***	0.497***	0.497***	0.497***	0.498***	0.498***
	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]	[0.013]
Month-Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Building-Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	–0.496***	–0.496***	–0.497***	–0.497***	–0.498***	–0.499***
	[0.007]	[0.007]	[0.007]	[0.007]	[0.007]	[0.007]
No. of Building-Months	421,519	421,519	421,519	421,517	421,455	421,519
No. of Buildings	7,255	7,255	7,255	7,255	7,254	7,255
Adj. R^2	0.860	0.860	0.860	0.860	0.860	0.860

Notes: Standard errors, clustered at the building level, are in brackets.
, **, and * indicate significance at the 0.10, 0.05, and 0.01 levels, respectively.*

rates, better liquidity, and higher transactions prices (Eichholtz, Kok, and Quigley 2013). Few studies, however, have investigated the concurrent state of the commercial real estate sector's energy performance and how environmental certification programs relate to actual energy efficiency. In addition, the environmental performance effects of specific interventions to improve energy efficiency are largely unknown.

The results presented in this article indicate that the commercial real estate sector is on a trajectory to significant reductions in energy consumption: We document a reduction in energy use intensity of 42% over the past

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decade. Evaluating the efficacy of green labels, we show that, on average, energy consumption is reduced by 8% after certification. There is substantial variation in the decrease in energy consumption based on certification level and label vintage. These findings suggest that environmental building certification is not only associated with improved financial performance of buildings but also with enhanced energy performance. Moreover, specific interventions (e.g., retrofitting the HVAC system, retrofitting the lighting system, improving building controls, and developing occupier engagement programs) improve the energy efficiency of commercial buildings, with average effects per intervention ranging from 8% to 11%. We observe that these interventions in combination reduce energy consumption in commercial buildings by over 15%.

The implications of the findings and this article are important and relevant for all stakeholders in the commercial real estate industry. With increasing attention to the energy consumption of the commercial real estate sector, policymakers are actively drafting legislation targeting the sector. In addition, both equity investors in real estate and commercial real estate lenders have started to consider environmental certification and/or energy efficiency in financing and underwriting decisions. A variety of financial instruments now use environmental certification programs such as LEED for investment and lending decisions. For example, Fannie Mae provides a 10 bp–20 bp rate reduction on loans to green-certified multifamily assets. FTSE Russell, an index provider, recently launched a green REIT index that weighs higher those REITs with a larger share of green-certified buildings. Our results indicate that the sector has been responsive to these developments, rapidly reducing its energy footprint.

Of course, further research is needed on this issue. Notably, data on the cost of interventions (and the cost of environmental certification) are lacking in our analysis, limiting our ability to provide a full cost–benefit analysis. Furthermore, although the trends we observe are encouraging, we need a longer time period to understand whether this is just a new building effect (similar to Levinson 2016) fueled by the post-crisis real estate development boom or truly a systematic change in commercial building energy performance. Finally, our sample is a small representation of the full universe of income-producing properties. Although institutional real estate portfolio owners and investors may have engaged more actively in energy efficiency programs and projects, whether smaller investors have equally expended capital into the energy performance of their assets remains an open question.

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ADDITIONAL READING

Green Certification and Building Performance: *Implications for Tangibles and Intangibles*

Avis Devine and Nils Kok
The Journal of Portfolio Management
https://jpm.pm-research.com/content/41/6/151

ABSTRACT: *Commercial buildings represent a significant share of global energy consumption. In the general absence of regulation, voluntary labeling and green building certification schemes have been introduced to reflect this externality to building owners and tenants. The implications of such schemes have previously been documented to affect building financial performance. However, existing studies have focused mostly on the US market and, more importantly, generally include only a limited set of performance metrics. Using a rich, proprietary dataset from one of the largest building owners/managers in North America, the authors investigate the effects of green building certification on non-financial metrics, such as tenant satisfaction, incentives, and lease renewal. Their empirical results show that buildings certified through voluntary labeling schemes generally have a higher probability of lease renewal, offer lower incentives, and have more satisfied tenants. They then study the effects of green building certification on financial metrics, such as rents and occupancy levels. The findings for the US sample unambiguously confirm previously documented results—LEED and ENERGY STAR certified buildings command a small rent premium and have a lower vacancy risk. For Canada, the effects for LEED certified buildings are consistent with US results. The results show that the national green building scheme is not priced in, but that these buildings still offer greater overall stability versus non-certified buildings through increased releasing rates, lower incentives, and substantially higher tenant satisfaction levels. The findings reported in this article provide an important contribution to the understanding of underlying value drivers in more efficient, sustainable buildings and offer some first evidence for the international validity of otherwise mostly US-based studies on the financial performance of more efficient, "green" commercial buildings.*

Integrating ESG in Portfolio Construction

Roy Henriksson, Joshua Livnat, Patrick Pfeifer, and Margaret Stumpp
The Journal of Portfolio Management
https://jpm.pm-research.com/content/45/4/67

ABSTRACT: *In this article, the authors recommend an approach to integrate environmental, social, and governance (ESG) issues into portfolios that is based on two premises. The first is that classification of firms as good or bad ESG companies should be performed using ESG items that are material in that industry. The second premise is that it is possible to overcome the sparse voluntary ESG data reported by firms by constructing an ESG good minus bad (GMB) factor and then finding those firms whose returns load significantly on this factor. The authors provide evidence that shows the superiority of using material, industry-specific ESG items and the merits of expanding the ESG classification using the ESG GMB loadings. Their approach is particularly suitable for quantitative investment approaches that invest in portfolios with large number of positions and many small active exposures, wherein vendor ESG data can be used in portfolio construction efficiently without the need to employ detailed ESG analyses of many individual firms. With such portfolios, it is less about the ESG classification of an individual company than about the aggregate portfolio tilt toward good ESG and away from bad ESG at the portfolio level.*

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