A Different Look at Commercial Real Estate Performance: Insights into Energy Efficiency Improvements

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Abstract

This paper provides new insights into the performance of commercial real estate – focusing on the environmental performance of institutional assets. We employ a proprietary dataset of energy consumption data that includes more than 26,000 buildings between 2009 and 2018. We document that in our sample of commercial real estate, the median energy intensity decreased by more than 40 percent over the past decade. Using a difference-in-difference analysis, we find that adoption of environmental building certification (LEED) is associated with 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 significantly reduce ex-post energy consumption, with effects varying depending on the local climatic conditions.

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On January 16, 2018, Larry Fink, CEO of Blackrock, sent his annual letter to the CEOs of the world's largest publicly traded companies. Rather than focusing this yearly tradition on issues like global disorder or the macroeconomic environment, the CEO of the largest asset management firm in the world (with some $6 trillion in assets under management) this time laid out his beliefs in the purpose of the firm – beyond quarterly profits. Quoting Larry Fink "a company's ability to manage environmental, social, and governance matters demonstrates the leadership and good governance that is so essential to sustainable growth, which is why we are increasingly integrating these issues into our investment process." [1]

Such a public and high-profile embrace of environmental, social, and governance (ESG) factors shows how far both businesses and investors have advanced in their consideration of sustainability issues. Indeed, the integration of ESG factors into investments is slowly 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 percent of total annual U.S. energy consumption, of which half is consumed by commercial real estate. Importantly, the EIA predicts that energy consumption in commercial real estate is slated to increase by 19.5 percent until 2050, despite energy efficiency improvements. In contrast, the predicted growth in energy consumption to 2050 for the residential sector is "just" 5.7 percent. The increase in commercial buildings' energy consumption is largely due to growing

[1] See https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter.

floor space and increasing technology needs, which offset efficiency gains in lighting and appliances.[2]

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 non-certified real assets. See, for example, Devine and Kok (2015), Eichholtz et al. (2010, 2013), and Holtermans and Kok (forthcoming). However, not much is known about the actual *environmental* performance of commercial buildings, beyond case studies and anecdote. How does the sector fare when it comes to reducing its energy consumption? In addition, the environmental performance effects of specific building interventions are largely undocumented, and that also holds for the relationship between environmental performance and environmental certification. Both initiatives are typically part of public policy efforts and investor engagement with REITs and private equity real estate investments. Understanding the efficacy of these interventions is thus important to ensure appropriate allocation of resources to improve the energy efficiency of the built environment.

Kahn et al. (2014) is among the few studies that 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 document 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 the utilities are bundled with the rent consume *more* energy and respond *less* to temperature shocks as opposed to tenants that are

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

responsible for their own utility bill. In related work, Kahn et al. (2016) exploit 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 document 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 most progress in improving energy efficiency between 2007 and 2013, reducing consumption by 35 percent over the seven-year period.

The literature on energy consumption in real estate has mostly focused on the residential space, where consumption is determined both by physical buildings characteristics, as well as heterogeneous occupants. For example, Brounen et al. (2012) investigate household energy consumption and document 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 subject of quite a few recent studies.[3] Jacobsen and Kotchen (2013) show that stricter building codes improve energy outcomes, and that reductions in energy consumption are persistent. However, Levinson (2016) counters that such effects are merely due to the "newness" of construction, and that efficiency gains from more recent building codes disappear over time. Fowlie et al. (2018) develop a large field experiment in Michigan, documenting much smaller treatment effects following energy retrofits than what engineering estimates would suggest, perhaps due to the often-cited rebound effect (Aydin et al., 2017).

[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 et al., 2018).

The current research lacuna on the economics of commercial building energy consumption, both in the cross-section and over time, is mostly due to the fact that information on energy consumption in commercial buildings is notoriously hard to obtain, contrasting widespread 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 (CBECS), but data from this survey is available on an irregular basis, with information on just a small set of buildings to represent the U.S. 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, providing access to a proprietary set of longitudinal data on some 26,000 buildings. These buildings are owned and managed by renowned institutional real estate investors such as Clarion Partners, CBRE Global Investors, and USAA Real Estate, 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 interventions and environmental certification on energy consumption, covering the 2009-2018 period.

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

The non-parametric statistics show that, although energy intensity (i.e. energy consumption per square foot of space) varies widely both within and across property types, the average energy consumption of commercial real estate decreased by 42 percent 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 LEED (Leadership in Energy and Environmental Design) label that is used by many landlords as a signaling device for "green" building practices, we document that the energy efficiency of a building *after* certification increases by eight percent, on average. However, the level of certification matters for the extent of energy savings, and while the effects are increasing four years after certification, the efficiency gains start to slowly dissipate after that. The results on the effect of energy interventions – investments in lighting, HVAC, building controls, etc. – 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. Especially "soft" behavioral interventions (e.g. tenant engagement programs) lead to significant reductions in energy consumption in warmer climates.

This study is important for multiple reasons. First, whereas there is a voluminous literature on matters of energy consumption and energy efficiency in the housing market, the commercial real estate sector has been mostly overlooked. Given that the commercial real estate sector represents 18 percent of U.S. energy consumption, and that such consumption is increasingly scrutinized by policy makers and investors alike, understanding the current energy performance of commercial real estate can provide useful insights to set benchmarks and reduction targets, and to design optimal energy policy.

Second, we investigate the environmental performance effects of specific building interventions in commercial real estate, and to date such evaluations have been scant. A critical look at the impact of energy efficiency investments is important for appropriate allocation of capital – for example, our findings show the efficacy of behavioral (or "soft") interventions in warmer climates, which are typically low-cost programs.

Third, the diffusion of "green" building certification has taken flight over the past years, with some 20 percent of the U.S. office stock LEED-certified.[5] There are now a variety of financial instruments that use environmental certification programs such as LEED for investment and lending decisions. For example, Fannie Mae provides a 10-20bp 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. Given that building certification is typically based on ex-ante, assessed energy performance rather than actual performance, 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

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

affect commercial buildings' energy consumption. We address the first research question in a non-parametric, descriptive analysis. We then empirically assess the second and third research question, estimating the following regression equations, designed to control for the effects of unobservable factors that also determine energy consumption trajectories:

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

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

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. 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 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, providing 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, for example 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, 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 most closely 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 sq. ft.), corresponding to some 4 GWh per year (or: 15.27 kWh per sq. ft.). We observe quite some heterogeneity in energy

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[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 6 months of energy consumption information before and after each certification activity or energy efficiency improvement. Non-treated buildings have at least 2 months of available energy consumption information.

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 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 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, etc.).

Exhibit 2 Panel B shows the relationship between construction period and energy consumption, with buildings constructed before the 1970s being the least energy-efficient, with a monthly median consumption of 1.5 kWh per square foot. The exhibit also shows a clear trend towards 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 contrasting the findings of Kahn et al. (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 in 2018, a reduction of approximately 42 percent. This is likely due to the

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

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 paper is LEED – Leadership in Energy and Environmental Design. 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, etc. 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]

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 percent in 2018.

Exhibit 2 provides further insight into green certification in our sample. We observe most certification activity in office buildings: 92 percent 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 is awarded a Silver, Gold or Platinum label. Overall, 57 percent of the building certifications levels are LEED Gold, followed by LEED Silver at 28 percent. We also have information about the adoption of specific LEED programs: Operations and Maintenance (EBOM), Building Design and Construction (BDC), and Core and Shell (CS).[11] The EBOM and

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[10] Within the different LEED programs credit is awarded for "Advanced Energy Metering," the implementation of monitoring equipment. Although 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.

[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.

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 where 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 between 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. 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 also 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 2 and Exhibit 3 Panel B 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, aiming 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.[12] 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 to implement other energy efficiency measures.

Exhibit 4 provides the results from the estimation of Equation (1) using environmental building certification to explain commercial building's 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, both monthly cooling and heating degree days have a significantly positive impact on energy consumption.

Columns 1 and 2 present the association between LEED certification and monthly energy consumption per square foot. The average building in our sample consumes 8.2 percent 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, is not associated with a significant reduction in (average) monthly energy consumption, while the most frequently observed certification levels, LEED Silver and Gold, are both significantly affecting energy consumption. The effect ranges from 11.1 percent for LEED Silver to 6.1 percent for LEED Gold. The reduction in energy consumption for a LEED Platinum label, the designation that signals the highest level of sustainability, is largest, at 12.3 percent.

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

Column 3 of Exhibit 4 documents the results for different LEED programs. The programs Operations and Maintenance (EBOM) and Building Design and Construction (BDC) are both associated with increased energy efficiency, whereas the Core and Shell (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 where 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 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 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 48 months after the certification was acquired, but energy performance stabilizes after that. 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 four 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 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. On average, the delta between pre- and post-intervention is 20 percent. This is largest for the occupier engagement intervention and smallest for the building controls intervention. But of course, these are just non-parametric comparisons, that do not control for confounding factors influencing energy consumoption.

Exhibit 7 presents the results from the estimation of Equation (2), relating various energy efficiency interventions to monthly energy consumption. 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 and/or buildings are more likely to consider energy efficiency than others. Our results may thus be slightly biased, upwards or downwards.

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 percent. This category encompasses twelve different interventions, such as retrofitting the HVAC, lighting, boiler system, fan system, installing high-efficiency appliances and equipment, and occupier engagement. The second intervention category – installing different high-efficiency appliances and equipment – documented in Column 2 reduces the average energy consumption by 8.4 percent. In total, four different interventions are captured by this category – retrofitting the HVAC, lighting, boiler system, and installing high-efficiency appliances.

Columns 3 to 7 disentangle the impact of four specific energy efficiency interventions. All of them lower energy use significantly. Average energy consumption decreases by 8.7 percent after a lighting retrofit, as displayed in Column 3. Similarly, retrofitting the HVAC system reduces energy consumption, on average, by 9.5 percent. Addressing building controls reduces the average energy consumption by 11.4 percent. For the average office building in the sample, these effects translate into a decrease in annual energy expenditure of USD 566,000 to 742,000.[13] Interestingly, engaging the occupiers of a building does not significantly reduce energy consumption. This is contrasting 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), the latter finding questions whether there is a salient behavioral component in commercial building energy consumption as well.[14]

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

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 improvement, 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,

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[13] 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).

[14] 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.

reduces energy consumption by 8.1 percent. However, a one standard deviation increase in the number of cooling degree days leads to a total decrease in energy consumption of 11 percent. A two standard deviation increase in the number of cooling degree days reduces energy consumption by 13.9 percent, following interventions in the Building Services category. Effects are quite similar for the GRESB energy intervention category.

For lighting retrofits, results are even stronger. While one may not directly relate lighting systems to cooling requirements, it is important to note that the immediate by-product 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 percent 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

The environmental performance of investments, often referred to as the Environmental, Social, and Governance (ESG) performance, is increasingly incorporated into mainstream investment decision making, and no longer the domain of just socially-responsible investors (Henriksson et al., 2019). In the consideration of environmental performance, commercial real estate is important, both from a policy and investment perspective: the sector consumes 18 percent of U.S. energy consumption, which is nearly the same amount as the residential sector, in a much smaller number of buildings. Therefore, building interventions enhancing energy efficiency in the commercial real estate sector can potentially have a large impact on overall energy consumption.

There is an extensive literature documenting 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 rates, better liquidity, and higher transactions prices (Eichholtz et al., 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 paper indicate that the commercial real estate sector is on a trajectory to significant reductions in energy consumption – we measure a reduction in energy use intensity of 42 percent over the past decade. Evaluating the efficacy of "green" labels, we document that, on average, energy consumption is reduced by 8 percent post-certification. There is substantial variation in the decrease of 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 of buildings. Moreover, specific interventions, such as retrofitting the HVAC system, retrofitting the lighting system, improving building controls, and occupier engagement programs, improve the energy efficiency of commercial buildings, with average effects per intervention ranging from 8 to 11 percent. In combination, we observe that these interventions reduce energy consumption in commercial buildings by over 15 percent.

The implications of the findings and this paper are important and relevant for all stakeholders in the commercial real estate industry. With increasing attention to the energy consumption (and corresponding carbon emissions) of the commercial real estate sector, policy makers are actively drafting legislation targeting the sector. In addition, both equity investors in real estate as well as commercial real estate lenders have started to consider environmental certification and/or energy efficiency in financing and underwriting decisions. Our results indicate that the sector has been responsive to these developments, rapidly reducing its energy footprint. Environmental certification, loved as a tool by many, but despised by some, seems to lead to actual reductions in energy consumption. In addition, investments in energy interventions seem to have the desired supply-side effect, leading to increased energy efficiency.

Of course, the results in this paper need further work for broader application and adoption of energy efficiency investments in the real estate industry to take hold. Notably, data on the cost of interventions (and, the cost of environmental certification) is lacking in our analysis, limiting our ability to provide a full cost-benefit analysis. And, although the time trend on energy use intensity is 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 just a small representation of the full universe of income-producing properties. While institutional real estate portfolio owners and investors may have engaged more actively in energy efficiency programs and projects, it remains an open question whether smaller, mom-and-pop investors, have equally invested capital into the efficiency of their assets.

ENDNOTES

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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 (percent)[1]					
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 (#)	988	907	72	3	6
LEED level (#)					
Certified	60	50	6	1	3
Silver	281	246	33	2	-
Gold	559	527	29	-	3
Platinum	88	84	4	-	-
LEED program (#)					
Existing Buildings: Operations and Maintenance (EBOM)	768	755	8	1	4
Building Design and Construction (BDC)	104	57	47	-	-
Core and Shell (CS)	103	95	4	2	2
Homes	13	-	13	-	-
Interventions (#)					
CDP - Energy-efficiency: Building Services[2]	1,074	489	222	114	249
GRESB - Installation of HE Equipment and Appliances[3]	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
Number of building-months	421,537	247,813	75,614	65,535	32,575
Number of buildings	7,273	3,542	1,637	1,577	517

Notes: Standard deviations in parentheses.

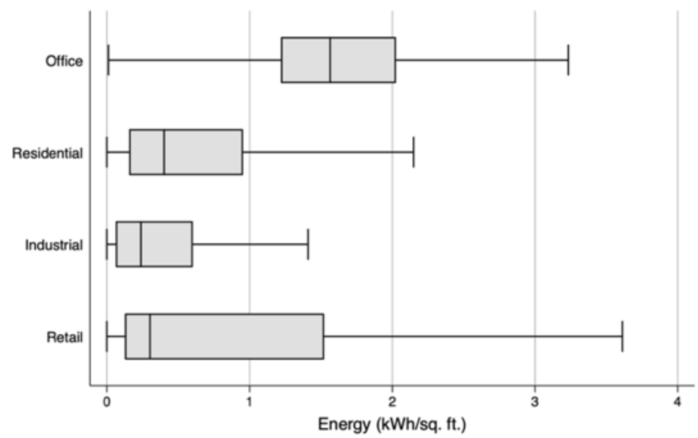
[1] Year of construction is not known for the entire sample. This information is available for 320,582 observations, pertaining to 5,077 buildings.

[2] 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 Retro-commissioning.

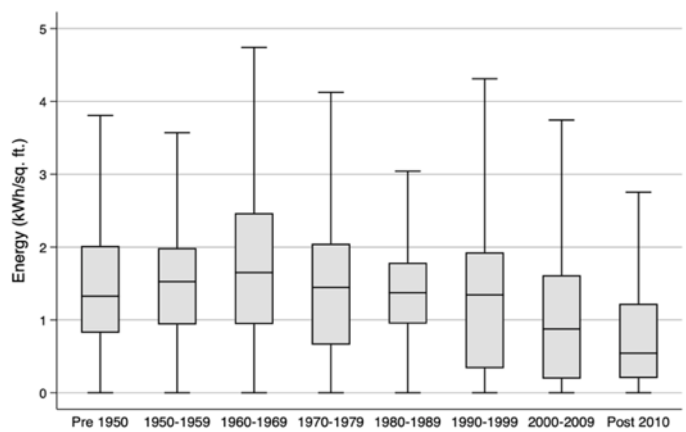
[3] Includes: HVAC, Lighting, Boiler System, and High-efficiency Appliances.

EXHIBIT 2
Energy Consumption Across Building Categories and Time

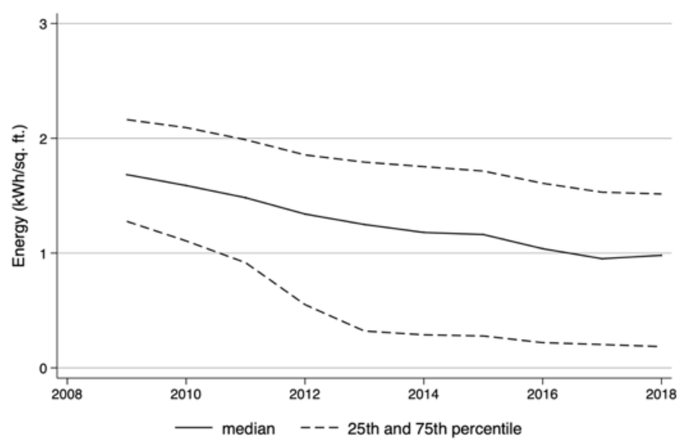
Panel A: Energy Consumption by Property Type



Panel B: Energy Consumption by Construction Period



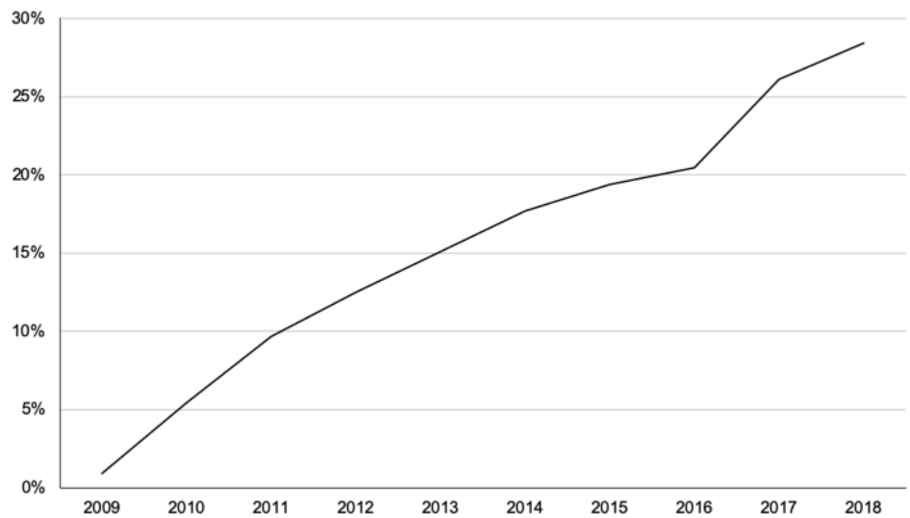
Panel C: Energy Consumption over Time (2009-2018)



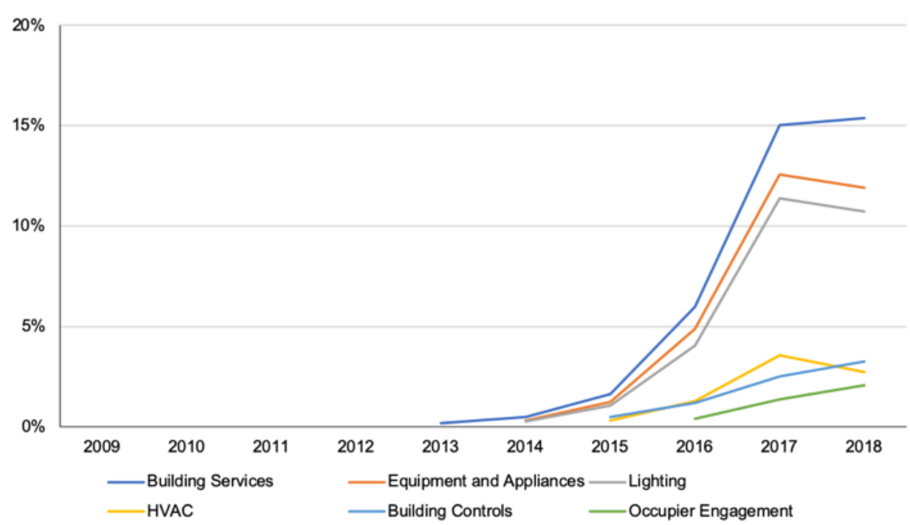
Notes: Panel A presents boxplots of energy consumption per property type. Panel B indicates differences in energy consumption by construction period. Panel C displays the energy consumption trajectory for the sample over time. The solid line depicts the 50th percentile, and the dashed lines represent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

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

Panel A: LEED Certification



Panel B: Energy-Efficiency Improvements



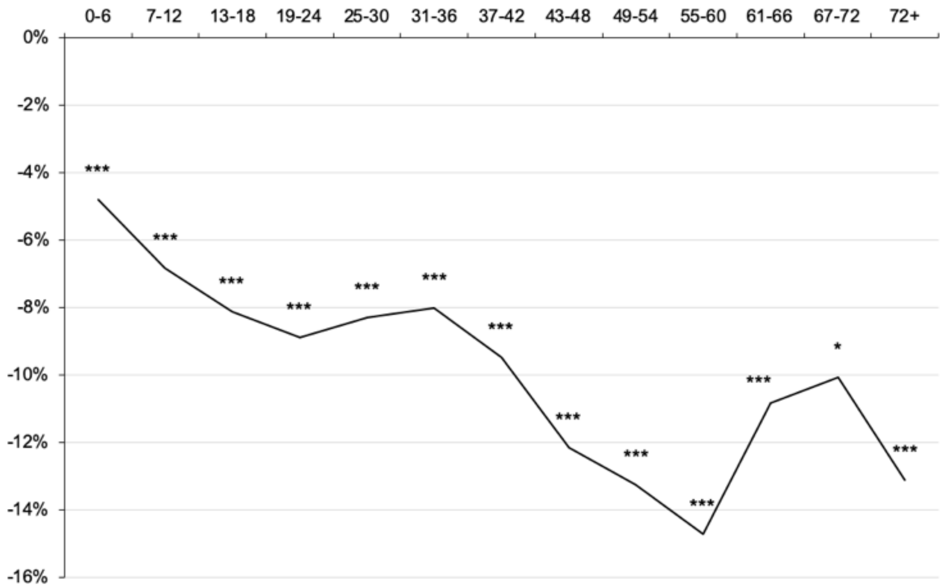
Notes: The graphs in Panel A and B illustrate the adoption of LEED certification and various energy-efficiency improvements in our sample over time.

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)				
Existing Buildings: Operations and Maintenance (EBOM)			-0.097***	
			[0.013]	
Building Design and Construction (BDC)			-0.133***	
			[0.042]	
Core and Shell (CS)			0.111**	
			[0.054]	
LEED certification tenure (1=yes)				
Up to 6 months				-0.048***
				[0.013]
7 to 12 months				-0.068***
				[0.013]
13 to 18 months				-0.081***
				[0.014]
19 t0 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	0.430***	0.430***	0.431***	0.431***
(monthly in thousands)	[0.019]	[0.019]	[0.019]	[0.019]
Heating degree days	0.405***	0.405***	0.405***	0.404***
(monthly in thousands)	[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-squared	0.729	0.729	0.729	0.729

Notes: Standard errors, clustered at the building level, are in brackets. Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, and ***, respectively.

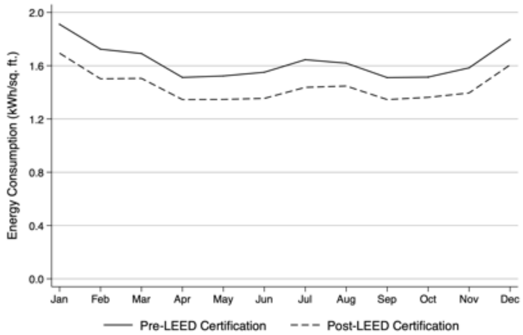
EXHIBIT 5
LEED Certification Tenure
(months)



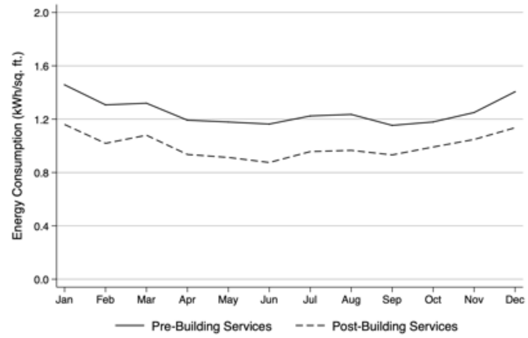
Notes: Exhibit 4 displays the decrease in energy consumption as a function of LEED certification age, based on the point estimates documented in Exhibit 3. Significance of the point estimates at the 0.10, 0.05, and 0.01 level is indicated by *, **, and ***, respectively.

EXHIBIT 6
Energy Consumption Before and After Certification and Energy-Efficiency Improvements

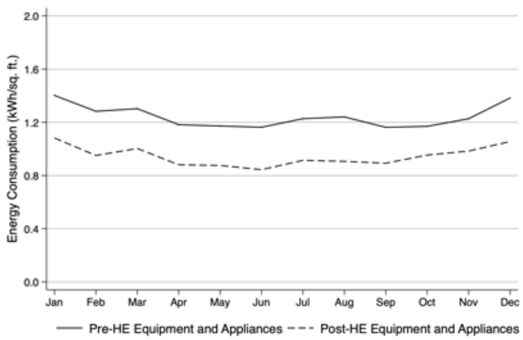
Panel A: LEED Certification



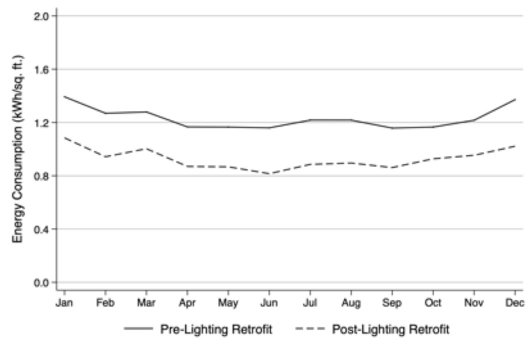
Panel B: Building Services Retrofit



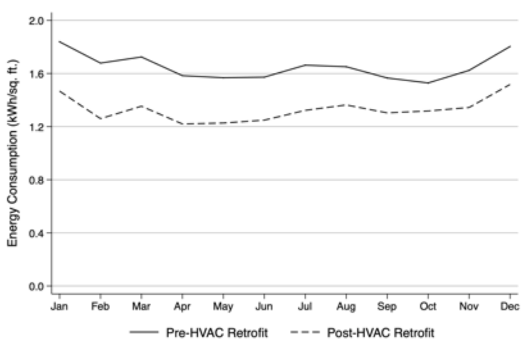
Panel C: Equipment and Appliances Retrofit



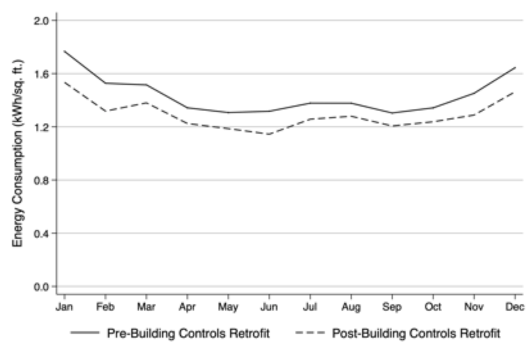
Panel D: Lighting Retrofit



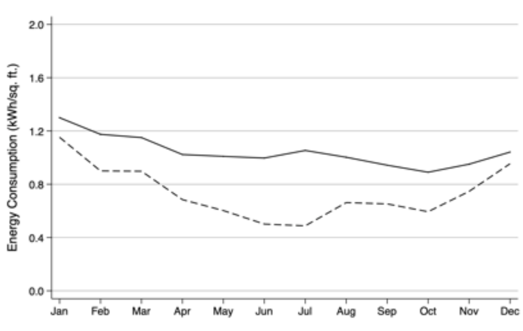
Panel E: HVAC Retrofit



Panel F: Building Controls Retrofit



Panel G: Occupier Engagement



Notes: Graphs in Panel 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.

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	0.419***	0.419***	0.419***	0.418***	0.418***	0.417***	0.419***
(monthly in thousands)	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]
Heating degree days	0.497***	0.497***	0.497***	0.497***	0.498***	0.498***	0.497***
(monthly in thousands)	[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]
Number of building-months	421,519	421,519	421,519	421,517	421,455	421,519	421,519
Number of buildings	7,255	7,255	7,255	7,255	7,254	7,255	7,255
Adj. R-squared	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. Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, and ***, respectively.

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	-0.057***					
(1=yes)	[0.019]					
CDP - Energy-efficiency: Building Services * Cooling degree days	-0.171***					
(1=yes)	[0.050]					
GRESB - Installation of High-efficiency Equipment and Appliances		-0.063***				
(1=yes)		[0.021]				
GRESB - Installation of High-efficiency Equipment and Appliances * Cooling degree days		-0.154***				
(1=yes)		[0.055]				
Lighting			-0.060***			
(1=yes)			[0.023]			
Lighting * Cooling degree days			-0.197***			
(1=yes)			[0.062]			
HVAC				-0.107***		
(1=yes)				[0.023]		
HVAC * Cooling degree days				0.090		
(1=yes)				[0.074]		
Building Controls					-0.091**	
(1=yes)					[0.039]	
Building Controls * Cooling degree days					-0.191*	
(1=yes)					[0.114]	
Occupier Engagement						0.043
(1=yes)						[0.047]
Occupier Engagement * Cooling degree days						-0.573***
(1=yes)						[0.167]
Cooling degree days	0.423***	0.422***	0.422***	0.417***	0.418***	0.419***
(monthly in thousands)	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]
Heating degree days	0.497***	0.497***	0.497***	0.497***	0.498***	0.498***
(monthly in thousands)	[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]
Number of building-months	421,519	421,519	421,519	421,517	421,455	421,519
Number of buildings	7,255	7,255	7,255	7,255	7,254	7,255
Adj. R-squared	0.860	0.860	0.860	0.860	0.860	0.860

Notes: Standard errors, clustered at the building level, are in brackets. Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, and ***, respectively.