Energy Economics 93 (2021) 105039

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Beyond building certification: The impact of environmental interventions on commercial real estate operations

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ARTICLE INFO

Article history:
Received 10 December 2019
Received in revised form 20 September 2020
Accepted 18 November 2020
Available online 27 November 2020

Keywords:
Commercial real estate
Energy efficiency
Tenant engagement
Green building certification
Capital expenditures
Monitoring

ABSTRACT

We extend the commonly-studied definition of investment in sustainable and energy efficient real estate beyond environmental building certification to include three additional types of environmentally-focused building interventions: environmentally-focused capital expenditure (capex); monitoring; and, tenant engagement. Appealing to behavioral economics and finance theory, we test for a connection between changes in tenant and property management behavior and electricity consumption. Through a partnership with a global institutional investment manager, this study examines ten years of asset-level operating statement and electricity consumption data in Canadian and U.S. office buildings, measuring both the initial impact of such interventions as well as any adjustments observed over time. Analysis of the proprietary intervention data allows us to better understand the impact of varied environmental interventions on the electricity consumption of commercial real estate. We find that all four intervention categories, including building certification, are associated with decreased electricity consumption, with tenant engagement providing an immediate decrease that is maintained over time. Environmentally-focused capex is also associated with decreased electricity consumption in both Canada and the U.S. Taken together the results indicate that utility consumption and its associated costs are only minimized when multiple environmental interventions are implemented.

1. Introduction

Real estate is one of the largest consumers of natural resources, particularly through electricity consumption. In the U.S., buildings are associated with approximately 74% of total electricity consumption, split evenly between commercial and residential uses.[1] Understanding how to reduce energy consumption in buildings is therefore key in achieving broader climate goals as set out in the Paris Agreement and reiterated at COP25 in Madrid.

Energy consumption reductions in buildings can be realized through various channels including building codes, labeling and certification programs, and other interventions. Jacobsen and Kotchen (2013) documents that stricter residential building codes improve energy efficiency, and that reductions in energy consumption are persistent. However, a study by Levinson (2016) suggests that such gains are merely due to the newness of construction, and that efficiency gains from more recent buildings codes disappear over time. Papineau (2017b) shows realized savings from U.S. commercial energy code adoption are approximately 25% lower than predicted. Taken together, this indicates that building codes matter, but perhaps not as much as may be expected in the long term.

Voluntary (or mandatory) environmental building certification and labeling programs also play an important role in shaping energy consumption by improving transparency through provision of information on buildings' environmental characteristics which is otherwise difficult to observe (Pérez-Lombard et al., 2009). Previous studies of the commercial real estate market provide evidence on the efficacy of adoption and capitalization of such programs (Eichholtz et al., 2010; Holtermans and Kok, 2019; Papineau, 2017a; Scofield, 2009; Scofield and Doane, 2018). Building interventions (including certification) aimed at improving energy efficiency are also shown to be effective in reducing energy consumption in buildings (Eichholtz et al., 2019). Finally, building energy efficiency may be maximized by engaging with the occupants. In commercial real estate, research on this last topic has been scant, despite a similar environmental footprint as the residential sector.

While research has focused on the structural and mechanical attributes of buildings, the impact of the building users has been largely overlooked. Not understanding the impact of the user is problematic in two ways. First, there is the sheer magnitude of user impact; Hafer

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[1] Authors' calculation based on "Table 7.6: Electricity End Use" from the U.S. Energy Information Administration (2020). Retrieved from: https://www.eia.gov/totalenergy/data/monthly/pdf/sec7_19.pdf

https://doi.org/10.1016/j.eneco.2020.105039
0140-9883/

(2017) shows that nearly 40% of electricity usage in office buildings is related to plug load, and Gunay et al. (2016) indicates that 75% of electricity plug load in private office space takes place during unoccupied periods, highlighting the spillover effect of the user into periods of office inactivity (i.e. leaving computers running and monitors on, etc.). Second, as certification and labeling efforts become standardized and building codes are tightened with respect to energy use, energy intensive building-related inefficiencies associated with HVAC (heating, ventilation, and air conditioning) and lighting are addressed, leaving user-related inefficiencies as the new lead driver of energy inefficiency. Hence, as building-focused programs and policies improve the efficiency of the building, users rise to the top of the list of sources of energy inefficiency in commercial real estate.

In this paper, we extend the existing literature by moving beyond environmental building certification and incorporating three additional types of environmental intervention at the asset management and tenant levels: environmentally-focused capital expenditures (capex); monitoring; and, tenant engagement. Building certification and capex are considered "hard" interventions, focused on the engineering of the building. We label the additional two interventions as "soft," being comprised of either relatively passive awareness and monitoring programs or more active engagement activities that strive to modify tenant and property management behavior. Through utilization of these environmental interventions, various building stakeholders can impact operations, particularly through utility consumption. In this study, we focus on the interventions' effect on electricity consumption and the resulting cost implications both in terms of greenhouse gas emissions and financial implications.

Several studies examine the impact of building certification on utility consumption. There is evidence of water-related cost savings (Kats, 2010), but results regarding power usage are mixed or inconclusive (Newsham et al., 2009; Scofield, 2009, 2013). Qiu and Kahn (2019) reports strong building level evidence of a link between the attainment of Energy Star certification and electricity consumption pre- versus post-certification, in a sample of properties in Phoenix, AZ. Similarly, Eichholtz et al. (2019) documents a reduction in aggregate energy consumption of approximately 8% after obtaining a LEED certification, employing a sample of U.S. commercial buildings.

While the literature examining the impacts of environmental building certification is extensive, research into other environmental building interventions is limited. There is research that recognizes the importance of all forms of capital expenditures, and that examines the impact on property financial performance (Bond et al., 2018). In residential real estate, Comerford et al. (2018) notes that the two paths to decreasing household energy consumption are curtailment and retrofitting, with the latter proving more effective in engineering models and randomized control trials. However, we are not aware of any research that focuses on capex targeted at reducing a commercial building's environmental footprint.

Research indicates that building-focused interventions alone are insufficient to maximize energy efficiency. Aydin et al. (2018) concludes that such "hard" interventions miss the mark for two reasons: engineering efficiency estimates are often overestimated due to the rebound effect; and, technology diffusion is slowed due to myopic discounting and a lack of consumer awareness. A possible complement to "hard" building interventions is a suite of "soft" behavioral interventions targeting building management and users. A growing body of research in psychology, behavioral economics, and finance suggests that such interventions can be powerful in altering behavior and choices.

In residential real estate, Allcott and Mullainathan (2010) and Allcott and Rogers (2014) evaluate the OPOWER program, which provides personalized feedback on a household's energy consumption, compares it to similar households, and combines it with energy conservation information. Based on randomized controlled trials the authors conclude that such home energy use reports lead to significant reductions in electricity consumption. In a similar spirit, we test for a connection between changes in office space management and user behavior, and electricity consumption. Heller et al. (2011) suggests that a large fraction of energy use is not controlled by building design, HVAC equipment, and maintenance, but by tenants. Hence, tenant behavior can have a significant impact on overall building energy use. The authors propose that various means to make tenants aware of their energy consumption might help significantly reduce their energy use. Yet this remains an unstudied topic.

Our paper empirically tests whether changes in behavior have significant effects from two intervention categories: monitoring and tenant engagement. Monitoring, or passive feedback, is considered an effective and valuable tool in a variety of fields including public health, organizational behavior, and education, and is well-researched in residential real estate energy efficiency (Aydin et al., 2018). Tenant engagement is differentiated by its proactive approach to eliciting behavioral changes. While research into these interventions is near non-existent for energy consumption in commercial buildings, one topical study examines the role of organizational network dynamics in feedback campaigns regarding energy conservation (Gulbinas and Taylor, 2014). Notably, the authors stress that the residential and commercial users respond differently to environmental feedback, reinforcing the importance of examining monitoring directly in commercial real estate.

The proprietary nature of the required information makes studying these interventions difficult. Energy consumption, its associated costs, and the building operations details needed for analysis are highly sensitive, proprietary data held by individual firms, and not aggregated in any data source. Further, much related research suffers from an inability to capture building and management quality, two key aspects endogenous to the questions of sustainable investment and energy efficiency. Through a partnership with a global institutional real estate investment manager we gain access to ten years of monthly operating statements for hundreds of assets in the U.S. and Canada. The firm's sustainability strategy goes beyond third-party building certification to also include formal tenant and property management expense awareness and engagement programs. Additionally, the firm tracks environmentally-focused capex investments. The sample is well balanced across the U.S. and Canada, providing the ability to examine effects in two countries.

The remainder of the paper is organized as follows: Section 2 lays out the methodology we employ to empirically test the impact of the different interventions on electricity consumption, while controlling for other factors and outside influences and maximizing model robustness. Section 3 describes the dataset we have compiled from property level operating data. It also provides an overview of the expense monitoring and reporting program and the sustainability engagement program targeted at property managers and tenants. Section 4 provides the results and discusses key findings. Section 5 presents a summary and implications of our findings.

2. Empirical framework

This research measures the trajectories of commercial building electricity consumption over time as they are treated with different environmental interventions. We utilize data from a global commercial real estate investment management firm's portfolio of investment-grade office assets in the U.S. and Canada over a ten-year period. This data includes building, ownership, and management characteristics as well as line-item operating data and detailed information on the observed environmental interventions. Through this detailed data we can offer credible estimates of the impact of such interventions in a non-experimental environment.

Assets within the firm's portfolio include properties which received varied combinations of environmentally-focused capex, environmental building certification, monitoring, and tenant engagement interventions. The first two interventions, building certification and capex, are deemed "hard" interventions focused on building engineering, while the latter two, monitoring and tenant engagement, are considered "soft" interventions aimed at shaping the actions of people who interact with the asset, such as property managers and building users.

Decisions regarding the investment into and operation of commercial real estate assets involve a variety of stakeholders. The most active parties include the owner, the asset manager, the property manager, and the tenants or building users. Investment management firms, such as the one from which our data is sourced, provide a variety of portfolio, asset, and property management services. Such firms differentiate themselves based on performance as well as technique. BentallGreenOak is known for being a leader in sustainability, and asset owners which use their services expect investment management techniques rooted in that mandate (BentallGreenOak, 2019).

Owners have the final say in investment-related decisions regarding an asset, including decisions concerning the purchase and sale of an asset as well as those related to major re-investment into the asset such as renovations or other major capital expenditure, or capex, undertakings. Capex represents the inconsistent improvements needed to maintain building quality (e.g. a new roof). Consistent improvements (e.g. interior repainting) are part of ongoing operating expenses. Environmentally-focused capex decisions, as with all capex decisions, lie with the asset manager and are informed by input from the property manager and the owner. These may be undertaken concurrently with pursuit of environmental building (re)certification or may be completed separately; no certification program requires specific capex actions. Asset management is the expertise hired by owners to optimize asset performance and is responsible for asset strategy. Property management reports to asset management and is responsible for the day-to-day operations of an asset. This position is often situated on-site (while asset management is not), and interfaces with the building users to meet their needs.

Mirroring the array of asset-related decisions, environmental intervention decisions are also implemented by various building stakeholders. Certification decisions are made by the owners (especially construction-related certification) and asset management. The decision whether or not to enroll in a tenant engagement program lies with property management, and the decision to participate in that program, and at what level of rigor, lies with each tenant in a building in which the program is offered (separating enrollment from uptake).[2] Enrollment in the monitoring program occurs across the full portfolio as related events arise, as the monitoring program assists in the execution of other interventions. For instance, when a property is enrolled in the tenant engagement program it is automatically enrolled in the monitoring program. If a building undergoes a (re)certification process, it will often be enrolled in the monitoring program. As the investment manager works toward 100% adoption of the monitoring program, regular onboarding of additional properties is also completed. If none of these apply, an asset manager may also directly pursue enrollment in the monitoring program. Finally, environmentally-focused capex decisions are made by the asset manager with input from the owner and property manager.

2.1. Behavior-focused interventions

Thaler and Sunstein (2008) "Nudge Theory" posits that human behavior can be influenced by small suggestions and positive reinforcements. Through this lens, we explore if engagement of tenants (building users) and property managers can stimulate or "nudge" behavior that has energy efficiency implications, both individually and in combination with other environmental interventions.

The firm has implemented environmentally-focused tenant and property management engagement programs, or "soft" interventions. The first program is a data tracking and visualization tool called Eco Tracker. Eco Tracker is a sustainability data management system that provides a single reporting and management system for energy, utilities, water, and waste. It also includes a modeling tool, Eco Modeler, to model reduction measures and predict decreases in consumption costs and greenhouse gas emissions. The original goal of this program was to assist in pursuit of environmental building certification (and re-certification). However, there is evidence that the provision of this type of information to building management and tenants provides transparency into consumption, which can lead to altered user and management behavior.

The second program, ForeverGreen, focuses on creating and reinforcing awareness and collaboration among property managers and tenants in making environmentally-conscious decisions. The goal of the program is increased efficiency of energy and water use, and a healthy, productive work environment for building users. The firm's long-term goal is increased commitment to the program, in terms of more enrolled buildings, more enrolled tenants, and tenants participating at higher levels of commitment. Any building that enrolls in ForeverGreen is co-enrolled in Eco Tracker, should the monitoring software not already be in use.

These two programs share the goal of altering the behavior of the people that interact most directly with the building in order to decrease the building's environmental footprint. Both programs carry additional benefits such as greater ease of data collection for reporting and reputational benefits from being associated with the execution of such programs. The key differentiating factors lie in where the enrollment decision resides, the target audience of the program, and the nature of the intervention.

The investment management firm is moving toward 100% enrollment of their assets into the Eco Tracker monitoring program, so most enrollment decisions are initiated in pursuit of general portfolio onboarding, building (re)certification, or enrollment in the tenant engagement program. In addition to these drivers, asset management may elect to enroll a building into the monitoring program. However, it is property management that utilizes the related data and analytics in building operation management activities with the goal of decreased utility consumption. Notably, the monitoring program is passive, in that it collects the data and completes the analysis, but the decision to view and utilize such data lies with property management.

On the contrary, the tenant engagement program is active, and targets both property management and building users in separate stages. Here, the decision to enroll lies with property management, while the decision to utilize lies with individual tenants and building users. Conditional on a building being enrolled in the ForeverGreen program (a decision made in the fourth quarter of each calendar year), individual tenants select a level of engagement from three pre-set options representing increasing commitments of time and effort (or elect to not actively participate). At the start of each calendar year, enrolled property managers share with tenants a schedule that identifies the timing of resources to be provided by topic, including energy, water, waste, health, and community. Each year a theme is adopted, and monthly topics are depicted in posters and handouts in informative and "change-incentivizing" ways. Topics are aligned with weather and seasonal events. Enrolled property managers and tenants receive educational and motivational resources such as posters, newsletters, and Green Team Packs which provide actionable content around the monthly environmental themes.

2.2. Regression methodology

We employ a fixed effects panel regression model to estimate the impact of hard and soft interventions on a building's electricity consumption. Exploiting the longitudinal nature of the data, we include

[2] Property managers are generally responsible for only one asset (or group of related properties) at a time, and their decision to enroll or not will be holistic. That is, they will not be selecting one building to enroll in lieu of others; they will either enroll their buildings or they will not.

building and month fixed effects. These fixed effects account for unobserved time-invariant differences between buildings that may cause differences in electricity consumption (e.g. building age, size, class, and location), and seasonality (e.g. summer and winter temperature) that may impact average electricity consumption across all buildings. As the adoption of the studied interventions is correlated with the year of observation (i.e. the sample is moving toward 100% adoption), and as we are specifically interested in the impact of these interventions on the electricity consumption of a building, we opt not to include year fixed effects in our baseline empirical model. Our identifying assumption is that there are no other unobserved time varying factors that are correlated with a building's electricity consumption.

Since the timing of the interventions varies by building and intervention type, our approach mimics a staggered difference-in-difference model. In addition to the variation in timing of the treatment, it should be noted that the adoption rate of the different interventions increases over time, which implies that the number of untreated control buildings decreases over time. The literature often employs matching methods (e.g. propensity score weighting, coarsened exact matching, or nearest neighbor matching) to control for observable differences between treated and untreated buildings. As the pool of untreated control buildings is small and decreasing over time we are not able to implement a matching method in our empirical strategy. However, related studies frequently employ these methods in cross-sectional settings, where observable differences between buildings are apparent. Including building fixed effects in our model accounts for such differences, and decreases the need for a matching method as we are mostly interested in within-building variation in energy consumption before and after the implementation of an environmental intervention.

We employ the following estimation approach, designed to control for the effects of unobservable building-level factors that also determine electricity consumption:

$$\ln CONS_{i,m,t} = \alpha_{i,m,t}FG + \beta_{i,m,t}ET + \gamma_{i,m,t}CERT + X_{j,i,m,t} + Y_i + Z_m + \epsilon_{i,m,t} \quad (1)$$

In Eq. (1), we examine three of the four interventions: tenant engagement; monitoring; and, building certification. $lnCONS_{i,m,t}$ measures the natural log of electricity consumption per occupied square foot of building i in month m and year t. Importantly, the variable of interest, electricity consumption, is normalized by monthly-varying occupancy rates. The three building interventions, ForeverGreen tenant engagement (*FG*), Eco Tracker monitoring (*ET*), and certification (*CERT*), are initially specified as "yes or no" at the aggregate level. The intervention indicators change from zero to one once a building undergoes an intervention. The parameters of interest (α, β, and γ) measure the average difference in electricity consumption subsequent to environmental interventions (*FG, ET,* and *CERT*), after adjusting for the fixed effects and other control variables. Subsequent analyses test for the differential impact of time since enrollment by one-year increments, using the year prior to implementation as reference category.

$X_{j,\ i,\ m,\ t}$ captures a vector of time-varying factors j for building i in month m and year t, which may impact consumption such as building occupancy, electricity prices, and local climate intensity. We control for differences in local climate intensity by including monthly heating and cooling degree days. For Canada this information is collected at the city level, for the U.S. we employ climate divisions as defined by the National Oceanic and Atmospheric Association.[3] Building fixed effects, Y_i, account for time-invariant differences in buildings' electricity consumption, and month fixed effects, Z_m, capture seasonality (e.g. summer and winter temperature) that generate changes in average electricity consumption across all buildings. For some analyses, month fixed effects are changed out for year fixed effects to measure economic variation over time; our sample size is insufficient to control for both month and year concurrently. Robust standard errors are clustered at the building level.

$$\ln CONS_{i,m,t} = \delta_{i,m,t}CAPEX + \alpha_{i,m,t}FG + \beta_{i,m,t}ET + \gamma_{i,m,t}CERT + X_{j,i,m,t} + Y_i + Z_m + \epsilon_{i,m,t} \quad (2)$$

Eq. (2) focuses on the fourth intervention: environmentally-focused capex (*CAPEX*) and its parameter of interest δ. This intervention is studied separately as it utilizes a subsample of the data employed for analysis under Eq. (1). For this subsample, all four interventions are concurrently measured and all control variables are included as described above. Subsequent estimations investigate the impact of the underlying categories and subcategories that constitute the *CAPEX* dummy variable on a building's electricity consumption.

2.3. Potential endogeneity issues

As this is not a randomized control trial, our data may be exposed to a number of sources of bias in both sample selection and measurement of the treatment. We benefit from uniquely deep data and have designed our study to address as many of these issues as possible. Asset and management quality are two common endogeneity concerns in measuring the impact of environmental interventions (McWilliams and Siegel, 2001). The assembled data provides the ability to control for both.

Management quality is implicitly controlled for through the single shared investment manager for all assets. All assets fall under the high-level investment guidelines set forth by the firm. It is this firm's extensive experience and expertise within the field of environmentally-sustainable commercial real estate that makes this study possible (BentallGreenOak, 2019). The firm has been an early adopter of many related technologies, creating sufficient treated operating history to allow for the study. A downfall of this early adoption is that assets managed by this firm are leading the industry adoption curve as it holistically moves to full adoption.[4] This means that as time passes in our panel, there are fewer "brown" control buildings to serve as a comparison.

A potential selection effect in the different types of management treatment is mitigated by the dispersion of decision making across many stakeholders (as described above) and the standardization of investment management practices within the sample. First, the sample is an unbalanced panel with assets entering and exiting the sample upon their placement into and removal from BentallGreenOak's investment management services (plus up to six months pre-entry data for baseline analysis when available). Individual asset ownership is effectively constant over the sample period.

Second, the impact of other stakeholder changes is minimized as much as possible. Managing ownership of assets is consistent within the sample with few exceptions.[5] Staffing changes at various management levels could impact the adoption of environmental interventions. Most strategic decisions lie with asset management, including the pursuit of monitoring (when applicable), building certification, and capex. Concurrent asset management within the same investment management firm is unlikely to differ substantially from one person to the next for two reasons: the prescribed role of asset management is to optimize asset value within the context of the owner's goals; and, the investment management firm provides standardized guidelines for how they approach asset management. The manner in which

[3] For more information, visit: https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php#history.

[4] Investment-grade commercial real estate assets are converging toward adoption of environmental interventions. For example, more than 42% of office space in the 30 largest U.S. office markets, as denoted by CBRE, were certified under LEED, Energy Star, or both by the end of 2018, with the leading markets showing adoption rates well above 60% (Holtermans et al., 2019).

[5] All results are robust to the exclusion of the few assets which experience changes in managing ownership during the sample period.

BentallGreenOak executes their investment management is a defining reason an owner elects to place their asset with this firm over other competing firms. Therefore, it is not up to the asset manager to decide what the optimal goal of the asset is. It is their job to curate and execute a strategy which meets the owner's goals given the investment manager's prescribed techniques.

The standardization of management quality and delivery applies to property management in the same way it does to asset management. That is, property managers may change during the sample horizon, but property management execution is much less likely to do so. In the Canadian sample, all property management is executed in-house by the investment management firm. In the U.S. sample, property management is outsourced to nationally recognized property management firms and is stable within buildings over the sample period. Therefore, the included building-fixed effects also control for property management. Further, the only intervention adoption decision assigned to property management, tenant engagement enrollment, is constrained to a short period of time (2014–2017), and with the short time horizon comes a lower probability of staffing changes. As property managers are often tasked with one asset, it is unlikely that they would vary their enrollment decision across the buildings which comprise that asset. To do so would increase the variation in property management efforts, effectively adding complexity to their work, while the marginal efforts needed to implement the tenant engagement program in all buildings associated with an asset is negligible. Therefore, while staffing may change, property management remains consistent throughout our analyses.

Third, enrollment and adoption processes are completed by different stakeholders, decreasing the chance of selection bias. For monitoring, enrollment is either an automated decision at the investment management firm level or instituted by asset management, while it is the property manager that must decide to utilize the data made available through the program. For tenant engagement, the enrollment decision lies with property management, while it is tenants and building users that must decide whether or not to participate in the program, and at what level.

Announcement effects and sorting issues are unlikely to impact the tenant engagement program adoption, given the constrained enrollment decision schedule. Property management decides whether or not to enroll a building in the upcoming year's tenant engagement program during the last quarter of the previous year – generally, an October decision for a January start date. Commercial office leases are long term, usually at least five years at a time and offering several stacked options to extend (observed specifically for this firm in Devine and Kok, 2015). When a tenant does pursue a new lease, this is a costly undertaking both in time and funds, as the negotiations can take several months, followed by the construction of needed tenant improvements in the new space. Therefore, an announcement effect is unlikely to have a short-term impact on building occupancy, and in the case that does occur, we include time varying measures for building occupancy to control for this.

Asset quality is controlled for through the inclusion of building fixed effects, which is possible as we observe all assets over an extended time period. By capturing all time-invariant observable and unobservable building characteristics, along with a sample construction that excludes buildings undergoing substantial renovations, we capture the building characteristics controlled for in the related literature, including (but not limited to): building class; size; age; height; amenities; and, transit accessibility. It is important to note that, while the full operating history in the sample is ten years, few properties are in the sample for that full period. Most enter, exit, or both within that period, shortening the period of within-building comparison and increasing the probability that building quality remains constant.

3. Data

BentallGreenOak provided access to monthly line-item information on properties for which the firm provides investment management or property management services.[6] This data offers asset-specific information at a level of detail rarely observed, and the time horizon required to test the temporal effects of environmentally-focused interventions. The sample includes assets in the U.S. and in Canada; the two samples have differing distributions on some of the key variables of interest, requiring analysis to be completed separately. Few studies have been able to study environmental building implications across countries, and there are reasons to believe results may not be the same across markets due to sample distinctions or country-specific distinctions (e.g. due to the policy environment, institutional arrangements, culture, and weather).

Operating information is collected on a monthly basis (or the most granular frequency available), capturing 159 buildings, 89 in Canada and 70 in the U.S., representing some 28 million square feet of office space and over 13,000 building-month observations. Buildings were restricted to traditional office use, with only negligible amounts of space dedicated to specialized office uses (i.e. data centers, medical office use) or other uses (i.e. retail). Table 1 reports detailed descriptive statistics for key variables, including electricity consumption, building characteristics, and local climatic conditions. These are reported separately for the Canadian (Panels A to C) and U.S. (Panels D to F) samples. The first column of the table displays summary statistics for the full sample in each country, and subsequent columns display the same statistics for subsamples both with and without three forms of the studied environmental interventions (building certification, monitoring, and tenant engagement). Building counts and number of building-month observations in each group are shown in the bottom two rows of the table.

Table 1 illustrates the dominant presence of building level certification, one of the "hard" interventions, in the sample. Environmental certification schemes included in this study are: the U.S. Green Building Councils' Leadership in Energy and Environmental Design (LEED) Existing Buildings Operations and Management (EBOM) program in both Canada and the U.S.; Building Owners and Managers Association (BOMA) BEST program in Canada; and, the Environmental Protection Agency's Energy Star program in the U.S.[7] Overall, 116 of the 159 buildings are certified (69 in Canada and 47 in the U.S.), representing over half of the building-month observations. Panels A and D indicate that certified buildings in Canada, on average, consume more electricity while the opposite is true in the U.S. The relative strength of the U.S. over Canadian buildings in this category is likely due to the Energy Star certification program (only available in the U.S. during the sample period), which focuses heavily on decreased electricity consumption. The finding of higher electricity consumption in certified buildings is in line with the existing literature, identifying certified buildings to more often being new, higher-tech "smart" buildings (Devine and Yönder, 2020).

Panel E indicates that buildings in the U.S. dataset are on average newer, with more than 70% constructed post-1990, and close to half since 2000. Conversely, Panel B highlights that the Canadian sample is comprised predominantly of buildings constructed in the 1970s and 80s, with three-quarters originally built prior to 1990. The substantial portion of the Canadian sample being existing buildings provides an important differentiating aspect from many existing green building studies (and from our U.S. sample) which examine newly-constructed buildings. Assessing the impact of environmental interventions on existing buildings is key for the developed world as so little of the building stock is newly constructed (approximately 2% in North America on an annual basis, CBECS, 2015). In this aspect, our sample more accurately reflects the local building stock than many existing studies.

[6] BentallGreenOak includes BentallGreenOak (Canada) Limited Partnership, BentallGreenOak (U.S.) Limited Partnership and the real estate and commercial mortgage investment groups of certain of their affiliates, all of which comprise a team of real estate professionals spanning multiple legal entities.

[7] For more information, visit: www.usgbc.org/LEED, www.energystar.gov, and www.bomacanada.ca/bomabest

Table 1
Descriptive statistics – Canada and the U.S.

	Total	Certified	Non-Certified	Eco Tracker	Non-Eco Tracker	ForeverGreen	Non-ForeverGreen
Panel A: Monthly consumption (Canada)							
Electricity consumption	1.977	2.062	1.900	1.950	2.138	1.743	2.104
(kWh/occupied sq. ft.)	(1.778)	(2.411)	(0.867)	(1.889)	(0.840)	(0.778)	(2.122)
Panel B: Building characteristics (Canada)							
Size (thousand sq. ft.)	160.617	175.014	147.591	156.189	187.029	157.502	162.308
	(190.376)	(212.179)	(167.194)	(180.763)	(238.237)	(179.921)	(195.813)
Occupancy Rate (%)	90.378	89.706	90.987	90.055	92.310	89.120	91.061
	(13.950)	(14.123)	(13.765)	(14.262)	(11.738)	(13.823)	(13.972)
Building Class (%)							
Class A	36.493	40.864	32.539	38.186	26.394	37.433	35.983
Class B	51.801	49.342	54.026	53.008	44.599	47.316	54.235
Unknown	11.706	9.795	13.435	8.805	29.007	15.251	9.782
Construction period (%)							
Pre 1950	5.328	5.266	5.384	5.461	4.530	3.839	6.135
1950–1969	3.652	2.738	4.478	2.263	11.934	3.839	3.550
1970–1979	25.938	27.225	24.774	25.102	30.923	27.302	25.198
1980–1989	39.932	38.468	41.258	40.756	35.017	38.749	40.575
1990–1999	5.615	6.266	5.026	6.060	2.962	3.377	6.830
2000 and after	19.535	20.037	19.081	20.356	14.634	22.894	17.712
Panel C: Local climate conditions (Canada)							
Cooling degree days (# per month)	15.174	14.316	15.951	14.860	17.049	15.204	15.158
	(32.772)	(31.320)	(34.017)	(31.735)	(38.346)	(30.760)	(33.817)
Heating degree days (# per month)	311.156	301.102	320.252	307.904	330.553	305.882	314.019
	(256.744)	(251.811)	(260.823)	(255.116)	(265.538)	(259.498)	(255.217)
Number of building-months	7996	3798	4198	6848	1148	2813	5183
Number of buildings	89	69	89	86	67	72	82
Panel D: Monthly consumption (United States)							
Electricity consumption	1.845	1.638	2.113	1.848	1.841	1.712	1.889
(kWh/occupied sq. ft.)	(1.300)	(0.694)	(1.767)	(1.487)	(0.896)	(0.724)	(1.437)
Panel E: Building characteristics (United States)							
Size (thousand sq. ft.)	202.157	237.590	156.400	227.298	159.576	246.779	187.437
	(177.667)	(215.244)	(93.780)	(205.837)	(101.954)	(207.575)	(164.014)
Occupancy Rate (%)	86.877	88.697	84.526	85.428	89.331	86.967	86.847
	(16.388)	(13.329)	(19.399)	(17.308)	(14.376)	(14.903)	(16.852)
Building Class (%)							
Class A	89.217	84.331	95.528	90.506	87.034	89.840	89.012
Class B	10.783	15.669	4.472	9.494	12.966	10.160	10.988
Construction period (%)							
Pre 1950	3.203	2.421	4.212	3.707	2.348	0.000	4.259
1950–1969	6.291	5.649	7.121	6.239	6.381	4.584	6.855
1970–1979	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980–1989	10.404	16.274	2.822	10.579	10.107	3.667	12.626
1990–1999	19.007	20.242	17.412	18.897	19.193	16.501	19.834
2000 and after	61.095	55.414	68.432	60.579	61.970	75.248	56.426
Panel F: Local climate conditions (United States)							
Cooling degree days (# per month)	83.061	83.635	82.320	84.793	80.127	84.394	82.621
	(128.279)	(123.338)	(134.413)	(128.536)	(127.821)	(118.236)	(131.434)
Heating degree days (# per month)	373.814	383.941	360.737	367.043	385.283	358.280	378.939
	(379.349)	(390.299)	(364.391)	(370.488)	(393.734)	(376.786)	(380.099)
Number of building-months	5277	2974	2303	3318	1959	1309	3968
Number of buildings	70	47	61	70	63	33	70

Notes: Standard deviations in parentheses.

In addition to being an older sample, the majority of the Canadian buildings are classified as class B properties and located outside the downtown core. The age distribution, quality, and location of certified buildings generally tracks that of the full sample quite closely. However, Canadian certified buildings tend to be significantly larger properties. A much higher proportion of the U.S. sample buildings are suburban (non-CBD) and class A properties. As with the Canadian properties, U.S. certified buildings skew toward larger, newer, class A assets, situated within urban cores.

The fourth and sixth columns in Table 1 report descriptive statistics on buildings enrolled in the Eco Tracker and ForeverGreen programs, respectively. With 86 properties (6848 building-months) in Eco Tracker and 72 properties (2813 building-months) in ForeverGreen, the Canadian sample shows a high level of engagement. Engagement lags in the U.S., partially due to the programs initially being introduced in Canada and later expanded south of the border. Panels A and D show that ForeverGreen buildings are, on average, associated with lower electricity consumption compared to non-ForeverGreen buildings in both countries, with only negligible differences associated with Eco Tracker enrollment.

Fig. 1 displays the cumulative adoption of three interventions across the portfolio, broken down separately for Canada (Panel A) and the United States (Panel B). This represents the first time each building experiences each intervention while in our sample period (with many interventions occurring prior to the sample period). Monitoring and tenant engagement programs were first introduced in Canada and

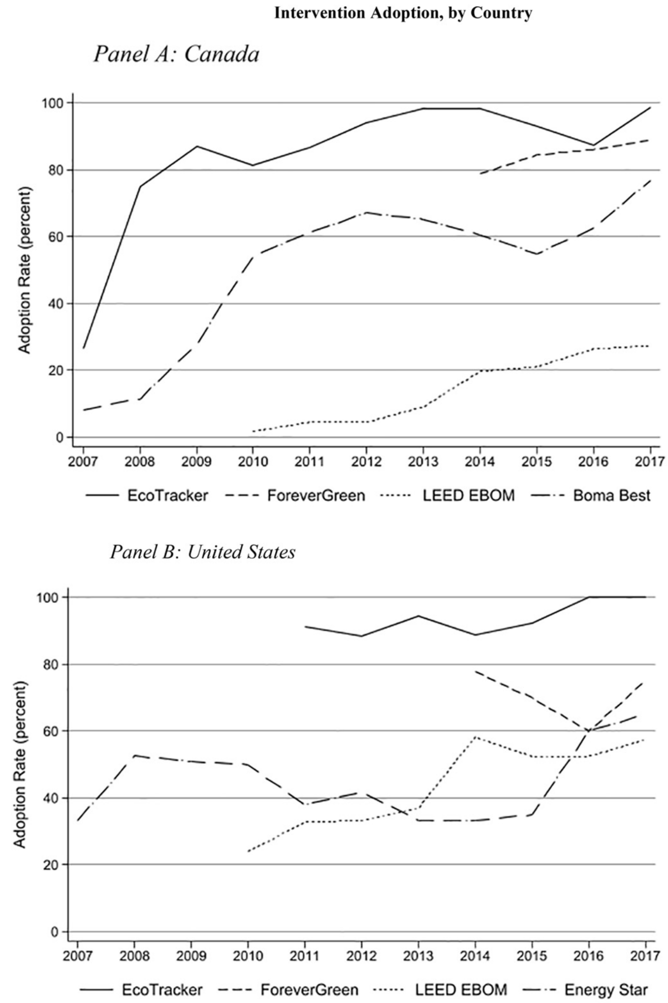

Fig. 1. Intervention Adoption, by Country. *Notes*: Each graph presents the percent of the sample that is governed by each identified intervention category, by sample year. Environmental building certification activity was present in some buildings under prior ownership/management. Similar to the Canadian sample, monitoring was introduced in the U.S. in the mid-2000s, albeit on a limited basis. It is first observed in our sample in 2011 when substantial monitoring adoption was instituted by the investment firm.

were subsequently introduced into the U.S. portfolio. The graphs highlight the intervention adoption order and the investment firm's movement toward full adoption. First, environmental building certification (both within our sample and under prior ownership/management) is undertaken. This is commonly observed beginning in the early 2000s and increasing notably for a decade before leveling off. Second, monitoring is introduced by the investment management firm in the mid-2000s, originally with the goal of aiding in certification and recertification activities. Adoption of this first "soft" intervention increases quickly, as the decision to adopt lies with the investment manager, not other stakeholders. Monitoring in the U.S. also began in 2007, but was broadly instituted in 2011 which is the first time it is observed in our sample. Finally, tenant engagement programs are introduced in the mid-2010s, and with strong encouragement from the investment manager, adoption increases sharply over the first few years.

Fig. 2 presents nonparametric comparisons on the impact of environmental interventions on electricity consumption. For the Canadian (left column) and U.S. (right column) samples, Panels A, B, and C present electricity consumption for buildings both with and without environmental building certification, monitoring, and tenant engagement, respectively. It compares median building level consumption on an occupied square foot basis at a monthly frequency (allowing for the observation of seasonality) over the full sample period. The graphs provide some evidence of lower electricity consumption, particularly relating to soft interventions in the Canadian sample. In all six cases, intervened buildings are associated with less or equally volatile resource consumption. This is consistent with research indicating environmentally certified buildings are lower risk assets (Devine and Kok, 2015).

4. Empirical results

In our estimation approach we first report the impact of three interventions, certification, monitoring, and engagement, on electricity consumption based on the full sample described in the data section and summarized in Table 1. We test for the joint impacts of these interventions on electricity consumption. Hence, coefficient estimates on specific intervention variables are marginal or incremental effects after controlling for, and independent of, the impact of the other interventions. Following this analysis, we provide estimates of the impact of environmental capex derived from the smaller subset of properties for which we have detailed capex information.

Table 2 reports estimates of Eq. (1), analyzing the impacts of hard (environmental building certification) and soft (Eco Tracker and ForeverGreen) interventions on electricity consumption, on a per occupied square foot basis. Results are reported separately for Canada, Columns (1) through (3), and the U.S., Columns (4) through (6). We include time-varying occupancy and local weather intensity (heating and cooling degree days) as control variables. Electricity cost controls are also included in Columns (2), (3), (5), and (6). This inclusion restricts the sample, but adds important explanatory power. Building fixed effects capture unobserved variation in building characteristics that might impact electricity consumption. While sample size constraints disallow year-month fixed effects, each are captured separately to measure the impact. Month fixed effects capture seasonal variation not captured by heating and cooling degree days, and are included in Columns (1), (2), (4), and (5); year fixed effects capture changes in average electricity consumption over time and are included in Columns (3) and (6).[8]

The results provide evidence that the tested forms of interventions are generally associated with reductions in electricity consumption post-implementation. In Canada, Forever Green is associated with a both economically and statistically significant 14.8% decrease in electricity consumption. Controlling for electricity costs and year fixed effects in Columns (2) and (3) mutes the impact of ForeverGreen on electricity consumption, yet the significance persists. EcoTracker usage is associated with lower electricity consumption in the first two columns of Table 2, but the result is negated when year fixed effects are included. This is unsurprising as the monitoring program in particular is being actively moved toward full adoption, implying a strong correlation with sample year. U.S. results are generally uninformative, suffering from a smaller sample size particularly when including controls for electricity cost.

Environmental certification programs return mixed results in both countries. In Canada, LEED EBOM presents consistently strong economic results with weakening statistical strength across the three reported estimations, while BOMA BEST certification appears to have little to an increasing effect on electricity consumption with weak statistical significance. In the U.S., Energy Star certification proves strongly statistically and economically significant in all models, while LEED EBOM

[8] We also considered which geographically-unique characteristics might be time-varying over the short term, and therefore not captured in building fixed effects. Given the nature of the interventions, we focused on characteristics which would increase the local population's propensity to be green. We tested the inclusion of variables often associated with higher commitment to environmentalism, including education level, income level, and the demand for electric car charging stations. None of the included variables added explanatory power to the results, indicating that these characteristics are likely relatively constant over the short term, and captured in the building fixed effects.

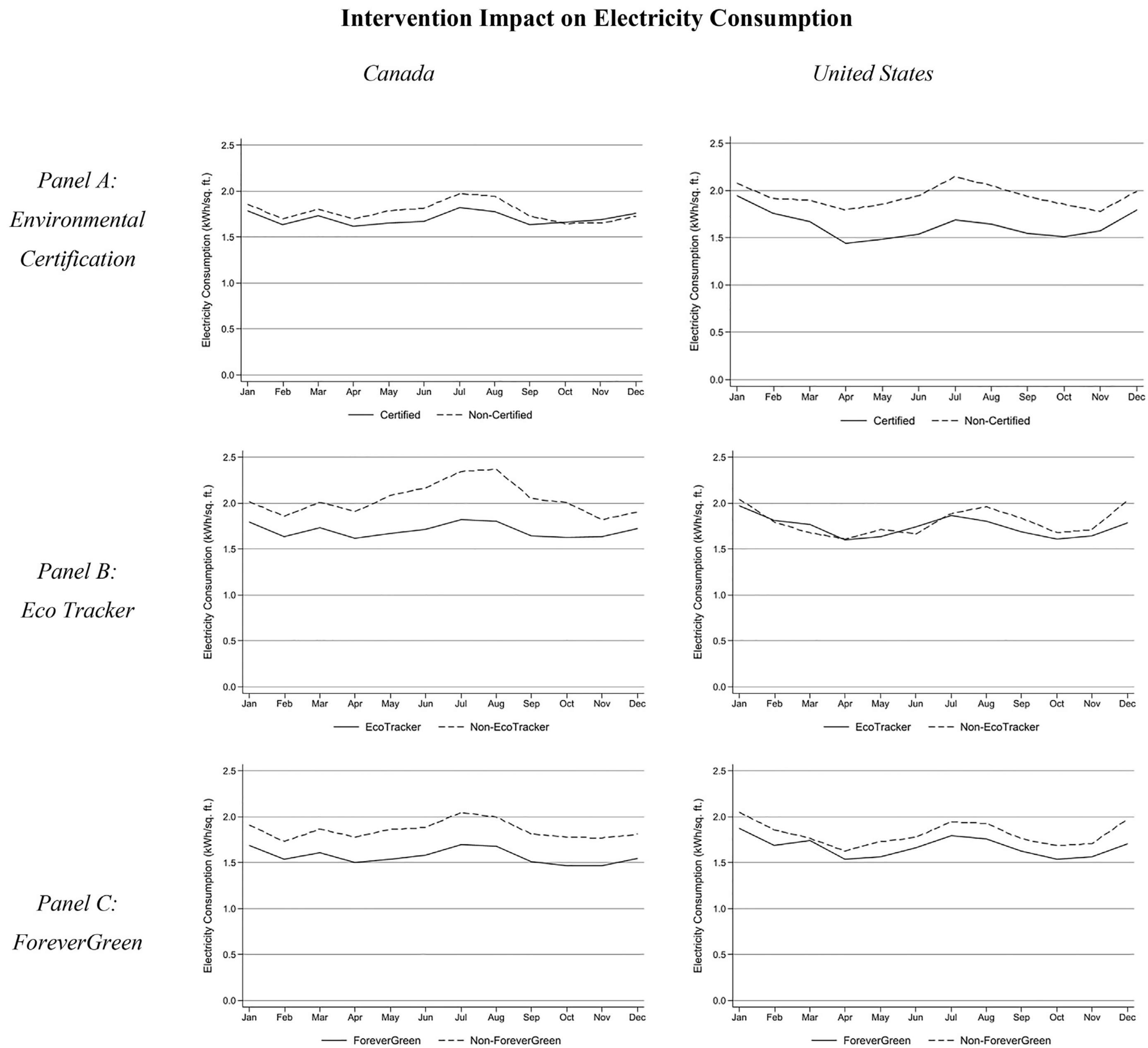

Fig. 2. Intervention impact on electricity consumption. *Notes*: Each graph presents the median monthly electricity consumption (measured in kilowatt hours per occupied sq. ft.) by country for the sample separated into two groups: those with and without each environmental intervention. Three interventions are examined: environmental building certification; Eco Tracker; and, ForeverGreen. Certification programs include LEED in both the U.S. and Canada, Energy Star in the U.S., and BOMA BEST in Canada. These values are not normalized.

reports higher electricity consumption. However, it should be noted that in many cases each pair of certifications are co-adopted, indicating that a "net" impact of certification may more accurately represent the effect on electricity consumption. This is particularly true in the U.S. where Energy Star is a required first step in pursuing LEED EBOM certification.

The explanatory power of the model is strong as reflected in the adjusted R-squared goodness of fit measures in excess of 75%. Such a robust fit in a parsimonious specification reveals the importance of including time and building fixed effects. An examination of control variables indicates that local weather conditions matter, and more so for the U.S. sample where both cooling and heating degree days show strong statistical significance, whereas only heating degree days is significant in Canada. In the U.S. sample, a one standard deviation increase in cooling (heating) degree days translates into approximately a 6% (19%) higher electricity consumption.

4.1. Persistence

The observed benefits to environmental interventions are not likely to be fully achieved at the time of implementation. For building certification, it takes time for the different stakeholders to recognize and adjust to the label and what it involves. This is especially the case with LEED EBOM and BOMA BEST which apply to existing buildings with existing tenants, long-term leases, and the associated search and relocation frictions. Soft interventions such as Eco Tracker and ForeverGreen, which engage and nudge behavior, may also experience a lag before any benefit is observable. A common finding in the psychology and behavioral economics fields is that shifts or permanent changes in human behavior require repeated reinforcement and learning. To address this, we extend the model specification in Eq. (1) to allow the environmental building certification, Eco Tracker, and ForeverGreen variables to be measured by time since implementation, or "Tenure."

Table 2
Electricity consumption and interventions.

	Canada			United States		
	(1)	(2)	(3)	(4)	(5)	(6)
ForeverGreen	−0.148***	−0.122***	−0.054*	−0.081**	−0.042	0.013
(1 = yes)	[0.029]	[0.028]	[0.028]	[0.036]	[0.030]	[0.059]
EcoTracker	−0.044**	−0.036*	0.017	−0.022	−0.071	−0.008
(1 = yes)	[0.020]	[0.021]	[0.027]	[0.043]	[0.049]	[0.032]
BOMA BEST	−0.014	0.020	0.041*			
(1 = yes)	[0.021]	[0.024]	[0.022]			
Energy Star				−0.092***	−0.080***	−0.062***
(1 = yes)				[0.035]	[0.018]	[0.022]
LEED EBOM	−0.116***	−0.092*	−0.081*	0.044*	0.057*	0.062*
(1 = yes)	[0.044]	[0.046]	[0.046]	[0.026]	[0.028]	[0.031]
Occupancy	−1.233***	−1.295***	−1.324***	−1.348***	−0.856***	−0.870***
(percent)	[0.235]	[0.263]	[0.263]	[0.261]	[0.107]	[0.107]
Electricity Cost		−0.245***	−0.138***		−0.178***	−0.116**
(ln($/MWh))		[0.046]	[0.048]		[0.056]	[0.045]
Heating Degree Days	0.013	0.010	−0.000	0.049***	0.047***	0.033***
(in hundreds by month)	[0.009]	[0.010]	[0.005]	[0.006]	[0.008]	[0.004]
Cooling Degree Days	0.002	0.045	0.121***	0.049***	0.050***	0.075***
(in hundreds by month)	[0.024]	[0.029]	[0.020]	[0.014]	[0.018]	[0.009]
Constant	−5.160***	−3.985***	−4.349***	−5.553***	−5.125***	−5.200***
	[0.229]	[0.384]	[0.382]	[0.237]	[0.265]	[0.261]
Month fixed effects	yes	yes	no	yes	yes	no
Year fixed effects	no	no	yes	no	no	yes
Building fixed effects	yes	yes	yes	yes	yes	yes
Number of building-months	7996	6300	6300	5277	3165	3165
Number of buildings	89	65	65	70	35	35
Adj. R-squared	0.79	0.77	0.77	0.84	0.92	0.92

Notes: The dependent variable is the natural log of energy consumption, measured in megawatt hours (MWh), scaled by occupied square feet. Columns (1) through (3) and (4) through (6) report results for the Canadian and U.S. samples, respectively. Month fixed effects are included in Columns (1), (2), (4), and (5), and year fixed effects are included in Columns (3) and (6); building fixed effects are included in all analyses. Robust standard errors, clustered at the building level, are in brackets. Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, ***, respectively.

We find strong support that tenure matters, for both hard and soft interventions, as it applies to the impact on electricity consumption reduction. Fig. 3 shows how electricity consumption is impacted by intervention tenure for three interventions.[9] The impact of the studied interventions on electricity consumption over time is compared to the year prior to the adoption ("base year") of the respective program, and each specification controls for the presence of other interventions.

Similar to the base result reported in Table 2, Panel A indicates that the adoption of BOMA BEST does not lead to a statistically significant decrease in electricity consumption post implementation, although the observed trend since adoption suggests a slow decrease in electricity consumption over time. The Panel B results for LEED EBOM in Canada indicate a statistically significant decrease in electricity consumption for the first three years after adoption before slowly dissipating, which aligns with the five-year recertification schedule. In contrast, this relationship is not present in the U.S. sample.

Similar to the LEED EBOM results, Eco Tracker monitoring adoption is associated with a statistically significant decrease in electricity consumption post implementation in Canada, but not in the U.S., as depicted in Panel C. The reduction in electricity consumption further increases after the implementation of Eco Tracker in Canada. The observed trend in the U.S. is encouraging, yet the confidence bounds are too wide to make any inferences about statistical significance. Panel D displays the results for ForeverGreen. While the results for the other interventions indicate marked differences between the Canadian and U.S samples, the results for ForeverGreen are quite similar in both countries. From the moment of implementation, the tenant engagement program leads to immediate reductions in electricity consumption that are persistent over time. This result is especially salient as the cost of implementation is negligible, and the presence of any of the other interventions is also captured in the analysis. The results from Panels B and C support existing behavioral findings that continued priming can lead to continued results.

4.2. Environmental capex

The emphasis to this point has been on results associated with environmental building certification and the two soft interventions, monitoring and tenant engagement. Table 3 extends and completes the analysis by addressing the fourth (and second "hard") intervention: environmentally-targeted capex through estimation of Eq. (2). The skew in the age distribution of our sample suggests the potential exists for productive capital expenditures (capex) focused on environmental goals. Our building level dataset includes a subset of properties, 36 in Canada and 27 in the U.S., for which detailed environmental-focused capex information is provided. These expenditures represent the second form of "hard" environmental intervention. As with Table 2, results are reported separately for Canada, Columns (1) through (3), and the U.S., Columns (4) through (6).

This analysis is separated from the other three interventions due to sample definition. While all buildings experience capital expenditures, and some of those capex activities will carry environmental goals and benefits, it has historically not been the norm to track environmental motivation behind each capital expenditure. BentallGreenOak is in the process of adopting accounting procedures which track environmental motivation, expected utility and greenhouse gas emission savings, and related costs. As only some of the buildings within the sample have adjusted their accounting methods to track intention for all capex, for analysis of this intervention our sample is restricted to the building-months governed by these accounting techniques. As with adoption of

[9] The graphs display coefficient estimates on each intervention's tenure within a building in an expanded version of the model shown in Table 2, Columns (2) and (5). Energy Star tenure is not measured due the the annual recertification schedule. Full estimation results are available upon request.

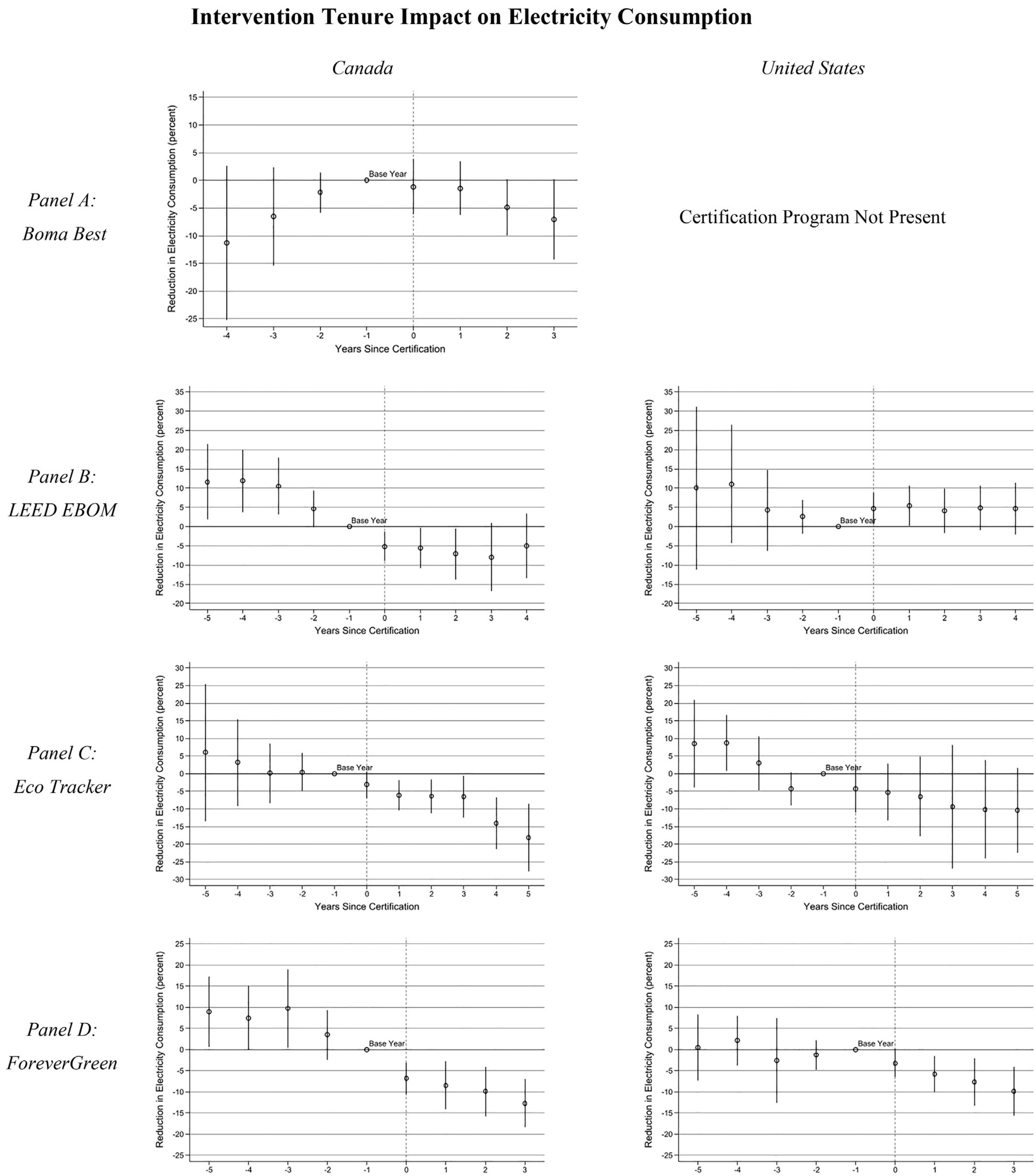

Fig. 3. Intervention tenure impact on electricity consumption. *Notes*: Each graph presents how electricity consumption is affected by each intervention's implementation within a building. These point estimates are based on regression estimates. Each hollow circle represents the point estimate, the whiskers represent a 95% confidence interval. Energy Star analysis is excluded due to data limitations.

the monitoring program, this is a ramp-up process that is occurring across the firm's portfolio. Selection bias concerns are mitigated as the decision of which assets are moved to the new accounting system does not lie in the same hands as the decision of which capex activities to pursue (which, as discussed in the Section 2, lies with asset management).

Table 3
Electricity consumption and capital expenditures.

	Canada			United States		
	(1)	(2)	(3)	(4)	(5)	(6)
CAPEX	−0.061**			−0.045**		
(1 = yes)	[0.023]			[0.018]		
CAPEX Category (1 = yes)						
Operational		−0.005			0.009	
		[0.027]			[0.041]	
Systems		−0.087***			−0.054	
		[0.025]			[0.044]	
Tenant		0.005				
		[0.031]				
CAPEX Subcategory (1 = yes)						
Operational change			−0.055*			−0.013
			[0.032]			[0.036]
Lighting retrofit			−0.075***			−0.099**
			[0.025]			[0.046]
ForeverGreen	−0.059	−0.049	−0.053	−0.055*	−0.056*	−0.042
(1 = yes)	[0.035]	[0.034]	[0.037]	[0.027]	[0.029]	[0.029]
EcoTracker	−0.022	−0.018	−0.022	−0.029	−0.038	−0.030
(1 = yes)	[0.030]	[0.029]	[0.026]	[0.032]	[0.034]	[0.029]
BOMA BEST	0.048*	0.051*	0.047*			
(1 = yes)	[0.026]	[0.026]	[0.025]			
Energy Star				−0.059***	−0.063***	−0.064***
(1 = yes)				[0.018]	[0.020]	[0.019]
LEED EBOM	−0.085**	−0.079**	−0.077**	0.039**	0.041**	0.036**
(1 = yes)	[0.040]	[0.039]	[0.037]	[0.016]	[0.016]	[0.017]
Occupancy	−0.537***	−0.547***	−0.539***	−0.911***	−0.907***	−0.899***
(percent)	[0.195]	[0.199]	[0.195]	[0.069]	[0.071]	[0.065]
Electricity Cost	−0.096*	−0.085*	−0.097*	−0.183**	−0.189**	−0.189**
(ln($/MWh))	[0.048]	[0.047]	[0.051]	[0.067]	[0.069]	[0.068]
Heating Degree Days	0.012	0.011	0.012	0.049***	0.050***	0.049***
(in hundreds by month)	[0.011]	[0.011]	[0.011]	[0.007]	[0.007]	[0.007]
Cooling Degree Days	0.003	0.005	0.004	0.048**	0.048**	0.049**
(in hundreds by month)	[0.033]	[0.033]	[0.033]	[0.018]	[0.018]	[0.018]
Constant	−5.378***	−5.417***	−5.375***	−4.954***	−4.936***	−4.938***
	[0.303]	[0.310]	[0.319]	[0.324]	[0.329]	[0.321]
Month fixed effects	yes	yes	yes	yes	yes	yes
Building fixed effects	yes	yes	yes	yes	yes	yes
Number of building-months	3984	3984	3984	2293	2293	2293
Number of buildings	36	36	36	22	22	22
Adj. R-squared	0.79	0.80	0.80	0.84	0.84	0.85

Notes: The dependent variable is the natural log of energy consumption, measured in megawatt hours (MWh), scaled by occupied square feet. Columns (1) through (3) and (4) through (6) report results for the Canadian and U.S. samples, respectively. Month fixed effects and building fixed effects are included in all analyses. Robust standard errors, clustered at the building level, are in brackets. Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, ***, respectively.

During each period observed in our subsample, it is possible that a building does not experience any capex, experiences capex without an environmental focus, or experiences environmentally-focused capex. The dummy variable will be equal to one if the last statement is true; this analysis is agnostic to concurrent non-environmentally-focused capital expenditures. We initially specify the capex intervention variable in aggregated form, in Columns (1) and (4), indicating whether the building has undergone an environmentally-focused capex intervention during that period or not, then follow this with more granular categorizations of the type of capex. Environmental capex are aggregated into three broad categories: operational; systems; and, tenant (Canada only), which are concurrently examined in Columns (2) and (5). Additionally, there is enough depth in the data to analyze two specific subcategories: operational change (mostly heating, ventilation and air conditioning, or HVAC, related); and, lighting retrofits, examined in Columns (3) and (6).

Columns (1) and (4) in Table 3 add the aggregate capex intervention indicator variable as a fourth intervention while controlling for the three other intervention categories, building and month fixed effects, and the other control variables included in Table 2. The results provide evidence of a statistically and economically significant relationship between environmental capex and electricity consumption in both the Canadian and U.S. samples, with environmentally-focused capex associated with a 6.1% reduction in electricity consumption in Canada and 4.5% in the U.S. While not as robust, the results suggest that the capex impact is in addition to the reductions associated with green building certification, monitoring, and tenant engagement. This finding is intuitive since capex specifically targets a consumption reduction that is independent of the forces exerted by the other three interventions.

Columns (2) through (3) and (5) through (6) report the results for more granular specifications of the capex variable, for the Canada and U.S. samples, respectively. Columns (2) and (6) break capex down into three broad categories related to the type of investment target: operational; systems; and, tenant (tenant-category capex is only observed in the Canadian sample). The Canadian results indicate that the significance of capex reported in Columns (1) is driven by capex focused on systems. Systems investments are those related to building controls and optimization of lighting use, heating and cooling systems, and a matching of supply of resources to times of demand. The U.S. analysis proves uninformative. There is enough depth in the data to permit closer examination of two subcategories: operational changes and lighting retrofits. Columns (3) and (6) provide evidence to suggest that both operational changes, largely changes or adjustments to HVAC systems, and lighting retrofits provide significant gains, driving down electricity consumption in Canada by 5.5% and 7.5%, respectively. In the U.S. sample, lighting retrofit stands out as statistically significant, while operational change has the anticipated sign but is not statistically significant.

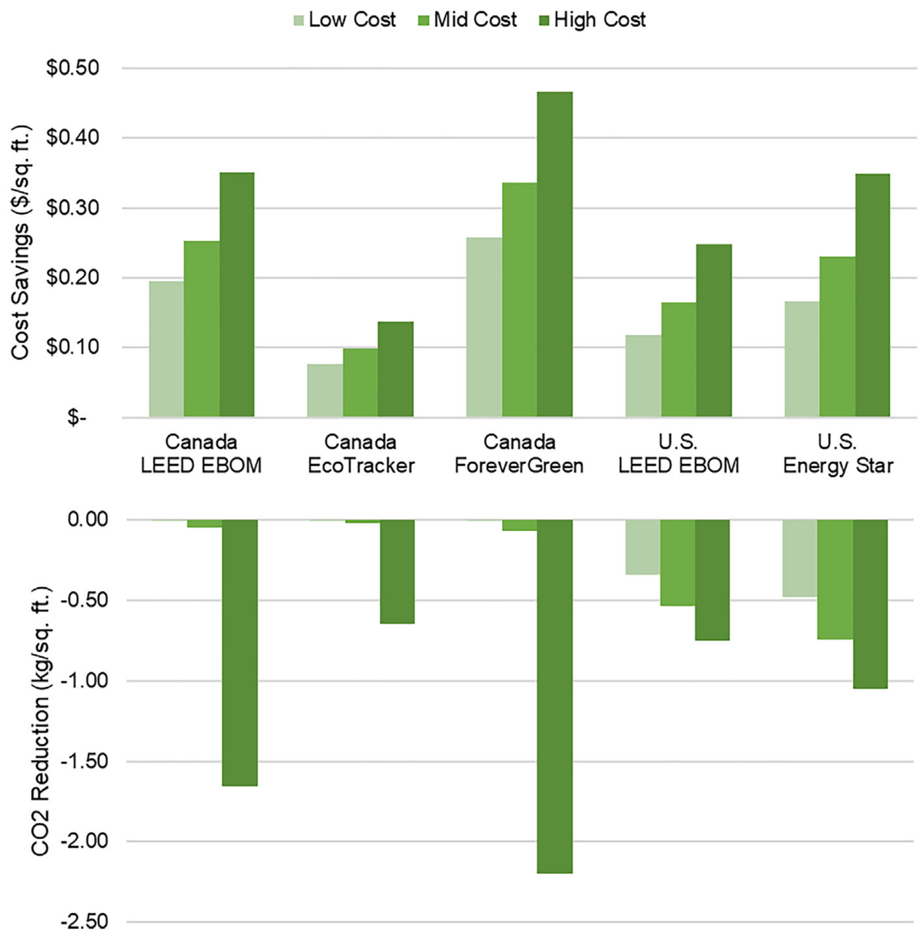

Fig. 4. Annual Electricity Cost Savings and CO2 Reduction Analysis. *Notes:* The above graphs apply the statistically significant intervention regression results from Table 2 to the sample average electricity consumption. The upper portion of each graph presents the cost savings per occupied square foot associated with the consumption reduction, and the lower portion presents the related CO2 reduction per occupied square foot. Consumption is annualized, based on the monthly average. Financial costs are in the local currency and based on 2018 average monthly bill rates for the buildings in the sample, annualized. CO2 equivalent estimates (in kilograms) utilize 2018 Canadian and U.S. federal government estimates, by province and region, respectively. Factors are separated into High, Mid, and Low categories (terciles). For financial cost, factors are equal weighted based on building-month billed utility rates in-sample for 2018. For CO2 cost, factors are value weighted based on the number of buildings in each region during 2018. Results are not meant to be compiled, as some gains to different interventions will overlap.

4.3. Back of the envelope cost savings analysis

For voluntary adoption of new technology by the industry to be successful, the financial implications must be clear. Our findings regarding reductions in electricity consumption imply cost savings, both in terms of dollars and greenhouse gas emissions. One of the benefits of our information is that it provides historic monthly electricity costs for many of the assets, as well as the costs associated with each tracked capex project. This allows for a high-level estimation of the possible savings associated with each intervention, and a comparison to average cost of the intervention.

Fig. 4 displays our estimates in the form of a range of possible outcomes derived by combining our regression estimates with low to high resource costs estimates. Specifically, we apply the statistically significant intervention regression results from Table 2, Columns (2) and (5) to the sample average electricity consumption. The upper portion of each graph presents the cost savings per occupied square foot associated with the consumption reduction, and the lower portion presents the related CO2 reduction per occupied square foot. Consumption is annualized, based on the monthly average. Financial costs are in the local currency and based on 2018 average monthly bill rates for the buildings in the sample, annualized. CO2 equivalent estimates (in kilograms) utilize 2018 Canadian and U.S. federal government estimates, by province and region, respectively. Factors are separated into High, Mid, and Low categories (terciles). For financial cost, factors are equal weighted based on building-month billed utility rates in-sample for 2018. For CO2 cost, these are value weighted based on the number of buildings in each region during 2018.

Our estimates suggest that if the estimated electricity reductions are observed and replicatable, the result could be substantial cost savings and emissions reduction. For example, based on the Canadian results, investment in ForeverGreen would result in a $0.26 to $0.47 per occupied square foot saving annually, and an offset of up to approximately 2.2 kg of carbon dioxide, depending on local costs. BentallGreenOak indicates that the ongoing cost of the tenant engagement program is negligible, which is consistent with other literature addressing the cost of encouraging behavioral changes (Aydin et al., 2018).

A similar analysis was completed on environmentally-focused capex results, comparing the cost outlay to electricity bill savings. While the broad capex categories cover too wide a range of improvements to evaluate cost versus savings, such analysis is possible for the subcategories analyzed. Given the small sample sizes, we provide only averages and ranges for these analyses. An operational change in Canada has an average one-time cost of approximately $0.02 per occupied square foot and could save between $0.14 and $0.26 and up to 1.2 kg of carbon dioxide per occupied square foot annually. Lighting retrofits in Canada (U.S.) can save $0.23 to $0.27 ($0.18 to $0.39) in electricity costs and up to 1.3 (1.1) kilograms in carbon dioxide per occupied square foot, for a one-time cost of, on average, $0.08 per occupied square foot. These findings indicate payback periods less than one year, which is consistent with applied findings, particularly regarding lighting retrofits (Mahlia et al., 2011).

5. Conclusion

Adoption of environmental building certification has become mainstream in the commercial real estate industry, and the focus has recently turned to new ways to further improve the environmental sustainability of the built world. This paper contributes to research on environmental building performance by shifting the lens from the building's structure and mechanicals alone to also include the behavior of property managers and tenants inside the building.

Through a partnership with a global investment management firm, we gain access to ten years of monthly asset-level operating statement data in a sample of Canadian and U.S. office buildings. We broaden the definition of investment in environmental sustainability and energy efficiency from exclusively environmental building certification to include three additional types of environmentally-focused building interventions: environmentally-focused capex; monitoring; and, tenant engagement. Monitoring and engagement are deemed “soft” interventions, passive and proactive, respectively, that strive to alter building user and management behavior. A growing body of research in psychology and behavioral economics concludes that soft interventions can be powerful in changing behavior and choices.

We document that adoption of environmental building certification, a monitoring program, and a tenant engagement program significantly improve the energy efficiency of Canadian assets. Participation in ForeverGreen is associated with a 12.2% decrease in electricity consumption, while Eco Tracker enrollment and LEED EBOM certification are associated with further electricity consumption reductions, although the economic and statistical significance are considerably weaker. In contrast to the Canadian findings, only environmental building certification is associated with economically and statistically significant findings in the U.S. As expected, an Energy Star label significantly improves the energy efficiency of an office building. Environmentally-focused capex is also shown to generate significant reductions in electricity consumption, 6.1% in Canada and 4.5% in the U.S. post implementation, based on a subsample of our dataset for which we have information on environmentally-focused capex.

The psychology and behavioral economics literature documents that shifts or permanent changes in human behavior require repeated reinforcement and learning (Bandura, 1974). We find strong support for the notion that tenure matters, as it applies to the impact on electricity consumption reduction, especially so for LEED EBOM and Eco Tracker in Canada, and ForeverGreen in both Canada and the U.S. The proactive ForeverGreen engagement program has an immediate benefit upon enrolment which retains its strength as long as the building remains active in the program.

Our findings indicate the potential for awareness, engagement, and reinforcement of the message to have real impacts on environmental performance, complementing building certification. While highly encouraging, our results apply to a single property type employing data provided by a single investment manager. A fruitful direction for future research in this area includes expanding the analysis to other property types. Retail assets, for example, increasingly have similar tenant and customer (user) programs that are less about electricity consumption and more about packaging and waste. Retail and apartment properties, like office, are also transitioning to place more emphasis on tenant experience in shared spaces, demanding increased plug load that could offer opportunities for engagement type programs to benefit electricity use. Future work might also consider a deeper dive into lease structures and the impact of tenant awareness and engagement programs. Split incentives arguably play an important role in achieving energy efficiency improvements (Jessoe et al., 2020). Further, it would be interesting to consider whether these findings ultimately could affect lease structures themselves, as incentivizing and rewarding tenants for environmental, social, and governance (ESG) successes would benefit ESG initiatives.

In our unique institutional office dataset, tenant engagement and reinforcement have a significant impact on electricity consumption, indicating that to maximize the cost savings available to environmentally-sensitive buildings, efforts must include all stakeholders. The collective impacts of design, operating efficiency, and maintenance of equipment, along with an effective strategy to engage and help tenants understand and reduce energy consumption, further adds to a buildings' bottom line, energy consumption, and carbon emissions. These findings have important implications for building owners and managers as well as ESG-related policy initiatives. It shows that the behavior of building users matters, and that communication, awareness, and active engagement provide opportunities to educate building managers and tenants on strategies to reduce carbon-footprint related expenses on a long-term basis. Building certification remains key, but certification alone does not optimize financial and environmental benefits.

Role of the funding source

BentallGreenOak provided the data for the study along with funding to support the research. They were involved in the data collection process, as the data was collected from several of their databases. They were not involved in study design, data analysis or interpretation, writing the report, or deciding where to pursue for publication. The Real Estate Research Institute (RERI) and the Lawrence Berkeley National Laboratory (LBNL), under the operation of the Department of Energy (DOE), also provided grant funding for this project. Quarterly phone meetings were held with research staff from LBNL, administrative staff from RERI, and the study authors to ensure advancement of the research in a timely manner. LBNL and RERI were not involved in: study design; data collection, analysis, and interpretation; report writing; or, deciding where to pursue for publication.

Declaration of Competing Interest

This work was financially supported by BentallGreenOak, the Real Estate Research Institute, and the Lawrence Berkeley National Laboratory, under the Department of Energy. None of these institutions were involved in the execution of the research.

Acknowledgements

We gratefully acknowledge BentallGreenOak for providing the data, and we acknowledge the firm along with the Real Estate Research Institute (RERI) and Lawrence Berkeley National Laboratory for funding. All errors in analysis and interpretation are the responsibility of the authors.

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