White Paper on Beyond Building Certification: The Impact of Environmental Interventions on Commercial Real Estate Operations*

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"You can have a very efficient car but if you drive it in the wrong manner, the car still consumes quite a lot of fuel, and it's the same with buildings."
Pieter Roozenboom, CBRE Global Investors[1]

1. Introduction

There is an extensive body of research on the environmental performance of commercial real estate (CRE), and mounting evidence that environmentally-certified buildings may experience stronger financial performance in the form of higher transaction prices, higher rents, and higher more stable occupancy rates, and that they are associated with a lower cost of debt, and lower default rate.[2] The majority of studies to-date focus on the impact of environmental building certification programs, including Leadership in Energy and Environmental Design (LEED), Energy Star, and other designations.[3] While environmental building certification is important, both in terms of measuring and signaling environmental commitment, it is just one way in which energy efficiency and sustainability can impact commercial real estate assets.

There is growing awareness in the CRE investment management community of the need to move beyond environmental building certification and inside the buildings themselves, for a deeper look at key resource-related operating expenses (e.g. energy, natural gas, and water), the impact of capex targeted at reducing these, and the behavior of occupants or users of the space.[4] In this research, we extend the existing literature by moving beyond the impact of environmental building certification and incorporating three additional types of environmental intervention at the asset management and tenant levels: environmentally-focused capex, monitoring, and tenant engagement. Building certification and green-focused capex are "hard" interventions. 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. Generally, pursuit of these interventions would occur in that order, moving from the technically-rooted "hard" building certification and capex (often executed in pursuit of certification), to a passive monitoring software system, and

[1] As quoted in the article by O'Dea (2019).
[2] See for example Miller et al. (2008), Eichholtz, Kok and Quigley (2010), Wiley et al. (2010), Fuerst and McAllister (2011), Devine and Kok (2015), Holtermans and Kok (2017), Eichholtz et al (2019), and An and Pivo (2018). Zhu (2018) provides a recent review of the body of the literature that highlights both the knowledge gains and also the gaps in existing energy efficient and sustainable real estate research to help guide the direction of future research.
[3] Qui and Kahn (2019) is a recent example that pushes the analysis beyond top line income numbers to estimate the impact of green building certification on electricity consumption but continues the singular focus on building certification as the only form of intervention.
[4] See O'Dea (2019).

finally to a proactive tenant engagement program. A timeline of environmental intervention adoption is visually depicted in Figure 1. [5]

**** *insert Figure 1 near here* ****

The impact of certification on utility consumption has been well studied. There is evidence of water-related cost savings (Kats, 2010), but results regarding power usage are mixed or inconclusive (Newsham, Mancini, & Birt, 2009; Scofield, 2009, 2013). Qiu and Kahn (2019) report 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.

While the literature examining the impacts of environmental building certification is extensive, research into the other studied interventions is limited. There is research that recognizes the importance of capital expenditures, broadly defined, and that examines the impact of these on property financial performance (Bond, Shilling, and Wurtzebach, 2018). However, we are not aware of any research that focuses specifically on capex targeted at reducing a building's environmental footprint. The few studies that examine environmental interventions on operating expenses provide evidence only at a high level.

A growing body of research in psychology, behavioral economics, and finance suggests that "soft" interventions can be powerful in changing 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 trends and social comparison (e.g. relative to neighbors), as well as energy conservation information. In a similar spirit, we test for a connection between changes in office space management and user behavior and utility (energy and water) consumption. Heller, Heater and Frankel (2011) suggest 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, though is an understudied topic. They propose that various means to make tenants aware of their energy consumption might help

[5] Capex is a potential exception to the general ordering of intervention timing illustrated in Figure 1. In some cases, expenditures may be undertaken after involvement in monitoring and engagement activities reveals areas for improvement. Our point is that it is a "capital related" cost for equipment or equipment related systems aimed at improving environmental performance, as opposed to behavioral changes that are captured by our soft interventions. Our models and empirical analysis do not depend on the relative timing of interventions introduced at the property level.

significantly reduce their energy use. Our paper offers a unique approach to testing whether changes in this behavior has real effects.

Through a partnership with BentallGreenOak, a global institutional investment manager, we gain access to fifteen years of monthly operating statements for hundreds of assets in the U.S. and Canada, and carefully examine and rigorously quantify the impact of third-party environmental building certification and environmentally-targeted capex, monitoring, and tenant engagement on building performance.[6] The firm's sustainability strategy goes beyond third-party building certification to also include formal tenant and property management expense awareness and engagement programs, "Eco Tracker" and "ForeverGreen," respectively. The overall portfolio is well balanced across the U.S. and Canada, providing the ability to examine the above question in two different countries.

In addition, we explore how these interventions interact. While environmental building certification and capex may decrease consumption, what is the effect when tenants and management are fully informed about and encouraged to capitalize on those unique improvements? The implications of these interventions, and their compounded effect, are of key importance to building owners and operators. This may provide another impetus to improve the environmental performance of the building stock through behavioral-focused interventions, potentially offering a relatively low-cost action to significantly impact outcomes.

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 key operating expense lines items, while controlling for other factors and outside influences and maximizing model robustness. Section 3 details the dataset we have created from property level operating data provided to us by institutional real estate investment manager BentallGreenOak. It also provides an overview of the firm's "Eco Tracker" expense monitoring and reporting program, and the "ForeverGreen" sustainability engagement program targeted at property managers and tenants. Section 4 provides the econometric results and a discussion of key findings. Section 5 presents a summary and implications of our findings.

[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.

2. Empirical Methodology

Thaler's (2008) "Nudge Theory" posits that consumer behavior can be influenced by small suggestions and positive reinforcements. Through this lense, we explore if tenant and property management engagement acts as a stimulus or "nudge" to affect real behavior that has sustainability implications, both individually and in combination with other environmental building interventions. We explore the intervention combinations to examine whether multiple environmental interventions can enhance the impact on building operations, or if certain interventions dominate the effectiveness of others.

BentallGreenOak's operating data allows us to create a building level dataset to study the trajectories of different utility consumption components over time. Assets within the firm's portfolio, which includes the properties for which BentallGreenOak provides investment management or property management services, received varied combinations of environmentally-focused capex, green building certification, monitoring, and tenant engagement interventions at specific points in time. Our main interest is to understand how these different interventions are related to electricity and water consumption.

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

$$lnCONS_{i,m,t} = \beta_{i,m,t} INT + X_{i,m,t} + \alpha_i + \delta_m + \epsilon_{i,m,t} \quad (1)$$

Where $lnCONS_{i,m,t}$ measures the natural log of electricity or water consumption (or peak electricity demand) per occupied square foot of building *i* in month *m* and year *t*. The INT indicator changes from zero to one after a building undergoes an intervention. An intervention entails either environmental building certification (*e.g.* BOMA BEST, LEED EBOM, or Energy Star), environmentally-focused capex, monitoring through BentallGreenOak's proprietary Eco Tracker program, or tenant engagement through the firm's ForeverGreen program. Building interventions (INT) are initially specified as "yes or no" at the aggregate level, and subsequently in a more granular format to test for the differential impact of levels of building certification achieved (e.g. LEED EBOM and BOMA BEST bronze, silver, gold and platinum) and tenure (time) of enrollment in the three different intervention programs. A binary control variable is also included for any periods during which a building is certified under a LEED design and construction-related scheme. These certifications are not explored in-depth, as they are not related to operations, yet they are always included as a control variable.

Equation (1) includes building fixed effects, α_i, to account for permanent differences in buildings' electricity and water consumption, and month fixed effects, δ_m, to capture seasonality (*e.g.* summer and winter temperature) that generate changes in average electricity and water consumption across all buildings. $X_{i,m,t}$ captures other time-varying factors which may impact consumption such as building occupancy and local climate. The parameter of interest is β, which measures the average difference in electricity or water consumption subsequent to building interventions (INT), after adjusting for the fixed effects. Robust standard errors are clustered at the building level.

The two most common endogeneity concerns in measuring the impact of environmental building certification, or other building level interventions such as tenant engagement, regard asset and management quality. The assembled data provides the ability to control for both. Management quality is intrinsically controlled for given the single operator for all examined assets in Canada, and explicitly captured (and tested) given the included management company data in the U.S. Asset quality is controlled for through the inclusion of building-fixed effects, which is possible since we observe all assets over an extended time period. It is important to note that, while the full operating history in the sample is 15 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

The data is derived from a partnership with BentallGreenOak, an institutional investment manager that operates and/or manages a global portfolio of commercial assets. Access to fifteen years of monthly line-item information provides us with asset-level information at a level of detail rarely observed. This provides the time horizon required to test the temporal effects of environtentally-focused interventions. Moreover, the sample includes assets in the U.S. and in Canada, enabling cross-country comparisons and providing further insight into how country-specific differences may influence the outcomes of the studied interventions. Very few studies have been able to compare green building implications across countries, and there are reasons to believe results may not be the same across markets (e.g. due to the policy environment, institutional arrangements, culture, and weather).[7]

The fact that all information is retrieved from a single firm which provides its services to a variety of institutional owners may lead to sample selection bias, for example regarding the proportion of high-quality buildings, which are mostly situated in major metropolitan areas. Importantly, decisions to implement different interventions lie with various building stakeholders (owner, asset manager, property manager, and tenants). Therefore these interventions are not necessarily voluntary actions by the impacted user, reducing some of the concern about observing such activities only in buildings with stakeholders that are more committed to energy efficiency and sustainability.

Operating information is collected on a monthly basis (or the most granular frequency available greater than monthly) covering the 2004–2017 period. The final dataset includes 261 buildings, 116 in Canada and 145 in the U.S., representing some 44 million square feet of space and over 25,000 building-month observations. The fact that our sample is comprised of a large number of existing buildings, as opposed to newly constructed properties, is an important differentiating aspect of our study. A major limitation of many existing studies' data is the focus on newly constructed buildings. Assessing the greening of 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).

Table 1 reports detailed descriptive statistics for key variables, including utility consumption, building characteristics, and local climatic conditions. We measure the impact of environmental interventions on utility consumption as represented by consumption of electricity and water.[8] Electricity consumption is measured in kilowatt hours per occupied square footage of space in each building and water by cubic meters per occupied square foot. These are reported separately for the Canadian (Panels A to C) and U.S. (Panels D to F) building samples. The first column of the table displays summary statistics for the total sample in each country, and subsequent columns display the same statistics for subsamples both with and without the three forms of studied environmental intervention (building certification, monitoring,

[7] Two of the only studies doing such work are completed by a member of this research team (Devine and Kok, 2015; Devine and Yönder 2018).
[8] Other utilities were examined, most notably natural gas. However, data was either too limited or results proved uninformative.

and tenant engagement). Building counts and number of building-month observations in each group are shown in the bottom two rows of the table.

****** *insert Table 1 near here* ******

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) and various design and construction-related programs (LEED D&C) 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. Overall, 146 of the 261 buildings are certified (77 in Canada and 69 in the U.S.), governing one-third of the building-month observations. This indicates that many buildings earned certification later in the sample period. Panels A and D indicate that, on average, environmentally-certified buildings are associated with markedly lower water consumption compared to non-certified buildings, yet certified buildings in Canada, on average, consume more electricity. Electricity consumption in certified buildings is also lower in the U.S. The relative success 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. Aside from that, the finding of higher electricity consumption in certified buildings has been identified in the existing literature, related to certified buildings often being new, higher-tech “smart” buildings (Devine & Yönder, 2018).

Panel B highlights that the Canadian sample is dominated (60%) by buildings constructed in the 1970s and 80s, with nearly three-quarters originally built prior to 1990. In addition to being an older sample, the majority of the buildings are classified as class B properties and located outside the downtown core Central Business District (CBD). The age distribution, quality, and location of certified buildings generally tracks that of the total sample quite closely. However, Canadian certified buildings tend to be significantly larger properties. Panel E reports building characteristic summary statistics for the U.S. sample, revealing key differences in the samples of the two countries. Buildings in the U.S. dataset are on average newer, with more than 70% constructed post-1990, and close to half since 2000. 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 towards larger, newer, class A assets, situated within urban cores.

The older skew in the age distribution of our property sample suggests the potential exists for productive capital expenditures focused on environmental goals. While not shown in Table 1, our building level dataset includes a subset of properties, 36 in Canada and 27 in the U.S., for which detailed environmental-focused capex is provided. These expenditures represent the second form of "hard" environmental intervention. Thirteen subcategories of environmental capex are tracked but owing to data thinness we aggregate these into three broad categories for purposes of analysis: operational, systems and tenant. At the subcategory level there is enough depth in the data to analyze two specific subcategories – operational change (mostly HVAC related) and lighting retrofits. Data limitations also prevent us from testing the impact of green capex intervention on water consumption, and hence our attention is focused on electricity consumption.

The firm has also implemented environmentally-focused tenant and property management engagement programs, what we term "soft" interventions. The first program is a data tracking and visualization tool called Eco Tracker. Eco Tracker is BentallGreenOak's sustainability data management system that provides a single reporting and management system for energy, utilities, water, and waste. It also includes a modeling tool, EcoModeler, to model reduction measures and predict reductions in consumption costs and greenhouse gas emissions. The original goal of this program was to assist in pursuit of environmental building certification (and recertification). 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-related decisions.[9] The goal of the program is increased efficiency of energy and water use, plus a healthy, productive work environment for building users. The decision to participate in the ForeverGreen program lies with the property manager. Conditional on a building being enrolled in the ForeverGreen program, individual tenants

[9] BentallGreenOak's engagement program is differentiated by properties in which tenants are working (office, industrial, retail) where it is labelled ForeverGreen@Work, and multi-family residential rental property where tenants live at which it is termed ForeverGreen@Home. Given our focus on office properties we are investigating the ForeverGreen@Work engagement program, but for simplicity will drop the "@Work" part of the label.

select a level of engagement from three preset levels representing increasing commitments of time and effort. BentallGreenOak'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.

At the start of each year, enrolled property managers share with tenants a calendar 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. For example, in 2018 the ForeverGreen theme was "Repackaging the Sustainability Conversation" and monthly topics were depicted as popular products/packages with slogans that have an environmental/green connection to the product. In a previous year the theme was movies and each month the topic and a "nudge" for the behavioral change goal was woven into a popular movie title. Enrolled property managers and tenants received educational and motivational resources such as posters, newsletters, and Green Team Packs which provide actionable content around the monthly environmental themes. Any building that enrolls in ForeverGreen is co-enrolled in Eco Tracker, should the monitoring software not already be in use at the building.

The fifth and seventh columns in Table 1 report descriptive statistics on buildings enrolled in the Eco Tracker and ForeverGreen programs, respectively. With 88 properties (6,789 building-months) in Eco Tracker and 73 properties (2,468 building-months) in ForeverGreen, the Canadian sample shows a high level of engagement that bodes well for robust empirical analysis. 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 and water consumption compared to non-ForeverGreen buildings in both countries. Eco Tracker is associated with reduced electricity and water consumption in the U.S. sample (as opposed to non-Eco Tracker), but only water consumption is reduced in the Canada sample, a result that mirrors the finding on building certification.

Figure 2 displays the cumulative adoption of three interventions across the portfolio, broken down separately for Canada (Panel A) and the United States (Panel B).[10] The monitoring and tenant

[10] See Appendix Table A1 for a building count breakdown of all possible intervention pairings observed within our sample.

engagement programs were first introduced in Canada and were subsequently introduced into the U.S. portfolio. It should be noted that this represents the first time each building experiences an intervention while in our sample. In some cases, buildings experienced additional environmental building certification activity in prior years under different ownership/management. In connection with this fact, the graphs highlight the intervention adoption order described in Figure 1. 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 parties. 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. While Figure 2 highlights adoption by buildings over time, the tenant engagement adoption focus now lies within assets, with the goal of increasing the number and commitment level of tenants so as to maximize the benefits of the intervention.

****** *insert Figure 2 near here* ******

Figure 3 presents early evidence of the impact of environmental interventions on utility consumption. For the combined Canada and U.S. sample, Panels A, B, and C present electricity and water consumption for buildings both with and without Environmental Building Certification, Monitoring, and Tenant Engagement, respectively. It compares median building level consumption on a square foot basis at a monthly frequency (allowing for the observation of seasonality) over the full sample period. The graphs on the left provide strong evidence of lower electricity consumption in buildings with environmental interventions. The Eco Tracker and ForeverGreen soft interventions are associated with consumption benefits throughout the year, while the benefits from environmental building certification seem to be associated with significant reductions only in late spring through early fall, but they wane in the winter months. Water consumption graphs on the right of Figure 3 reveal a strong seasonal pattern, with buildings subject to intervention showing lower consumption levels during the summer months. Soft interventions are associated with higher water consumption in winter months, yet building certification retains lower consumption patterns year-round, although at a smaller relative benefit during the winter months. This early non-parametric analysis points to a common theme in water consumption: the role of landscaping. Agriculture is the single largest use of potable water, and the related aspect in CRE operations is landscaping, which would peak in use during the summer months.[11] Notably, in all six cases intervened buildings experience less utility consumption volatility. This is consistent with research indicating environmentally certified buildings are lower risk assets (Devine & Kok, 2015).

** *insert Figure 3 near here* **

4. Empirical Results

Three of the four building-level interventions we study, third-party environmental building certification, green-targeted capex, monitoring, and tenant engagement programs, are largely separate decisions. In our sample, monitoring is highly correlated with the other programs, as it was introduced to support pursuit of certification, and is always in place in buildings with tenant engagement programs. However, building certification is a building owner decision encompassing building materials, design and equipment standards, while tenant engagement programming is induced and reinforced by property manager intervention and tenant demand. Recognition of this distinction guides our estimation approach, in which we test for the joint impacts of environmental building certification, monitoring, and tenant engagement on consumption of utilities. Hence, coefficient estimates on specific intervention variables are marginal or incremental effects after controlling for, and independent of, the impact of the other interventions.

We first report the impact of the three interventions, one "hard" (certification) and two "soft" (monitoring and engagement) on electricity and then water consumption based on the full sample described in the data section and summarized in table 1. Following this detailed analysis, we provide estimates of the impact of green or environmental capex on electricity consumption derived from the smaller subset of properties for which we have detailed capex information.

Electricity Consumption

Table 2 reports estimates of Equation (1), testing for the impacts of "hard" (environmental building certification) and "soft" (Eco Tracker and ForeverGreen) interventions on electricity consumption, on a per occupied square foot basis. The estimation strategy we employ initially specifies the intervention variables in aggregated form, just indicating whether the building has that intervention or not. These

[11] https://www.oecd.org/agriculture/topics/water-and-agriculture/

results are reported in Columns (1) and (2) separately for Canada and U.S. We include occupancy and local weather (heating and cooling days) as control variables, as well as monthly- and building-fixed effects to capture seasonal variation not captured by heating and cooling degree days and unobserved variation in building level characteristics that might impact electricity consumption.

****** *insert Table 2 near here* ******

The results provide strong evidence that all tested forms of interventions have a significant impact on electricity consumption in the Canadian sample, both in terms of statistical and economic significance. In Table 2, Column (1), electricity consumption per square foot of occupied space is on average 19% lower in buildings with both BOMA BEST and LEED EBOM certification. Participation in the ForeverGreen tenant engagement program is associated with a 13.6% decrease on average, while the Eco Tracker monitoring program reports a 4.3% decrease on average. Results in Column (2) show ForeverGreen engagement also has a statistically significant impact on electricity consumption in the U.S. sample, although the economic significance is considerably smaller than in the Canadian sample (7.3% reduction compared to 13.6%). In contrast to the results for Canada, LEED EBOM building certification does not seem to impact electricity consumption in the U.S. data, while both LEED design and construction-related programs and Energy Star certification do.

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. Despite a lack of statistical significance associated with the LEED EBOM or Eco Tracker interventions, the explanatory power of the model is higher with the U.S. data, a finding that could be associated with the stronger significance of the weather-related control variables, and especially cooling degree days, shown in the bottom part of the table.

An examination of control variables indicates that local weather conditions matter, and more 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 heating (cooling) days translates into 4.8% (4.9%) higher electricity consumption. Additionally, as noted in Figure 2, adoption of the different interventions followed unique paths in the two countries. This is why we isolate the countries in this analysis, where the differences are notable, and why we should not compare the findings against each other. Differences in findings may just as likely reflect sample distinctions as country-specific distinctions.

Columns (3) and (4) present more granular results of the full sample specifications in columns (1) and (2) with LEED EBOM and BOMA BEST environmental building certification specified by the level achieved. Both the Canadian and U.S. samples indicate that the highest levels of certification (Gold and Platinum) are consistently driving the economic and statistical significance of the aggregate results. In the U.S. results, there is a positive coefficient on the higher levels of LEED EBOM certification which may be due to sample size limitations of these small subsample groups, or a consistent pairing of other certifications with these (such as LEED D&C) which are reporting strong, negative coefficients. The coefficient estimates on ForeverGreen retain their magnitude and statistical significance, as does Eco Tracker in Canada.

Columns (5) and (6) display the results of estimating the models shown in Columns (1) and (2) with the dependent variable specified as “peak demand” electricity consumption during the month instead of overall total monthly consumption. Peak demand represents the highest kW consumption of electricitity duting the month (usually the highest 15 minute segment), and this level of demand is (often) used to determine the price for the energy; the greater the peak demand the higher the overall cost per unit (kWh).

A building that can reduce peak demand may experience lower energy costs (total cost can be any combination of regulated “base” fee, energy fee, and taxes). The results in Column (5) reveal economically and statistically significant negative coefficient estimates on building certification and Forever Green engagement. The parameter estimates are slightly lower in magnitude compared to the full monthly electricity consumption model in Column (1), but applied to peak demand consumption imply significant overall cost reductions at peak times. These results support the notion of a building with less variance in demand having lower energy cost, which is consistent with green buildings being characterized as lower risk. In contrast to the Canadian sample findings, the U.S. results in Column (6) show no statistically significant coefficient estimates on intervention variables, likely owing to the smaller sample and other issues discussed above as pertaining to the results in Column (2).

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 marketplace to recognize and adjust to the label and what it means. This is especially the case with LEED EBOM and BOMA BEST on existing buildings with existing tenants, long-term leases, and the associated search and relocation frictions. Soft interventions such as Eco Tracker and ForeverGreen that aim to build awareness, engage and nudge behavior are also expected to take time. A common finding in the psychology and behavioral economics fields is that shifts or permanent changes in human behavior require repeated reinforcement and learning.[12] To address this, we extend the model specification to allow the environmental building certification, Eco Tracker and ForeverGreen variables to be measured by length of time, or "Tenure," the building has been enrolled in the respective programs.

****** *insert Figure 4 near here* ******

We find strong support that tenure matters, for both hard and soft interventions, as it applies to the impact on electricity consumption reduction. Figure 4 shows how electricity consumption is impacted by intervention tenure for three interventions. 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 (1) and (2).[13] Panel A indicates that both BOMA BEST and LEED EBOM exhibit electricity consumption benefits from the initial point of certification, with a continued decrease in consumption as time extends. LEED EBOM shows less substantial and statistically insignificant reductions in electricity consumption compared to BOMA BEST in this sample. The fact that both programs present decreased consumption as of the time of certification speaks to the utility consumption goals of the certification program, whereas further consumption decreases may reflect refined consumption behavior and the co-location of tenants desiring environmentally-certified space (and therefore, using their space with greater environmental sensitivity). Further, capital expenditures in the building may also enhance building performance.

Panel B indicates that Eco Tracker takes time to impact a building's electricity consumption. Consistent, significant decreased electricity consumption for Eco Tracker begins after four years, on average, but then continues to present efficiency gains year-over-year through ten years (the end of our sample period). This effect is net of the benefits associated with the other interventions, which are also captured in this analysis. Compared to the other interventions, monitoring proves to offer the greatest impact on

[12] See for example Thaler and Sunstein (2008) for a general discussion, and Heller et al. (2011) for a tenant engagement perspective.
[13] The full estimation results are provided in Appendix A2.

electricity consumption in the long run. Panel C displays the coefficients on the ForeverGreen tenure, measured in six-month increments, and reveals a strong immediate benefit of enrolment. Notably, this initial effect is the largest decrease to electricity consumption of the three examined intervention categories, and it proves both highly statistically significant and consistent over time. Results from Panels B and C both support existing behavioral findings that continued priming can lead to continued results.

Water Consumption

Table 3 extends the consumption analysis to water. The sample size of buildings with observations on water is smaller than that for electricity and as a result analysis can only be completed on the combined sample (Canada and U.S. results). However, by combining the countries, we can stratify the sample by urban core (CBD) versus suburban location.[14] This stratification is key for water consumption, as the leading uses of water are agricultural, which for office buildings would be landscaping-related uses. Owing to the inherent differences in characteristics of CBD versus suburban properties, including the relative proportion of non-land to land, we expect differences in water consumption, with the higher demand for lawns and landscaping with suburban assets.

****** *insert Table 3 near here* ******

Table 3 reports the estimation results of hard and soft interventions on water consumption, including the same controls and fixed effects employed in the electricity consumption models. The impacts of the three interventions are examined sequentially in isolation before being brought together in one fully specified model to examine marginal effects conditional on the other interventions. Odd-numbered columns examine CBD buildings, and even-numbered columns examine Suburban buildings.

Consistent with expectations, water usage relates strongly to building location in the downtown core (CBD) or suburbs. This finding is likely attributable to landscaping and grounds maintenance and is consistent with the seasonal bump in water consumption observed in the Summer months (Figure 3). Certain environmental interventions matter in the Suburban sample but generally do not play a role in explaining variation in CBD buildings. The only exception is LEED design and construction-related

[14] This stratification was also tested for electricity consumption and operating statement items and proved uninformative.

certification program, which is associated with decreased water consumption in CBD assets, both in isolation (Column (1)) and in the fully specified model (Column (7)). In isolated Suburban analyses, all building certification programs except for Energy Star are associated with decreased water consumption, as are Eco Tracker and ForeverGreen. When brought together in the fully specified model (Column (8)), it is BOMA BEST and LEED design and construction certification programs, and Eco Tracker that stand out as the important interventions. ForeverGreen proves uninformative when the effects of other interventions are captured. This is to be expected, as the water-hungry activities related to landscaping are not user impacted. That is, decreasing water consumption is about how the property itself is designed and managed, not the users therein.

Environmental Capex and Electricity Consumption

The emphasis to this point has been on results associated with green building certification and the two “soft” interventions, monitoring and engagement. Table 4 extends and completes the analysis by adding the fourth (and second “hard”) intervention: environmentally-targeted capex. Consistent with our estimation strategy for building certification, Eco Tracker and ForeverGreen interventions above, we initially specify the CAPEX intervention variable in aggregated form, indicating whether the building has that intervention or not, then follow this with more granular categorizations of the type of capex.

Columns (1) and (5) in Table 4 add the aggregate capex intervention indicator variable as a fourth intervention while controlling for the three other intervention categories, building- and monthly-fixed effects, and the other incorporated control variables. Analysis is completed with the subsets of properties that report capital expenditures (36 in Canada and 27 in the U.S.) and are reportedly separately for the two countries. The results provide strong 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 7.3% reduction in electricity consumption in Canada and 6.2% in the U.S. While not as robust, the results also suggest that the Capex impact is on top of or 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. Consistent with the earlier results reported in Table 2, the explanatory power of the model is much higher in the U.S. (92.9% R-squared) than in Canada (68.5% R-squared), potentially owing to the greater variation in electricity consumption being captured by the heating and cooling day control variables.

** *insert Table 4 near here* **

Columns (2) through (4) and (6) through (8) report the results for more granular specifications of the capex variable, for the Canada and U.S. samples, respectively. Columns (2) and (6) break the capex down into three broad categories related to the type of investment target: operational; systems; and, tenant. The results in both countries reveal that the significance of capex reported in Columns (1) and (5) is driven by capex focused on systems. Systems investments are those related to controls and optimization of lighting use, heating and cooling systems, and a matching of supply of resources to times of data demand. There is enough depth in the data to permit closer examination of two subcategories. Columns (3) and (4) provide evidence to suggest that both operational changes, largely changes or adjustments to HVAC systems, and lightning retrofits provide significant gains in electricity reduction, driving consumption in Canada about 8.2% lower. In the U.S. sample lighting retrofit stands out as strong statistically significant, while operational change has the anticipated sign but is not statistically significant.

5. Discussion and Implications

Adoption of environmental building certification has become mainstream in the CRE industry, and the focus has recently turned to additional and new ways to further improve the environmental sustainability of the built world. As new approaches are explored, there concurrently develops a need to evaluate their effectiveness, both independently and in conjunction with green building certification.

In this paper we broaden the definition of investment in sustainability and energy efficiency from exclusively environmental building certification to also include three additional types of environmentally-focused building interventions: environmentally-focused capex, monitoring, and tenant engagement. Monitoring and engagement are “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. Appealing to Thaler’s (2008) “Nudge Theory” that consumer behavior can be influenced by small suggestions and positive reinforcements, we examine whether tenant and property management education and engagement acts as a stimulus or “nudge” to affect real behavior that has energy efficiency implications, beyond those achieved from building certification.

Through a partnership with a global institutional real estate investment manager that has been actively pursuing all four types of interventions for several years, we are able to examine the relative effectiveness of these environmental building interventions. Beyond the firm's extensive building certification activity and environmental-focused capex program, it has also implemented unique monitoring (Eco Tracker) and engagement (ForeverGreen) programs focused on the building's users and occupants. The dataset depth allows us to rigorously quantify the effect of interventions on energy and water consumption. Using a rigorous building fixed effects model, we are able to measure the impact of the interventions both in general and over the period of a building's exposure to the interventions.

We document that both adoption of environmental building certification and participation in ForeverGreen significantly improve the energy efficiency of Canadian assets. On average, electricity consumption is 16.5% lower in buildings certified under the LEED EBOM program, and 19% lower in buildings with both a LEED EBOM and BOMA BEST certification. Participation in ForeverGreen provides an additional 13.6% decrease, while Eco Tracker further reduces electricity consumption by 4.3%. In the U.S., ForeverGreen also has a significant impact on electricity consumption, although the economic significance is considerably smaller compared to Canada. In contrast to the Canadian findings, only LEED design and construction certification is associated with an increase in energy efficiency rather than LEED EBOM. 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 with a 7.3% in Canada and 6.2% in the U.S. based on a subsample of our dataset for which we have data on capex.

The psychology and behavioral economics literature documents that shifts or permanent changes in human behavior require repeated reinforcement and learning. We find strong support for the notion that tenure matters, as it applies to the impact on electricity consumption reduction. Eco Tracker monitoring show no benefits early on, but has a strong impact after a few years, and BOMA BEST has an immediate effect that improves over several years. The proactive ForeverGreen engagement has a strong immediate benefit upon enrolment which retains its strength as long as the building remains active in the program.

In contrast to electricity consumption, variations in water usage is more about building location (CBD or suburbs) and building certification, and less related to behavior of building users. We document that water consumption relates strongly to a building being situated in a suburban area, a finding likely attributed to landscaping and grounds maintenance. It is the building certification and monitoring that matter most in the suburban sample. The important role of building certification in water reduction is highlighted by the large magnitudes of reduction, -20.1% and -23.5%, implied by the coefficient estimates on the BOMA BEST (Canada) and LEED design and construction schemes (both Canada and the U.S.).

****** *insert Table 5 near here* ******

Our findings regarding consumption reductions mean cost savings, both in terms of dollars and emissions. Figure 5 displays our estimates in the form of a range of possible outcomes derived by combining our regression estimates with low to high resources costs estimates. Specifically, we apply the statistically significant intervention regression results from Table 2 to the sample average electricity consumption costs. The upper portion of the graph presents the cost savings per occupied square foot associated with the consumption reduction, and the lower portion presents the related CO_2 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. CO_2 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 CO_2 cost, these are value weighted based on the number of buildings in each region during 2018.

Our estimates suggest the existence of substantial costs savings and carbon footprint reductions. For example, based on Canadian results, investment in ForeverGreen would result in a $0.28 to $0.50 per occupied square foot savings annually, and an offset of up to approximately 2.4 kilograms of carbon dioxide, depending on local costs. Considering the negligible cost of implementing the tenant engagement program, these are substantial savings. A similar analysis was completed on environmentally-focused capex results. For example, 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 per occupied square foot annually.

Overall, we find significant support for the notion that both environmental building certification and ESG-related tenant awareness and engagement programs play crucial roles in reducing utility consumption. Much of the previous research in this area implicitly assumes that building design and equipment efficiency at the time of certification determines energy and water related expense reductions from building operations. This paper has taken advantage of a unique dataset that includes not only building certification but also “within building” awareness, education and engagement, and reinforcement of these programs over time.

This paper has focused on a single property type and 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 put more emphasis on tenant experience in shared spaces demanding increased plug load that could offer opportunity 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. Further, it would be interesting to consider whether these findings ultimately could affect lease structures themselves, as incentivizing and rewarding tenants for ESG successes would benefit ESG initiatives.

In our unique institutional office dataset, tenant engagement and reinforcement has a significant impact on electricity consumption, indicating that to truly maximize the cost savings available to environmentally-sensitive properties, efforts must span the building 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. 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 savings.

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Table 1: Descriptive Statistics - Canada

Panel A: Monthly consumption metrics	Total		Certified		Non-certified		Eco Tracker		Non-Eco Tracker		ForeverGreen		Non-ForeverGreen	
Electricity consumption	1.929	(1.782)	2.002	(2.405)	1.860	(0.836)	1.932	(1.916)	1.911	(0.749)	1.760	(0.792)	2.004	(2.069)
(kWh/occupied sq. ft.)	*7,854*	*[88]*	*3,815*	*[70]*	*4,039*	*[75]*	*6,601*	*[87]*	*1,253*	*[54]*	*2,405*	*[72]*	*5,449*	*[78]*
Water consumption	9.219	(7.682)	7.812	(4.559)	10.578	(9.604)	8.922	(6.849)	10.897	(11.168)	7.146	(5.066)	10.222	(8.492)
(liter/occupied sq. ft.)	*1,545*	*[22]*	*759*	*[17]*	*786*	*[17]*	*1,313*	*[21]*	*232*	*[11]*	*504*	*[17]*	*1041*	*[19]*
Panel B: Building characteristics														
Size (thousand sq. ft.)	134.5	(154.2)	168.9	(201.1)	114.1	(113.1)	142.3	(148.1)	122.0	(162.9)	162.2	(176.8)	126.5	(146.1)
Occupancy Rate (%)	88.1	(19.7)	88.8	(17.5)	87.7	(20.9)	88.1	(19.1)	88	(20.6)	88.3	(15.5)	88.0	(20.8)
Building Class (%)														
Class A	28.8		41.0		21.6		34.7		19.5		33.8		27.4	
Class B	49.8		47.5		51.2		54.0		43.1		46.5		50.8	
Unknown	21.4		11.5		27.2		11.4		37.4		19.7		21.8	
Construction period (%)														
Unknown	6.0		0.0		9.4		0.0		15.7		0.2		7.7	
Pre 1950	3.7		3.0		4.2		2.4		5.9		1.8		4.3	
1950-1969	3.1		4.5		2.3		4.4		1.0		5.2		2.5	
1970-1979	23.8		25.5		22.8		25.8		20.5		26.7		22.9	
1980-1989	35.8		36.0		35.7		41.9		26.0		40.5		34.4	
1990-1999	10.6		7.8		12.3		6.6		17.1		3.8		12.6	
2000 and after	17.0		23.2		13.3		18.9		13.8		21.8		15.6	
CBD (%)	29.1		32.9		26.9		35.1		19.4		43.2		25.0	
Number of building-months	11,009		4,098		6,911		6,789		4,220		2,468		8,541	
Number of buildings	116		77		105		87		88		73		107	
Panel C: Local climate conditions														
Cooling degree days (# per month)	15.4	(32.5)	14.5	(31.7)	15.9	(32.9)	14.9	(31.8)	16.2	(33.5)	15.6	(31.5)	15.3	(32.7)
Heating degree days (# per month)	310.0	(255.7)	304.7	(254.3)	313.2	(256.4)	309.3	(256.3)	311.2	(254.7)	307.0	(260.2)	310.9	(254.4)
Number of building-months	11,009		4,098		6,911		6,789		4,220		2,468		8,541	
Number of buildings	116		77		105		87		88		73		107	

Notes: Standard deviations in parentheses. Number of building-months and number of buildings for Panel A and B in italics and brackets, respectively.

Table 1 (cont.): Descriptive Statistics - United States

Panel D: Monthly consumption metrics	Total		Certified		Non-certified		Eco Tracker		Non-Eco Tracker		ForeverGreen		Non-ForeverGreen	
Electricity consumption	1.891	(2.984)	1.712	(3.463)	2.229	(1.951)	1.643	(0.794)	2.193	(4.178)	1.701	(0.716)	1.984	(3.433)
(KWh/occupied sq. ft.)	*4,873*	*[72]*	*2,997*	*[51]*	*1,876*	*[57]*	*2,498*	*[39]*	*2,375*	*[63]*	*1252*	*[36]*	*3,621*	*[71]*
Water consumption	7.400	(9.68)	6.395	(7.852)	8.919	(11.761)	5.721	(4.508)	9.170	(12.844)	5.824	(4.208)	7.931	(10.87)
(liters/occupied sq. ft.)	*4,974*	*[74]*	*2,992*	*[51]*	*1,982*	*[58]*	*2,552*	*[40]*	*2,422*	*[64]*	*1252*	*[36]*	*3,722*	*[73]*
Panel E: Building characteristics														
Size (thousand sq. ft.)	144.5	(141)	234.0	(203.1)	108.6	(82.4)	240.5	(229.2)	124.3	(103.3)	245.3	(211)	135.0	(128.6)
Occupancy Rate (%)	78.0	(29.2)	87.2	(16.8)	74.3	(32.1)	87.9	(14.2)	75.9	(31)	86.5	(16.8)	77.2	(29.9)
Building Class (%)														
Class A	74.1		84.7		69.8		90.2		70.7		89.6		72.6	
Class B	25.9		15.3		30.2		9.9		29.3		10.5		27.4	
Construction period (%)														
Pre 1950	1.2		1.7		1.0		5.3		0.3		0.0		1.3	
1950-1969	6.2		5.7		6.5		3.6		6.8		4.8		6.4	
1970-1979	0.0		0.0		0.0		0.0		0.0		0.0		0.0	
1980-1989	20.9		20.4		21.0		9.5		23.2		3.8		22.5	
1990-1999	24.1		16.5		27.2		17.5		25.5		17.1		24.8	
2000 and after	47.6		55.7		44.3		64.0		44.1		74.3		45.1	
CBD (%)	17.1		31.3		11.4		45.6		11.1		43.0		14.7	
Number of building-months	14,695		4,212		10,483		2,558		12,137		1,263		13,432	
Number of buildings	145		69		135		40		136		36		144	
Panel F: Instruments														
Cooling degree days (#)	70.3	(116.6)	79.4	(118.6)	66.6	(115.5)	79.1	(119.7)	68.4	(115.8)	83.1	(116.1)	69.1	(116.5)
Heating degree days (#)	397.9	(385.6)	382.6	(388.2)	404.1	(384.4)	377.3	(377.9)	402.3	(387)	359.3	(378.2)	401.6	(386.1)
Number of building-months	14,695		4,212		10,483		2,558		12,137		1,263		13,432	
Number of buildings	145		69		135		40		136		36		144	

Notes: Standard deviations in parentheses. Number of building-months and number of buildings for Panel A and B in italics and brackets, respectively.

Table 2: Hard and Soft Interventions and Electricity Consumption & Peak Demand

	-------- Ln(Consumption per Occupied SF)			--------	Ln(Peak Demand per Occupied SF)	
	Canada	U.S.	Canada	U.S.	Canada	U.S.
	(1)	(2)	(3)	(4)	(5)	(6)
BOMA BEST only	-0.040**				-0.025	
(1=yes)	[0.019]				[0.017]	
LEED EBOM only	-0.165***	0.054			-0.137***	0.023
(1=yes)	[0.055]	[0.041]			[0.035]	[0.025]
BOMA BEST & LEED EBOM	-0.190***				-0.125***	
(1=yes)	[0.058]				[0.033]	
LEED D&C	0.029	-0.123***	0.046	-0.127***	0.110	
(1=yes)	[0.157]	[0.046]	[0.149]	[0.040]	[0.089]	
Energy Star only		-0.096*		-0.078**		0.020
(1=yes)		[0.055]		[0.036]		[0.031]
LEED EBOM & Energy Star		-0.052**				-0.004
(1=yes)		[0.025]				[0.013]
Eco Tracker	-0.043**	-0.009	-0.043**	-0.008	-0.036	-0.029
(1=yes)	[0.019]	[0.044]	[0.019]	[0.043]	[0.022]	[0.035]
ForeverGreen	-0.136***	-0.073**	-0.133***	-0.075**	-0.079***	-0.012
(1=yes)	[0.024]	[0.030]	[0.024]	[0.030]	[0.014]	[0.025]
BOMA BEST Level (1=yes)						
Certified			0.014			
			[0.040]			
Bronze			-0.095***			
			[0.035]			
Silver			-0.037			
			[0.029]			
Gold & Platinum			-0.069**			
			[0.033]			
LEED EBOM Level (1=yes)						
Certified			-0.160	0.028		
			[0.173]	[0.040]		
Silver			-0.182*	0.091***		
			[0.092]	[0.027]		
Gold & Platinum			-0.115**	0.123**		
			[0.057]	[0.052]		
Occupancy	-1.305***	-1.497***	-1.304***	-1.500***	-0.891***	-0.958***
(percent)	[0.229]	[0.239]	[0.219]	[0.245]	[0.109]	[0.065]
Heating Degree Days	0.018**	0.050***	0.018**	0.050***	-0.011	0.026***
(in hundreds by month)	[0.009]	[0.006]	[0.009]	[0.006]	[0.010]	[0.009]
Cooling Degree Days	-0.003	0.047***	-0.002	0.047***	-0.018	0.033
(in hundreds by month)	[0.027]	[0.015]	[0.027]	[0.015]	[0.029]	[0.022]
Constant	1.765***	1.460***	1.761***	1.453***	-4.549***	-4.780***
	[0.219]	[0.218]	[0.210]	[0.215]	[0.120]	[0.122]
Month-fixed effects	yes	yes	yes	yes	yes	yes
Building-fixed effects	yes	yes	yes	yes	yes	yes
Number of building-months	7,854	4,873	7,854	4,873	5,498	2,348
Number of buildings	88	72	88	72	70	39
Adj. R-squared	0.754	0.843	0.755	0.843	0.767	0.898

Notes: Consumption is measured in kWh and peak demand is measured in kW; each is scaled by occupied square feet. 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.

Table 3: Interventions and Water Consumption

(dependent variable: natural log of water consumption per occupied sq. ft.)

	CBD	Suburban	CBD	Suburban	CBD	Suburban	CBD	Suburban
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
BOMA BEST only	0.096	-0.231**					0.067	-0.201*
(1=yes)	[0.143]	[0.102]					[0.145]	[0.101]
LEED EBOM only	0.273	-0.162*					0.232	-0.128
(1=yes)	[0.232]	[0.084]					[0.193]	[0.086]
BOMA BEST & LEED EBOM	-0.099						-0.131	
(1=yes)	[0.356]						[0.336]	
Energy Star only	-0.120	-0.096					-0.121	-0.114
(1=yes)	[0.123]	[0.094]					[0.130]	[0.093]
LEED EBOM & Energy Star	-0.052	0.049					-0.024	0.035
(1=yes)	[0.150]	[0.054]					[0.142]	[0.054]
LEED D&C	-0.411**	0.235***					-0.442**	0.235***
(1=yes)	[0.184]	[0.014]					[0.211]	[0.014]
Eco Tracker			0.124	-0.127**			0.108	-0.097*
(1=yes)			[0.220]	[0.052]			[0.175]	[0.055]
ForeverGreen					-0.011	-0.086**	-0.013	-0.041
(1=yes)					[0.085]	[0.037]	[0.064]	[0.037]
Occupancy	-0.178	-1.252***	-0.068	-1.277***	-0.008	-1.296***	-0.208	-1.275***
(percent)	[0.638]	[0.183]	[0.682]	[0.190]	[0.732]	[0.192]	[0.604]	[0.184]
Heating Degree Days	-0.047***	-0.051***	-0.045***	-0.052***	-0.047***	-0.051***	-0.046***	-0.052***
(in hundreds by month)	[0.012]	[0.017]	[0.012]	[0.017]	[0.012]	[0.017]	[0.012]	[0.017]
Cooling Degree Days	0.020	0.033	0.020	0.033	0.020	0.031	0.020	0.034
(in hundreds by month)	[0.029]	[0.050]	[0.029]	[0.050]	[0.029]	[0.050]	[0.029]	[0.050]
Constant	-4.924***	-4.116***	-5.187***	-4.090***	-5.130***	-4.128***	-4.969***	-4.033***
	[0.564]	[0.206]	[0.699]	[0.218]	[0.654]	[0.216]	[0.589]	[0.209]
Month-fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Building-fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Number of building-months	2,312	4,207	2,312	4,207	2,312	4,207	2,312	4,207
Number of buildings	37	59	37	59	37	59	37	59
Adj. R-squared	0.556	0.697	0.536	0.696	0.533	0.696	0.557	0.699

Notes: 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.

Table 4: Capital Expenditures and Electricity Consumption - Canada

(dependent variable: natural log of electricity consumption per occupied sq. ft.)

	(1)	(2)	(3)	(4)
CAPEX	-0.073***			
(1=yes)	[0.026]			
CAPEX Category (1=yes)				
Operational		-0.009		
		[0.032]		
Systems		-0.079***		
		[0.026]		
Tenant		-0.020		
		[0.034]		
CAPEX Subcategory (1=yes)				
Operational change			-0.082*	
			[0.048]	
Lighting retrofit				-0.082**
				[0.031]
BOMA BEST only	0.013	0.015	0.003	0.013
(1=yes)	[0.025]	[0.025]	[0.024]	[0.025]
LEED EBOM only	-0.097*	-0.086*	-0.097*	-0.104**
(1=yes)	[0.051]	[0.049]	[0.049]	[0.049]
BOMA BEST & LEED EBOM	-0.086*	-0.077	-0.091**	-0.090*
(1=yes)	[0.046]	[0.047]	[0.045]	[0.049]
LEED D&C	0.011	0.001	-0.004	0.006
(1=yes)	[0.188]	[0.182]	[0.198]	[0.181]
Eco Tracker	-0.061*	-0.059*	-0.073**	-0.071**
(1=yes)	[0.031]	[0.031]	[0.031]	[0.030]
ForeverGreen	-0.077*	-0.066	-0.095**	-0.081**
(1=yes)	[0.040]	[0.043]	[0.035]	[0.039]
Occupancy	-0.715***	-0.706***	-0.716***	-0.678***
(percent)	[0.180]	[0.181]	[0.178]	[0.168]
Heating Degree Days	0.013	0.012	0.013	0.013
(in hundreds by month)	[0.011]	[0.011]	[0.011]	[0.011]
Cooling Degree Days	-0.006	-0.004	-0.008	-0.005
(in hundreds by month)	[0.038]	[0.038]	[0.039]	[0.039]
Constant	1.285***	1.278***	1.285***	1.250***
	[0.185]	[0.184]	[0.183]	[0.175]
Month-fixed effects	yes	yes	yes	yes
Building-fixed effects	yes	yes	yes	yes
Number of building-months	3,872	3,872	3,872	3,872
Number of buildings	36	36	36	36
Adj. R-squared	0.685	0.687	0.683	0.685

Notes: Consumption is measured in kWh, scaled by occupied square feet. 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.

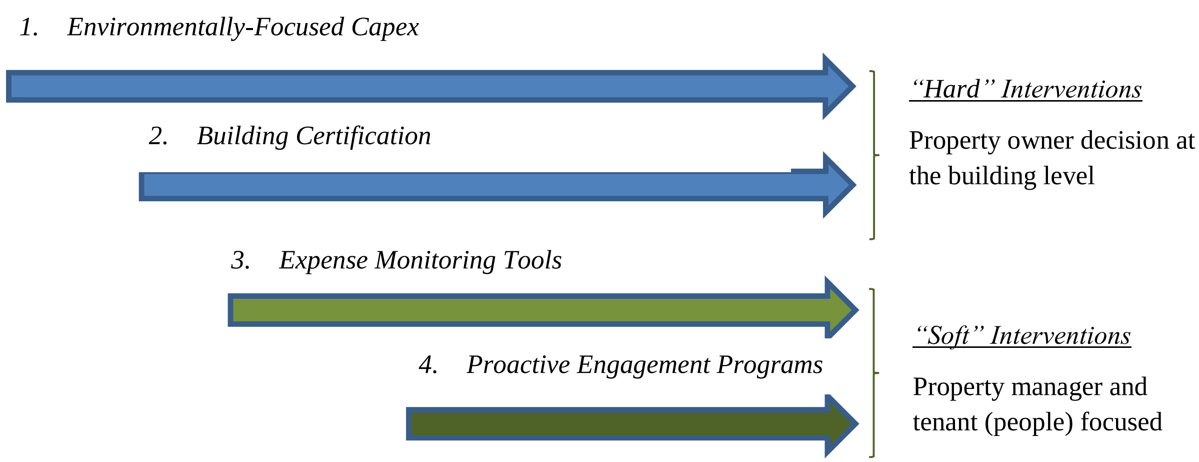
Table 4 (cont.): Capital Expenditures and Electricity Consumption - U.S.

(dependent variable: natural log of electricity consumption per occupied sq. ft.)

	(5)	(6)	(7)	(8)
CAPEX	-0.062***			
(1=yes)	[0.022]			
CAPEX Category (1=yes)				
Operational		0.002		
		[0.034]		
Systems		-0.067*		
		[0.038]		
Tenant				
CAPEX Subcategory (1=yes)				
Operational change			-0.030	
			[0.029]	
Lighting retrofit				-0.076**
				[0.035]
LEED EBOM only	0.024	0.030	0.044	0.027
(1=yes)	[0.032]	[0.032]	[0.031]	[0.030]
LEED D&C	-0.177***	-0.176***	-0.171***	-0.181***
(1=yes)	[0.058]	[0.055]	[0.055]	[0.058]
Energy Star only	-0.073**	-0.076**	-0.064*	-0.082**
(1=yes)	[0.031]	[0.033]	[0.032]	[0.032]
LEED EBOM & Energy Star	-0.036	-0.045*	-0.050**	-0.052**
(1=yes)	[0.022]	[0.023]	[0.022]	[0.021]
Eco Tracker	0.036	0.025	0.027	0.026
(1=yes)	[0.028]	[0.029]	[0.027]	[0.024]
ForeverGreen	-0.050**	-0.054**	-0.066**	-0.053**
(1=yes)	[0.020]	[0.021]	[0.026]	[0.021]
Occupancy	-1.066***	-1.055***	-1.089***	-1.063***
(percent)	[0.064]	[0.066]	[0.066]	[0.066]
Heating Degree Days	0.048***	0.048***	0.048***	0.048***
(in hundreds by month)	[0.007]	[0.007]	[0.007]	[0.007]
Cooling Degree Days	0.051***	0.051***	0.051***	0.051***
(in hundreds by month)	[0.015]	[0.015]	[0.016]	[0.016]
Constant	1.142***	1.130***	1.146***	1.139***
	[0.090]	[0.088]	[0.089]	[0.090]
Month-fixed effects	yes	yes	yes	yes
Building-fixed effects	yes	yes	yes	yes
Number of building-months	2,393	2,393	2,393	2,393
Number of buildings	27	27	27	27
Adj. R-squared	0.929	0.929	0.928	0.929

Notes: Consumption is measured in kWh, scaled by occupied square feet. 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.

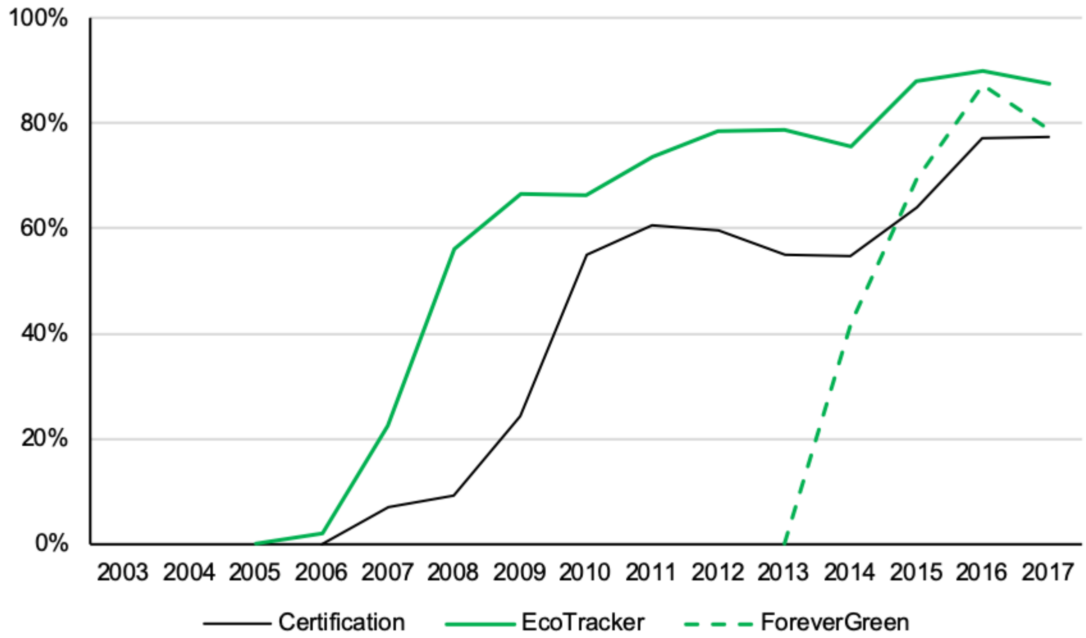
Figure 1: Environmental Interventions: Adoption/Implementation History



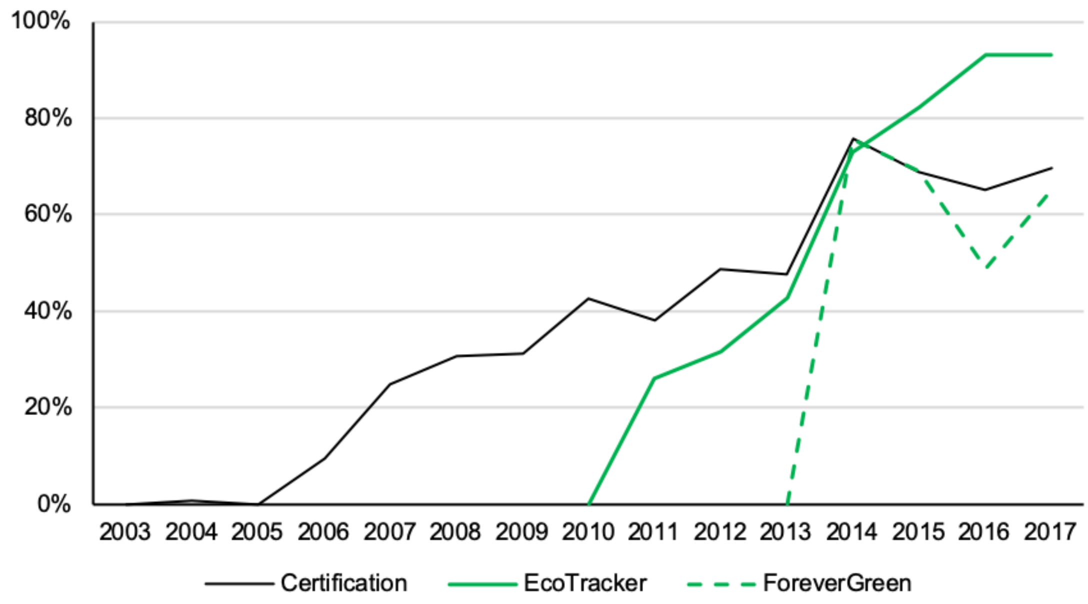
Notes: This figure represents the process, or general historical order, of environmental intervention adoption and implementation in commercial real estate in the developed world.

Figure 2: Intervention Adoption, by Country

Panel A: Canada



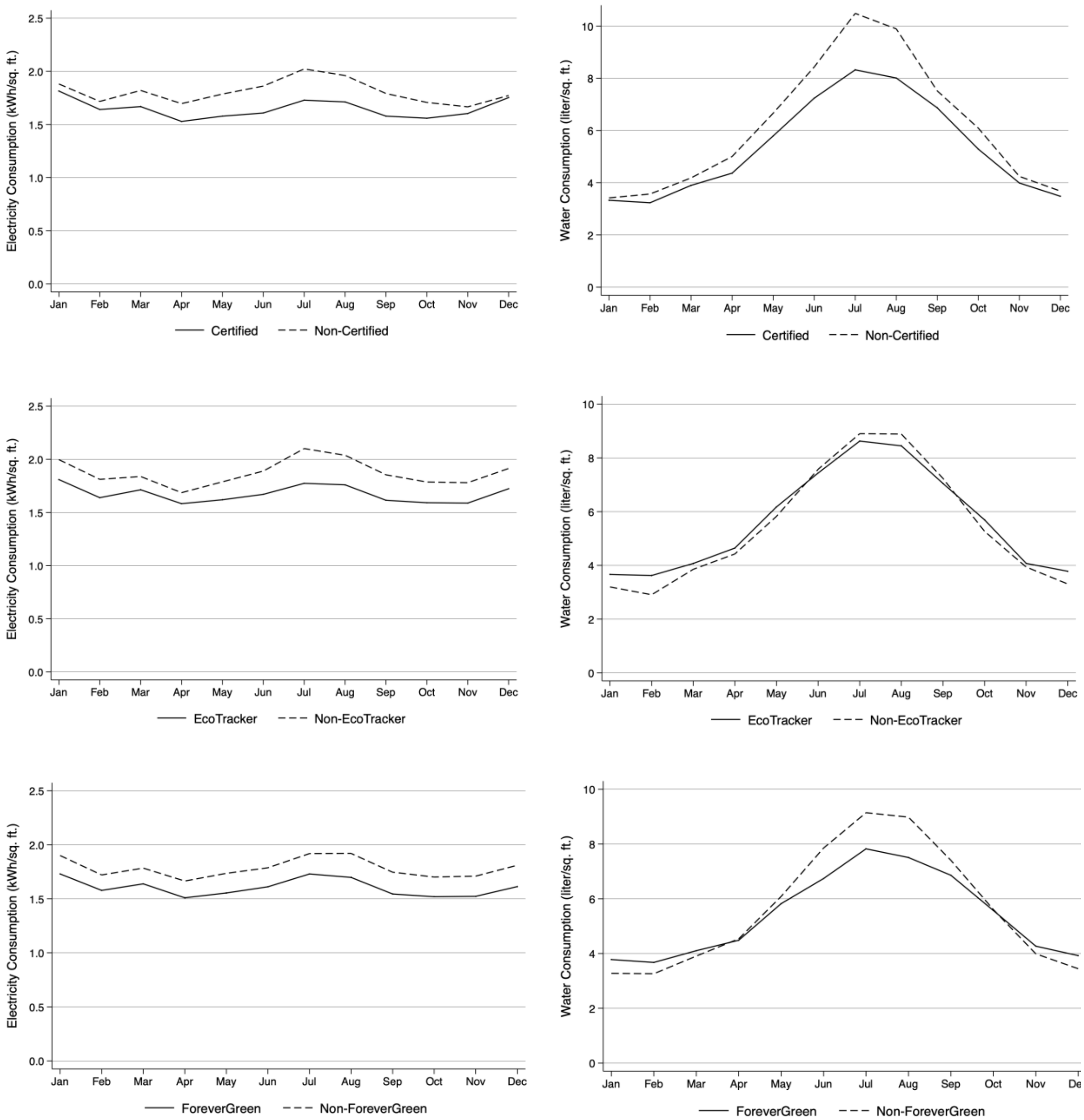
Panel B: United States



Notes: Each graph presents the percent of the sample that is governed by each intervention category, by year. It should be noted that environmental building certification activity was present in some buildings under prior ownership/management. As this lies outside the scope of our sample, that information is not portrayed in the above graphs.

Figure 3: Intervention Impact on Energy and Water Consumption

Electricity **Water**



Panel A: Environmental Certification

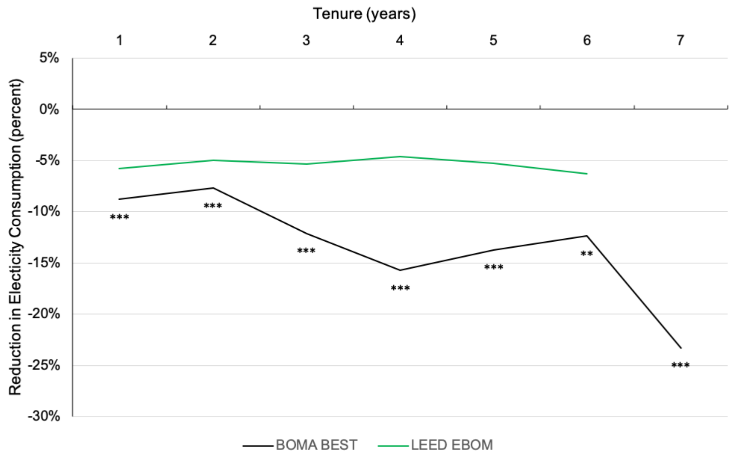
Panel B: Eco Tracker

Panel C: ForeverGreen

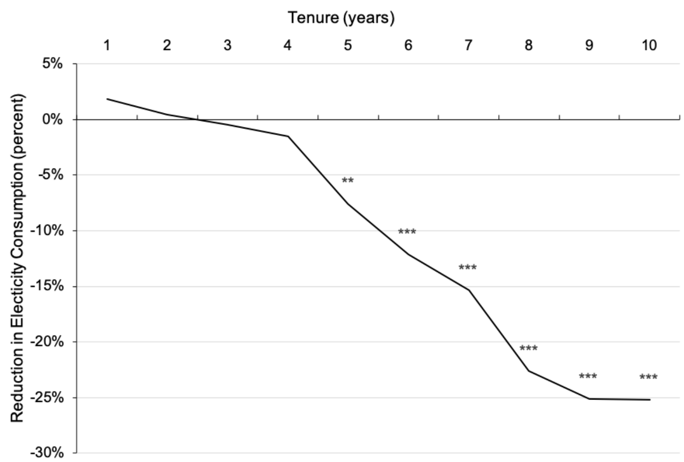
Notes: Each graph presents the seasonal median consumption of electricity (measured in kilowatt hours per sq. ft.) and water (measured in liters per sq. ft.) for the sample separated into two groups: those with and without each environmental intervention. Three interventions are examined: environmental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

Figure 4: Intervention Tenure Impact on Electricity Consumption

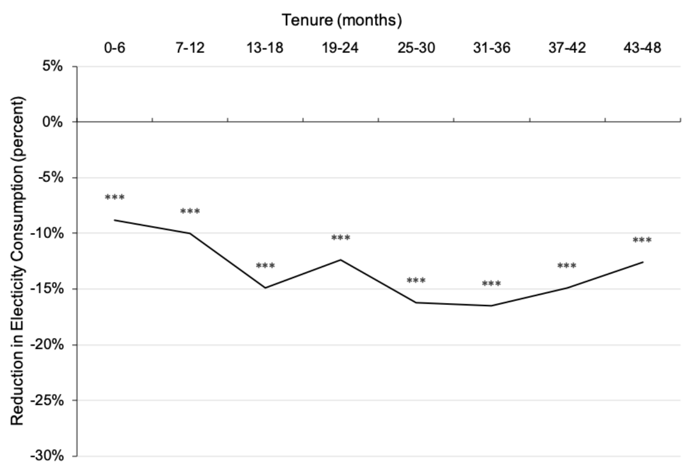
Panel A: Environmental Building Certifications



Panel B: Eco Tracker

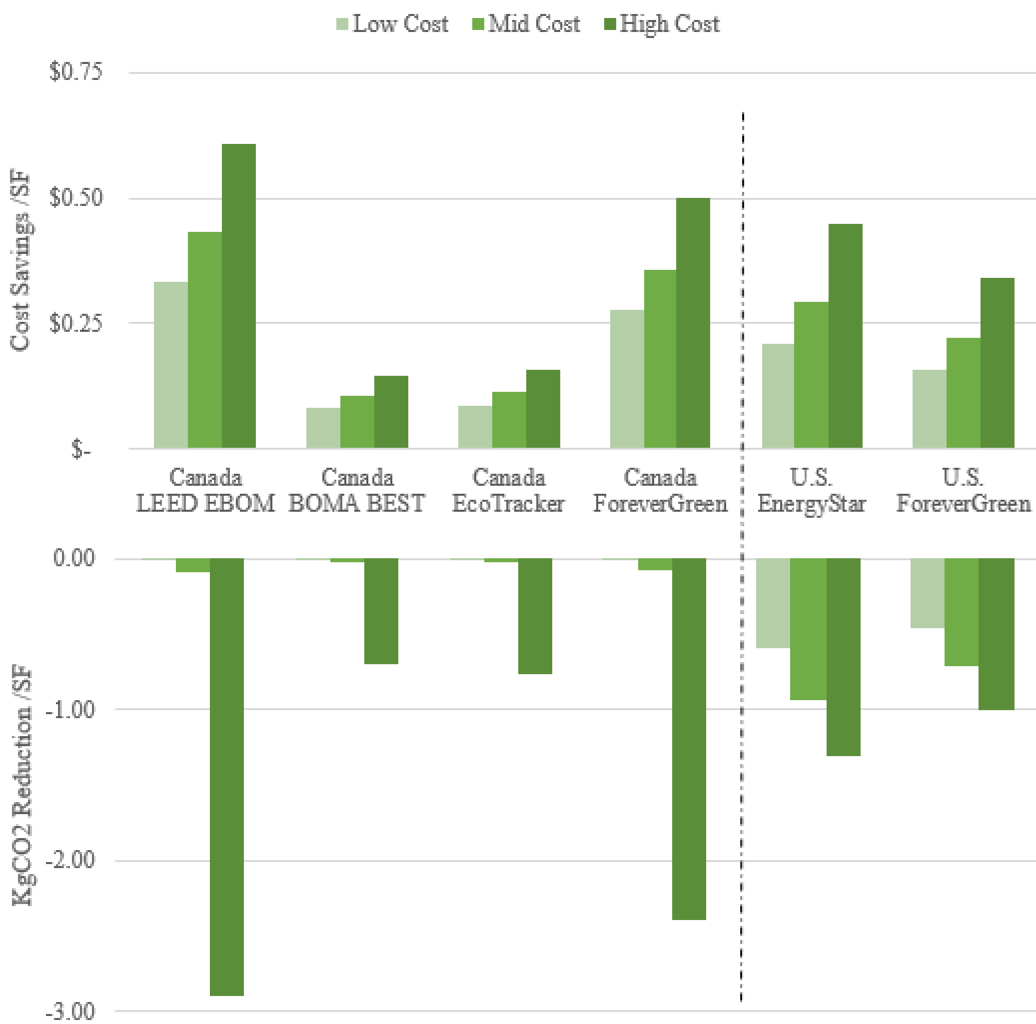


Panel C: ForeverGreen



Notes: Each graph presents how electricity consumption is affected by each intervention's tenure within a building. These point estimates are taken from regression estimates (see Appendix A2). Significance at the 0.10, 0.05, and 0.01 level is indicated by *, **, ***, respectively. Energy Star analysis is excluded due to data limitations.

Figure 5: 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 equally 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. Results are not meant to be compiled, as some gains to different interventions will overlap.

Appendix Table A1: Sample Composition by Interventions

	U.S.	Canada
Total	145	116
LEED D&C	9	10
LEED EBOM	26	23
BOMA BEST	N/A	70
Energy Star	67	N/A
Uncertified	135	105
LEED D&C & LEED EBOM	4	0
LEED D&C & BOMA BEST	N/A	9
LEED D&C & EnergyStar	7	N/A
LEED D&C, LEED EBOM & BOMA BEST	N/A	0
LEED D&C, LEED EBOM & Energy Star	4	N/A
Eco Tracker (ForeverGreen)	40 (36)	87 (73)
Non-Eco Tracker (Non-ForeverGreen)	136 (144)	88 (107)
Eco Tracker (ForeverGreen) & LEED D&C	5 (8)	8 (8)
Eco Tracker (ForeverGreen) & LEED EBOM	26 (22)	21 (20)
Eco Tracker (ForeverGreen) & BOMA BEST	N/A	63 (59)
Eco Tracker (ForeverGreen) & Energy Star	30 (25)	N/A
Eco Tracker (ForeverGreen), LEED D&C & LEED EBOM	4 (7)	0 (0)
Eco Tracker (ForeverGreen), LEED D&C & BOMA BEST	N/A	7 (7)
Eco Tracker (ForeverGreen), LEED D&C & Energy Star	4 (7)	N/A
Eco Tracker (ForeverGreen), LEED EBOM & BOMA BEST	-	16 (16)
Eco Tracker (ForeverGreen), LEED EBOM & EnergyStar	26 (18)	-
Eco Tracker (ForeverGreen), LEED D&C, LEED EBOM & BOMA BEST	-	0 (0)
Eco Tracker (ForeverGreen), LEED D&C, LEED EBOM & EnergyStar	4 (2)	-

Notes: Above lists building counts which experience the specified interventions at any time during the 15-year sample period. Analysis is completed monthly, so over the course of the period a building may populate multiple categories of interventions. All buildings which participate in the ForeverGreen program are concurrently enrolled in Eco Tracker, should they not already have the monitoring software in place. Therefore, ForeverGreen is a subset of Eco Tracker, and ForeverGreen-inclusive results are presented in parentheses following Eco Tracker results. BOMA BEST and Energy Star are Canada and U.S.-specific certification programs, respectively.

Appendix Table A2: Intervention Tenure and Electricity Consumption

(dependent variable: natural log of electricity consumption per occupied sq. ft.)

Tenure Measured	(1) BOMA BEST	(2) LEED EBOM	(3) Eco Tracker	(4) ForeverGreen
Tenure - 1 year	-0.088***	-0.058	0.018	
	[0.022]	[0.036]	[0.018]	
Tenure - 2 years	-0.077***	-0.050	0.004	
	[0.021]	[0.041]	[0.021]	
Tenure - 3 years	-0.121***	-0.053	-0.005	
	[0.023]	[0.045]	[0.024]	
Tenure - 4 years	-0.157***	-0.046	-0.015	
	[0.028]	[0.046]	[0.032]	
Tenure - 5 years	-0.137***	-0.053	-0.076**	
	[0.042]	[0.049]	[0.030]	
Tenure - 6 years	-0.124**	-0.063	-0.122***	
	[0.049]	[0.047]	[0.029]	
Tenure - 7 years (or longer)	-0.233***		-0.154***	
	[0.056]		[0.033]	
Tenure - 8 years			-0.226***	
			[0.040]	
Tenure - 9 years			-0.252***	
			[0.042]	
Tenure - 10 years (or longer)			-0.252***	
			[0.051]	
Tenure - 6 months or less				-0.088***
				[0.019]
Tenure - 7 to 12 months				-0.100***
				[0.019]
Tenure - 13 to 18 months				-0.149***
				[0.027]
Tenure - 19 to 24 months				-0.124***
				[0.022]
Tenure - 25 to 30 months				-0.162***
				[0.022]
Tenure - 31 to 36 months				-0.165***
				[0.023]
Tenure - 37 to 42 months				-0.149***
				[0.025]
Tenure - 43 to 48 months				-0.126***
				[0.027]
Occupancy	-1.331***	-1.369***	-1.378***	-1.376***
(percent)	[0.231]	[0.165]	[0.165]	[0.169]
Constant	1.793***	1.575***	1.559***	1.561***
	[0.222]	[0.149]	[0.146]	[0.150]
Base intervention controls	yes	yes	yes	yes
Local climate conditions	yes	yes	yes	yes
Month-fixed effects	yes	yes	yes	yes
Building-fixed effects	yes	yes	yes	yes
Number of building-months	7,854	12,727	12,727	12,727
Number of buildings	88	160	160	160
Adj. R-squared	0.759	0.797	0.803	0.796

Notes: BOMA BEST analysis for Canada only; all other for Canada and U.S. 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.