The Impact of Minimum Energy Performance Standards on the Commercial Real Estate Market

Piet Eichholtz, Nils Kok*, Xudong Sun

Maastricht University

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Abstract

This paper investigates the implications of a recently introduced minimum energy performance standard, regulation aimed to reduce the energy consumption of the commercial building stock in the Netherlands. The regulation, first announced in 2018, requires all office buildings larger than 100 m^2 to have an energy performance certificate C (on a scale from G to A) from 2023 onward. Since the regulation does not apply to other commercial property types, we can use these as a control group. By combining sales and rent transaction data gathered with energy performance data, and employing a difference-in-differences model, we find improvements in the energy performance of office buildings, as measured by changes in the energy performance certificate. After the announcement of the label-C obligation, office buildings display an increased likelihood of improving their energy performance, relative to other property types. The results also indicate a 19.9% increase in sales prices for offices with an energy label above C after the announcement of the regulation in 2018. Meanwhile, we find no significant effect of the regulation on rent levels, so while the regulation does affect investors, the impact on tenants seems negligible. Our results show that the regulation on minimum energy performance incentivizes property owners to enhance building energy performance, even in the absence of enforcement.

Keywords — real estate, energy efficiency, energy performance standards, energy performance certificate

*n.kok@maastrichtuniversity.nl (corresponding author)

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1 Introduction

The global drive to address climate change and reduce greenhouse gas emissions has led to a growing emphasis on energy efficiency, particularly in the building sector, which accounted for 30% (132 exajoules) of total global final energy consumption, or 15% (3 gigatons) of total global CO_2 emissions of all end-use sectors in 2021 (International Energy Agency, IEA, 2022). In Europe, the real estate sector is the single largest energy consumer: approximately 40% of EU energy consumption, producing 36% of CO_2 emissions (Economidou et al., 2020). Energy efficiency has become more pressing given the increase in energy prices due to the Russian invasion of Ukraine (Mbah and Wasum, 2022), which imposes a substantial financial burden on both the occupants of the buildings and their owners (Hasheminasab et al., 2023).

Commercial real estate, and in particular office buildings, has been identified as a critical sector for improving energy efficiency (Eichholtz et al., 2010) (Mantesi et al., 2022). Over the years, European and other governments have issued various policies to address energy efficiency issues in the building sector (Economidou et al., 2020) (Li et al., 2019), including office buildings (Sayce and Hossain, 2020) (Fuerst et al., 2017). For example, the Energy Performance of Buildings Directive (EPBD) aims to substantially reduce greenhouse gas (GHG) emissions and energy consumption in the EU building sector by 2030, and to make the sector "climate neutral" by 2050 (EU Parliament, 2010). Individual EU countries have taken different steps in this direction.

The Dutch government has been introducing a range of measures to improve the energy performance of buildings (Mayer, 2023) (Vringer et al., 2021), including subsidies, tax allowances, and a mandate to provide an energy performance certificate (EPC) at the time of rent or sale (Fuerst et al., 2017). From 2012 onward, the provision of EPCs has been legally required by the Dutch building code (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, BZK, 2012).

In October 2018, a stringent minimum energy performance requirement was introduced, known as the "label C obligation" (in Dutch, "label C verplichting"), which requires office buildings to have an energy performance certificate of at least level C (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, BZK, 2018), which corresponds to a maximum primary fossil energy consumption of 225 kWh per m^2 per year. Figure 1 provides a timeline of the policy announcement. Buildings failing to meet the minimum standard by January 1, 2023 are prohibited from being used as offices (Rijksdienst voor Ondernemend Nederland, RVO, 2018). The Dutch government requires a minimum standard of label C for all building types by 2030 (Rijksdienst voor Ondernemend Nederland, RVO, 2018) and aims to achieve at least label A for all existing buildings (Rijksoverheid, 2016) in the longer run.

This minimum energy performance policy was quite unique at the time it was introduced and differed from the few policies aiming to promote energy efficiency by setting a minimum standard in other countries, as the regulation focused solely on the office market.[1]. For researchers, this provides an empirical opportunity to assess the effectiveness of the policy using other types of commercial property as counterfactuals.

Another important element of the regulation is that the label C obligation applies to both existing and new office buildings (Rijksdienst voor Ondernemend Nederland, RVO, 2018). This policy can potentially change the supply of office buildings in a relatively short period, as the desire for inefficient buildings will decrease (Chegut et al., 2014) (Aroul and Hansz, 2012), and such buildings will become obsolete unless capital is invested to improve the assets.

This paper is the first to evaluate the effectiveness of the label-C obligation, and to do so from two main perspectives. First, we ask whether the policy change had an impact on the adoption of energy labels. Specifically, to what extent did the policy induce property owners to upgrade the energy performance of their assets? Given the novelty of minimum energy performance standards, there are only a few preliminary study assessing market reactions towards this regulation. For the United Kingdom Sayce and Hossain (2020) find that it has enhanced market awareness of energy efficiency on both the supply and demand side. McAllister and Nase (2023) compare several national policy regimes, in the United Kingdom, the Netherlands, and France, and discuss the interaction between policymakers, property owners, and tenant. However, these early studies on minimum energy performance policies typically do not measure actual improvements in the energy performance. The only study in

[1]For example, the minimum energy efficiency standards in the UK, while otherwise a close counterpart to the Dutch label C obligation, apply to the commercial property sector in a more general way (McAllister and Nase, 2019)

that direction provides a prediction rather than an evaluation. The Dutch Economic Institute for Construction (EIB) and the Energy Research Center of the Netherlands (ECN) predicted that making the energy label C the minimum requirement would result in energy savings in the office market of almost 25% (Arnoldussen et al., 2013).

Second, it has been widely shown that buildings with better energy performance have higher rents and values (Eichholtz et al., 2010) (Kok and Jennen, 2012) (Sayce and Hossain, 2020), but most of these studies are based on *levels* of rents and prices, rather than *changes* and as such can suffer from unobservables correlated with better energy labels. As a result, the direction of causality in these studies is not clear. Furthermore, the COVID pandemic unexpectedly initiated a hybrid work trend, reducing the demand for office space while intensifying competition for both capital and occupiers (Van Nieuwerburgh, 2023). As a result, buildings with lower levels of energy efficiency may experience a market penalty (Kok and Jennen, 2012), as stakeholders increasingly emphasize regulatory requirements and minimization of occupancy costs. Using the minimum energy performance policy as a market-wide exogenous shock, we can causally identify the price effect of energy performance in the form of capitalization in rents and sales prices.

Using both sales and rent transaction data gathered from the NVM (the Dutch Realtor Association), in combination with data from the energy label database from RVO (the Netherlands Enterprise Agency), we employ a difference-in-differences (DiD) model, to assess the causal impact of the label-C policy. The results show that offices have a higher propensity to get improved energy efficiency following the announcement of the regulation, relative to other property types such as retail or leisure. Given that we measure improvements through the energy performance certificate, our estimate is likely a lower bound of the actual changes in energy efficiency in the market. Furthermore, even though the relative energy efficiency of buildings is generally reflected in rent *levels*, tenants may not seem to differentiate more between energy-efficient and inefficient assets in the period after the announcement. Investors, on the other hand, show a decreased willingness to pay for inefficient office buildings after the regulation has been announced.

The results in this paper provide useful insights for policymakers and market participants.

Many governments, most notably the EU, are changing their policies to improve the energy efficiency of the building stock from carrot (e.g. subsidies) and voluntary information provision (e.g. disclosure of building energy performance) to stick, or a combination of the former and the latter. However, not much is known about the implications of such regulation.

Our findings show that building owners seem to respond to minimum energy efficiency requirements, but given the fact that by 2023, when the regulation became effective, many office buildings still had either no energy performance certificate or a certificate below C, there is a lingering question about enforcement. Without a clear enforcement mechanism, many market participants will simply take the stance of ”wait and see”. However, the capital market clearly takes a different view: Inefficient assets are sold at an increased discount, reflecting the capital expenditures needed to improve the energy efficiency of these assets.

The remainder of this paper is structured as follows. Section 2 presents our data sources and descriptive statistics. Empirical specifications are reported in Section 3, followed by empirical results in the fourth section. Section 5 provides a discussion and conclusion of our findings.

2 Data

2.1 Data on energy performance certificates

The RVO (The Netherlands Enterprise Agency) maintains records of all new and revised energy performance certificates of buildings, starting in 2007. As of Q4 2022, the RVO database includes 256,882 distinct commercial buildings. The data set contains information on office buildings (92,146), retail buildings (66,618), public meeting places (for example, a bar, restaurant, or club, 48,719 buildings in total), healthcare buildings (18,892), hotel buildings (13,007), sports facilities (12,041), and some other smaller categories. At the end of 2022, there were 199,910 buildings with the energy label C or better including 71,646 office buildings. And 56,972 buildings, including 20,500 offices, with energy label D or worse. Figure 2 shows the distribution of energy labels. For buildings with label C or better, we see a large percentage of buildings with label A (33,012 offices and 69,488 buildings of other types). For buildings below the minimum requirement of the label-C obligation, we find the largest fraction is label G, including 8,575 offices and 13,133 buildings of other types.

Note that having an energy performance certificate is not mandatory except at the time of sale or rental transaction of an asset. Since some bulding owners may enhance their asset's energy performance without applying for a certification, the RVO sample of buildings may underestimate the actual energy performance of the commercial real estate sector. We estimate that approximately 38,000 (30%) office buildings still have no energy performance certificate by the end of 2022.[2]

To inspect the effect of the label C policy, we first look into updates of the energy performance certificate, which occur when owners make modifications to their building and register a new energy performance certificate. For example, installing a heat pump or adding insulation will improve the energy performance certificate of a building. To look into updates to energy performance certificates, we select buildings with multiple energy label registration records in the RVO dataset, which means that the building has experienced updates to the energy label at least once. Note that it is typically not mandatory to register a new/revised energy performance certificate when making improvements to the asset (unless a lender or subsidy provider requires this); therefore, using certificate updates to measure the improvement of energy efficiency in the building stock will severely underestimate *actual* changes in the energy efficiency of the building stock, and, of course, energy performance certificates are just theoretical approximations of true energy consumption.

In Figure 3, we use a transition matrix to represent updates in energy performance certificates: the left-side axis represents the starting energy label, and the top axis is the energy label at the end of a period. Each cell in the matrix represents the percentage of the total stock (by square meter) of a certain transition. From January 2008 to October 2018 (policy announcement), we observed 2,608 offices (10 million m^2, on average 235 offices per year) and 2,664 commercial buildings of other types (6 million m^2, on average 240 properties per year) that have upgraded their energy performance certificates at least once, compared to 7,736 offices (23 million m^2, on average 1935 offices per year) and 5,260 commercial buildings of other types (10 million

[2] By the end of 2022, RVO reports that 55% of the Dutch office building stock has energy label C or better (Rijksdienst voor Ondernemend Nederland, RVO, 2023). As the RVO dataset contains records of all labeled buildings, we estimate the total volume of the office market to be approximately 130,000 buildings and since just over 92,000 of these have an energy certificate, 38,000 buildings lack it.

m^2, on average 1315 properties per year) after the policy announcement in October 2018 until December 2022. This provides some indication that energy performance upgrades for buildings have sped up for offices after the regulation, both absolute and relative to other types. On a square meter bases, this is even stronger.

The matrix for office buildings shows that, for all offices with an updated energy performance certificate (EPC) (11 million m^2) from 2008 to October 2018, 12.77% of upgrades led to an increase from rating D to rating C, while 16.97% improved from rating C to rating A or better. After the policy announcement, from 2018 to 2022, we observe that a large fraction (75%) of updates, 4,382 out of 7,736 offices (17 million m^2 out of 23 million m^2), led to label A or better (see the right column of each transition matrix), including approximately 32.39% from level D and below. This compares to just 17.46% upgraded to A or higher ratings from level D and below for other commercial property types.

The observations provide some interesting insights into the market response to the announcement of the label-C obligation. The original announcement stated that the minimum EPC requirement would not increase above label C in 2023(Rijksdienst voor Ondernemend Nederland, RVO, 2023). So while it is recommended that property owners improve their buildings' energy performance as much as possible (Rijksoverheid, 2016), there will be no legal obligation to do so. This may lead to building owners investing just the minimum amount of capital to meet the label C standard, instead of aiming for a more significant energy performance improvement of their assets. This concern is also voiced in recent studies on minimum EPC policies in the UK (Sayce and Hossain, 2020) and other European countries (McAllister and Nase, 2023), but the data presented in Figure 3 suggest that most owners are not going to aim for the minimum.

2.2 Data on sales and rent transactions

The dataset on rents and sales prices is provided by the NVM (the Dutch Realtor Association) and includes 112,795 rent and 47,964 sale transactions for 97,261 distinct buildings from 2010-2022. We match the NVM transaction data with the information from the RVO building energy label (see Figure 4). Considering that the label C obligation applies to both "decicated" office buildings and office spaces in mixed-use buildings, we use address, building function, and size to uniquely identify buildings and match the RVO and NVM datasets based on a unique building identifier. By tracking each unique building's energy label, sale or rent transaction records, we build a time-varying profile for each building.

2.3 Summary statistics

Table 1 shows the summary statistics of the merged dataset, with comparison of property types before and after the policy announcement in 2018. We have 25,275 distinct buildings with matched transaction records and energy label registrations. This sample is divided into two groups: a treatment group (offices) and a control group (commercial buildings of other types).

We identify 4,032 distinct office buildings and 3,204 distinct buildings of other property types (the control group) that transacted before the policy announcement in October 2018. After the announcement, the number of transactions for office buildings is 9,541, compared to 8,498 for other property types. The number of rent transactions is substantially larger than the number of sales transactions, as rent transactions include suites and floors within buildings. The total number of pre- and post-announcement office rent transactions was 3,770 and 10,468, respectively. For other property types, these numbers were 2,658 and 7,582.

The average rent price remained relatively stable over time, with a slight increase for office properties from €117.97 to €118.44 per sqm per year, and a minor decrease for other property types from €173.88 to €170.41 per sqm per year. These averages come with large standard deviations, as could be expected given the regional variation covered by the sample. The average nominal sale price for office properties increased from €1,009.85 to €1,229.80 per square meter, and for other property types from €1,289.61 to €1,506.16 per square meter.

Energy performance improved in both groups, with the average energy index decreasing for office properties from 1.31 to 1.16 and for other property types from 1.16 to 1.09. The energy index is constructed such that zero equates no energy consumption in the building. The Netherlands stopped using the energy index as a metric in 2021, so we also look at energy performance certificates. The percentage of buildings with an energy performance certificate above C increased for office properties from 63% to 77% and for other property types from 70% to 76%.

Furthermore, the data do not show substantial changes in the distribution of transactions in the three main metropolitan areas Amsterdam, Rotterdam, and The Hague before and after the announcement for both groups.

3 Method

3.1 Modeling the propensity of change in energy performance certificates

We assess the changes in energy performance certificates in the office market through a difference-in-differences (DiD) model, exploiting the announcement of the label-C obligation as an exogenous shock and thus allowing causal inference.

$$\begin{aligned} EnergyRatingUpdates_{i,t} = {} & \beta_1 AfterAnnouncement_t + \beta_2 Type_i \\ & + \beta_3 (AfterAnnouncement * Type)_{i,t} \\ & + \beta_4 X_{i,t} + \tau_t + \mu_i + \varepsilon_{i,t} \end{aligned} \tag{1}$$

The dependent variable, $EnergyRatingUpdates_{i,t}$ is the energy performance certificate update of building i at time t. For each record in the RVO dataset, we track the previous energy performance certificate and compare it to the newly registered certificate. The dependent variable takes two forms: the energy label rating difference or the "compliance" of building with the label-C obligation. For the energy label rating difference, we first translate the energy label from G to A++++ into a numeric score from 1 to 10. For example, if a property improved its label from C (4 points) to A (6 points), then $EnergyRatingUpdates_{i,t}$ equals 2, etc. Nevertheless, this specification is based on the assumption that each (incremental) change in energy label embodies a "uniform" difficulty, regardless of the initial energy label. For example, upgrading from G to F is as difficult as from A to A+. We will provide detailed robustness checks for this assumption in Appendix B. The "compliance" with the label-C obligation equals 1 if the building's label improves from below C to C or above, otherwise it is 0. We use the logit model for models with discrete dependent variables.

In Equation (1), $AfterAnnouncement_t$ equals 1 if an observation at time t is after the announcement of the label-C obligation policy. $Type_i$ includes $n-1$ dummy variables for n property types, with the office as the treatment group. In a simplified DiD setting, we only use two categories, "office" and "other types", in the variable $Type_i$. In this case, the coefficient β_3 captures the effect of the announcement of the policy on the office market only. $X_{i,t}$ includes time-variant hedonic features such as building age (and age squared to capture its nonlinear effect). μ_i captures time-invariant building-level features such as floor area and location, and τ_t is the time-fixed effect (label year), capturing the influence of macroeconomic changes on the propensity to obtain an energy label. The standard errors are clustered at the 4-digit ZIP code level.

3.2 Modeling the time-variation in the capitalization of energy labels

Similar to Equation 1, we use the announcement of the policy in October 2018 as an exogenous shock to identify the causal impact of energy labels on property prices and rents[3]. Compared to the widely used hedonic framework (Rosen, 1974) to evaluate the price effect of the characteristics of energy performance, our aim is to avoid the prevalent omitted variable bias in regular hedonic models by using a difference-in-difference approach that exploits the *changes* in rents and prices of office buildings versus other commercial buildings, relative to their energy efficiency, following the policy announcement (Callaway and Sant'Anna, 2021):

$$\begin{aligned} LogPrice_{i,t} = {} & \beta_1 EnergyLabel_{i,t} + \beta_2 (EnergyLabel * Type)_{i,t} \\ & + \beta_3 (AfterAnnouncement * EnergyLabel * Type)_{i,t} \\ & + \beta_4 X_{i,t} + \tau_t + \mu_i + \varepsilon_{i,t} \end{aligned} \tag{2}$$

The dependent variable in Equation 2, $LogPrice_{i,t}$ is the natural logarithm of the sales price per square meter for the sales models and the natural logarithm of the rent price per square

[3] We first evaluate the basic relationship between energy labels and property prices or rental rates without considering the exogenous shock, see Appendix A.

meter (per year) for the rent models.[4]

Similar to Equation 1, $AfterAnnouncement_t$ equals 1 if an observation at time t is after the announcement of the label-C policy, and $Type_i$ equals 1 if an observation corresponds to an office building. $EnergyLabel$ is the metric for the EPC rating, either the energy index or the energy label. β_3 captures the effect of the policy announcement on the office market. $X_{i,t}$ includes time-variant hedonic characteristics, such as building age, τ_t is a time-fixed effect (transaction year), and μ_i captures time-invariant hedonic features, such as floor area and location. The standard errors are clustered at the 4-digit ZIP code level.

4 Results

4.1 Energy label improvements

We start with the results of our difference-in-differences (DiD) analysis evaluating the impact of the label-C regulation on the magnitude of changes in the energy efficiency of office buildings compared to other buildings. The primary variable of interest in our analysis is the interaction term "AfterAnnouncement * Office". The coefficient of this variable captures the impact of the announcement of the label-C regulation on changes in energy labels for office buildings. The results shown in Table 2 suggest a significantly positive effect of the policy announcement on changes in the energy labels of office buildings. The coefficient estimates for the interaction term are positive and statistically significant in all but two models, indicating that the announcement led to an increase in the magnitude of energy label updates and a higher probability of having a label above C.

Specifically, the coefficient of the interaction term is 0.297 ($p < 0.01$) for the model that evaluates the magnitude of energy label updates (Column (1)). This result suggests that the magnitude of changes in energy labels increased significantly more for office buildings after the announcement of the label C obligation, with about a third of a label. Similarly, the coefficient is 0.040 ($p < 0.01$) for the P(above C) model (Column (2)), indicating that the

[4] Given the long right tail of the distribution of sales and rent prices, it is common practice to use the natural logarithm of the sales or rental price as the dependent variable (Kok and Jennen, 2012) (Fuerst et al., 2013); (Gabe et al., 2020).

probability of having a label above C increased by about 4 percent for office buildings after the announcement.

We separately analyze the rent and sales samples, to understand how these different samples affect the results. The positive and significant coefficients are observed for the rental market sub-samples (in Columns (4) and (7)), but the results for the sales sample, which is substantially smaller, are not statistically significant.

The table also provides some interesting evidence regarding the effect of ex-ante sales and rent levels on the probability of energy efficiency upgrades. Columns (3) and (6) show that the sales price coefficient is positive and statistically significant at the 0.05 level, both in the P(above C) and in the Label model, suggesting that a higher ex ante property sales price leads to a higher probability of having an energy label above C, and a stronger label improvement for after the policy announcement.

On the other hand, the rent price coefficient is not statistically significant in the P(above C) model (Column (4)), and significantly negative in the Label model (Column (7)). This indicates that a higher ex ante rent of the property is not associated with future energy label updates (Column (4)), and is associated with a smaller improvement in future energy label updates. Landlords with a strong tenancy in place seem less enticed to make changes to their buildings.

On the other hand,

4.2 The capitalization of energy labels

Table 3 shows the results of the analysis investigating the effect of the announcement of the label C obligation on sales price and annual rent per square meter for offices, compared to other property types. The DiD model shows no significant impact of the label C obligation policy announcement on the rent that tenants are willing to pay. While the coefficients in Columns (1) and (2) have the expected sign, they are not statistically significant. Column (3) reveals that this lack of significance holds for any energy performance level. There are several potential explanations for the observed lack of impact of the minimum energy label policy on the rental market. A primary reason is likely that tenants are not directly affected by the regulation – although landlords may receive a fine, tenants can continue to use non-compliant buildings. In addition, the duration of the lease may play a role in shaping the preferences of the tenants. Short-term tenants in 2019, for example, may not care much about a policy that only takes effect after 2023, as the immediate benefits of energy efficiency improvements may not be relevant to their lease period.

For the sales market, however, we do observe a significant impact of the label-C obligation. In Column (4), the DiD coefficient (see Equation 2) is -0.182 and is statistically significant at the 1% level ($p<0.01$). This suggests that after the announcement, a one-unit increase in the energy index (meaning that energy efficiency gets worse) is associated with a 18% decrease in the price per square meter for offices. In Column (5), the coefficient for the DiD term is 0.199 and is statistically significant at the 1% level ($p<0.01$). This implies that after the announcement, offices with an energy label of C or better experienced a 20% increase in the sales price per square meter. In Column (6), we further distill the results into individual label categories. Here, the most notable result is for offices with the worst energy performance. We observe a coefficient of -0.389 ($p<0.01$), which indicates that the price per square meter for G-label offices decreased by almost 40% after the announcement. This result shows that the price effect of the energy label is mainly driven by large discounts for buildings with the lowest energy performance, rather than by a higher premium for the most efficient offices.

5 Discussion

The global focus on the reduction of carbon emissions has led to a plethora of local policy responses to address the energy consumption of sectors that are either large emitters (e.g. the energy sector) or substantial end users of electricity (e.g., the real estate sector, which consumes about 79% of total electricity in 2022 (International Energy Agency, IEA, 2022)). This paper evaluates the effectiveness of regulation mandating a minimum energy performance standard in the commercial real estate market in the Netherlands, providing some first evidence regarding the impact on energy performance, as well as market rents and values. However, this is only half of the information the building owner needs to make a refurbishment decision: information about costs are missing. However, the literature on the costs of green building upgrades is limited. According to a study by Chegut et al. (2019), energy efficiency improvements on average cost 6.5% of the value of a building. The number goes up to 30% for the most intensive energy upgrades. Unfortunately, that study is of limited usefulness for us, as it is based on English data ending in 2014. Since this study, building technology has improved and the cost of refurbishment is likely to decrease.

Based on real-life case studies from the NVM, we obtain some insight into the cost of upgrading the energy performance of commercial buildings. Due to the heterogeneity of commercial office buildings, the actual cost of upgrading energy labels can vary substantially. Table 4 presents the cost of upgrading energy labels from label E (below the label-C policy) to label C, label A, and label A++++ (i.e. zero net energy), for four office buildings in the Netherlands. The table provides data on both the absolute costs and the percentage of this cost with respect to the appraised value of the property before the upgrade of the energy label (from rating E).

All four buildings use similar measures to improve energy efficiency, for example, roof and facade insulation, HR++ glazing, optimizing lighting systems using LED, implementing solar panels and heat pumps, etc. However, each building has distinct building-level characteristics that enable or limit improvement measures. For example, floor plan layout can significantly affect the need (and energy saving potential) of lighting, architectural design can make it more difficult to add facade insulation, or structural layout can pose challenges to implementing a heat pump system. Therefore, these varying conditions lead to quite different upgrading costs for the same level of energy efficiency upgrades. As shown in Table 4, the average cost of an improvement from E to C ranges from €9 to €61 per m2, and the average cost of an improvement from E to A ranges from €17 to €114 per m2. For comparison, our results in Table 3 show that, after the policy announcement, office buildings with above C label show a 19.9% increase in the per square meter sales price, which, at the point of means, corresponds to an approximately €240 increase in building value per square meter. This suggests that upgrading the energy label is a good investment after 2018.

6 Conclusion

This paper provides important insights into the effectiveness of minimum energy efficiency standards. This is especially important given the impending EU regulation on minimum energy efficiency standards for *all* buildings (including housing). Given the impact of such policies, leading to substantial capital costs for property owners, and, perhaps, a short-term reduction in the supply of eligible office space, it is essential to evaluate their effectiveness. The fact that some countries, such as the Netherlands, have already implemented this policy for part of the property market, allows us to do such a study before the EU implements it across the continent.

The findings of this paper suggest that the effect of the regulation on property owners has been small but significant. After the announcement of the label-C obligation, office buildings, on average, were 4% more likely to improve their energy efficiency to an energy label of C compared to other property types (e.g. retail, logistics, etc.). Office owners increased the energy efficiency of assets by a third of a label more, on average, compared to other buildings. Importantly, the capital market responded to the regulation with force: office buildings with a "qualified" energy label (of C or higher) had an increased sales price of 19.9% after the announcement of the regulation, relative to noncompliant buildings. This average treatment effect is primarily driven by office buildings with an energy label G – "brown" buildings that were clearly non-compliant.

In addition, this paper adds to the discussion on how energy performance is capitalized in rents and prices. Several studies have reported evidence on the price effect of energy ratings. For example, Energy Star ratings have been shown to result in a rental premium of 3.3% (Eichholtz et al., 2010) and energy labels of D or lower have been shown to result in a loss of value of 6.5-7.5% for Dutch commercial buildings (Kok and Jennen, 2012). Some studies highlight the prevalent limitations in empirical studies related to EPC such as selection bias (McAllister and Nase, 2019) (Fuerst et al., 2017) (Che Ani et al., 2022), and omitted variable bias (Khazal and Sonstebo, 2023) (Fuerst and Van de Wetering, 2015). However, there is no easy solution to such problems, because energy labeling tends to be endogenous. The paper at hand circumvents this issue by using an exogenous policy shock, comparing the effects on office buildings to the effects on other property types, using a difference-in-difference approach.

Although the results in this paper provide some initial evidence of the policy's effectiveness in improving the energy efficiency in commercial real estate, many questions remain. At the microlevel, the motivation of property owners plays a crucial role in determining whether they will invest in necessary energy label upgrades. A recent research report suggests that smaller owners tend to act less on the minimum energy efficiency policy, resulting in lower EPC ratings (Department of Business, Energy, and Industrial Strategy, BEIS, 2021). Institutional owners may have the financial capacity to implement these improvements, while smaller landlords may struggle due to the high costs involved. Including more information on owners and exploring the variations among different owner groups would provide useful insight into the heterogeneity of the policy effects across different buildings.

In addition, it is clear that tenants do not incorporate the regulation on minimum energy performance standards into their leasing decisions. This points, perhaps, to the lack of enforcement that is perceived in the market. If the maximum consequence of non-compliance is a fine for the landlord, tenant decisions will not be affected by the label-C regulation. For this policy to be even more effective, it should also affect users of space, with a clear pathway towards building closure if compliance prevails – that will further reduce tenant demand for inefficient buildings, and improve the business case to invest in the energy efficiency of assets. Regulation without strong enforcement will not sway the capital market into improving the efficiency of durable goods. Last but not least, there is the question of enforcement in general. The fact that only 59% of Dutch office buildings comply with the regulation requiring them to have the C label speaks for itself. Regulation without teeth is a wasted opportunity.

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7 Tables

Policy Intervention	Before Announcement		After Announcement	
Property type	Treatment: office	Control: other types	Treatment: office	Control: other types
Number of buildings	4,032	3,204	9541	8498
Rent transactions				
Number of rent transactions	3770	2658	10468	7582
Average rent price (euro per sqm per year)	117.97 (120.04)	173.88 (146.80)	118.44 (78.66)	170.41 (120.19)
Rent Transaction Area (sqm)	497.18 (1037.25)	277.45 (560.34)	490.55 (1435.60)	367.27 (1263.36)
Sale transactions				
Number of sale transactions	1605	999	3507	2661
Average sale price (euro per sqm)	1009.85 (1578.27)	1289.61 (1331.77)	1229.80 (1214.25)	1506.16 (1212.10)
Sale Transaction Area (sqm)	1180.15 (2014.45)	862.34 (1900.43)	987.97 (2018.52)	825.09 (2032.63)
Energy Performance				
Energy index (before 2021)	1.31 (0.54)	1.16 (0.48)	1.16 (0.47)	1.09 (0.47)
Above C level (percentage)	0.63 (0.48)	0.70 (0.45)	0.77 (0.42)	0.76 (0.42)
Energy label (percentage)				
A and better	0.36 (0.47)	0.46 (0.50)	0.50 (0.50)	0.55 (0.50)
B	0.12 (0.33)	0.11 (0.31)	0.12 (0.33)	0.10 (0.30)
C	0.15 (0.36)	0.13 (0.34)	0.15 (0.35)	0.13 (0.34)
D	0.10 (0.30)	0.10 (0.30)	0.07 (0.26)	0.08 (0.26)
E	0.08 (0.27)	0.07 (0.25)	0.05 (0.22)	0.05 (0.22)
F	0.05 (0.22)	0.04 (0.19)	0.03 (0.16)	0.03 (0.18)
G	0.14 (0.34)	0.09 (0.29)	0.08 (0.27)	0.07 (0.25)
Geolocation (Percentage, number of transactions)				
Amsterdam	0.11	0.11	0.08	0.08
Rotterdam	0.03	0.05	0.03	0.04
The Hague	0.01	0.03	0.01	0.03
Built year				
2020-present	0	0	194	67
2010-2020	356	196	1555	723
2000-2010	1713	584	4997	1748
1990-2000	1609	609	3723	1672
1980-1990	771	475	1750	1313
Before 1980	1494	1998	3427	5442

Table 1: Descriptive Statistics. NVM transaction data merged with energy label records from RVO.

	UpdateLevel	P(above C)	P(above C); sales	P(above C); rent	Label	Label; sales	Label; rent
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
AfterAnnouncement * Office	0.297***	0.040***	0.010	0.054***	0.144***	0.029	0.200***
	(0.085)	(0.012)	(0.020)	(0.014)	(0.053)	(0.093)	(0.061)
Price			0.019**	-0.008		0.087**	-0.073**
			(0.009)	(0.008)		(0.038)	(0.034)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Location fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Property type fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,098	33,250	8,772	24,478	33,250	8,772	24,478
R^2	0.400	0.212	0.273	0.195	0.296	0.358	0.280
Adjusted R^2	0.394	0.209	0.263	0.191	0.294	0.349	0.277
Residual Std. Error	1.462	0.391	0.392	0.389	1.771	1.758	1.769
F Statistic	12.770***	38.818***	28.330***	147.974***	48.845***	33.984***	32.759***
Note:							*p<0.1; **p<0.05; ***p<0.01

Table 2: Energy label updates after the label-C regulation announcement. The coefficient of the variable "AfterAnnouncement * Office" captures the causal impact of the label C-regulation announcement on the chnages in energy labels for office buildings, as compared to other property types, and to the period preceding the announcement. The model in Column 1 evaluates the magnitude of the change in the energy label. Columns 2 to 4 evaluate the probability of having an energy label above C, and Columns 5 to 7 evaluate the absolute level of the energy label.

	Rent	Rent	Rent	Sale	Sale	Sale
	(1)	(2)	(3)	(4)	(5)	(6)
Energy Index * After Announcement * Office Type	-0.007			-0.182***		
	(0.035)			(0.053)		
Energy of C or Higher * After Announcement * Office Type		0.056			0.199***	
		(0.035)			(0.058)	
A, office * after announcement			0.030			-0.024
			(0.060)			(0.096)
B, office * after announcement			0.067			-0.031
			(0.074)			(0.134)
C, office * after announcement			0.073			0.178
			(0.068)			(0.114)
E, office * after announcement			-0.046			-0.143
			(0.082)			(0.140)
F, office * after announcement			0.015			-0.085
			(0.104)			(0.156)
G, office * after announcement			-0.020			-0.389***
			(0.079)			(0.115)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Location fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Property type fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	22,649	24,478	24,478	7,800	8,772	8,772
R^2	0.436	0.443	0.444	0.476	0.488	0.491
Adjusted R^2	0.433	0.440	0.441	0.468	0.481	0.482
Residual Std. Error	0.458	0.454	0.454	0.545	0.542	0.541
F Statistic	147.188***	159.978***	151.345***	57.954***	58.732***	948.485***
Note:						*p<0.1; **p<0.05; ***p<0.01

Table 3: Time-variation in the capitalization of energy labels The table presents the results of six different model specifications, with Columns (1)-(3) for rental prices and Columns (4)-(6) for sales prices.

	Building 1 (2427 sqm)		Building 2 (1176 sqm)		Building 3 (1700 sqm)		Building 4 (3264 sqm)	
	Cost per sqm	% Market Value	Cost per sqm	% Market Value	Cost per sqm	% Market Value	Cost per sqm	% Market Value
E to C	€26.45	2.27%	€41.20	12.75%	€61.76	14.89%	€9.34	1.06%
E to A	€60.03	5.16%	€102.48	31.71%	€114.71	27.65%	€17.46	19.93%
E to A++++	€65.02	5.59%	€153.19	41.39%	€139.41	33.62%	€25.12	28.67%

Table 4: Cost of energy label upgrades The table presents data on the cost of upgrading energy labels from level E (below standard) to C, A, and A++++, for four office buildings in the Netherlands, with the total cost of building improvement in euros(Column 1, 3, 5, and 7) and the percentage of the upgrade cost with respect of the appraisal value before the energy label upgrade (Column 2, 4, 6, and 8).

8 Figures

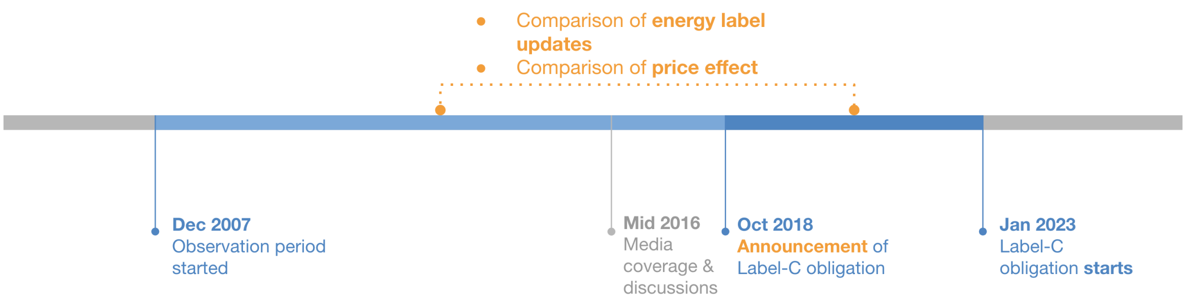

Figure 1: Timeline of label-C obligation This figure shows the overall timeline of the label-C obligation. While the policy was officially announced in October 2018, initial media coverage, public discussions, and policy evaluation started in mid-2016.

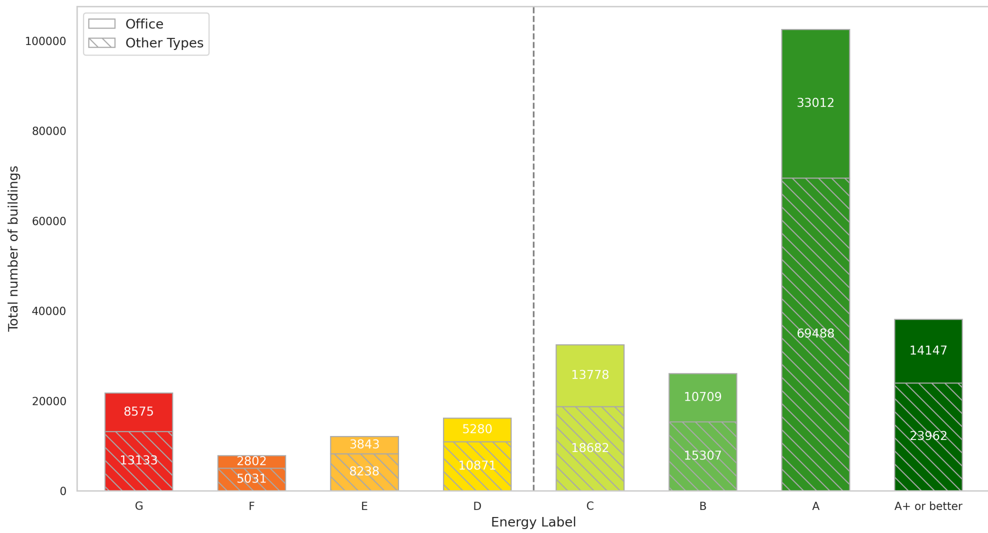

Figure 2: Commercial buildings with an energy performance certificate by the end of 2022 The x-axis shows energy labels from label G (lowest) to label A+ or better, the y-axis shows the count of buildings.

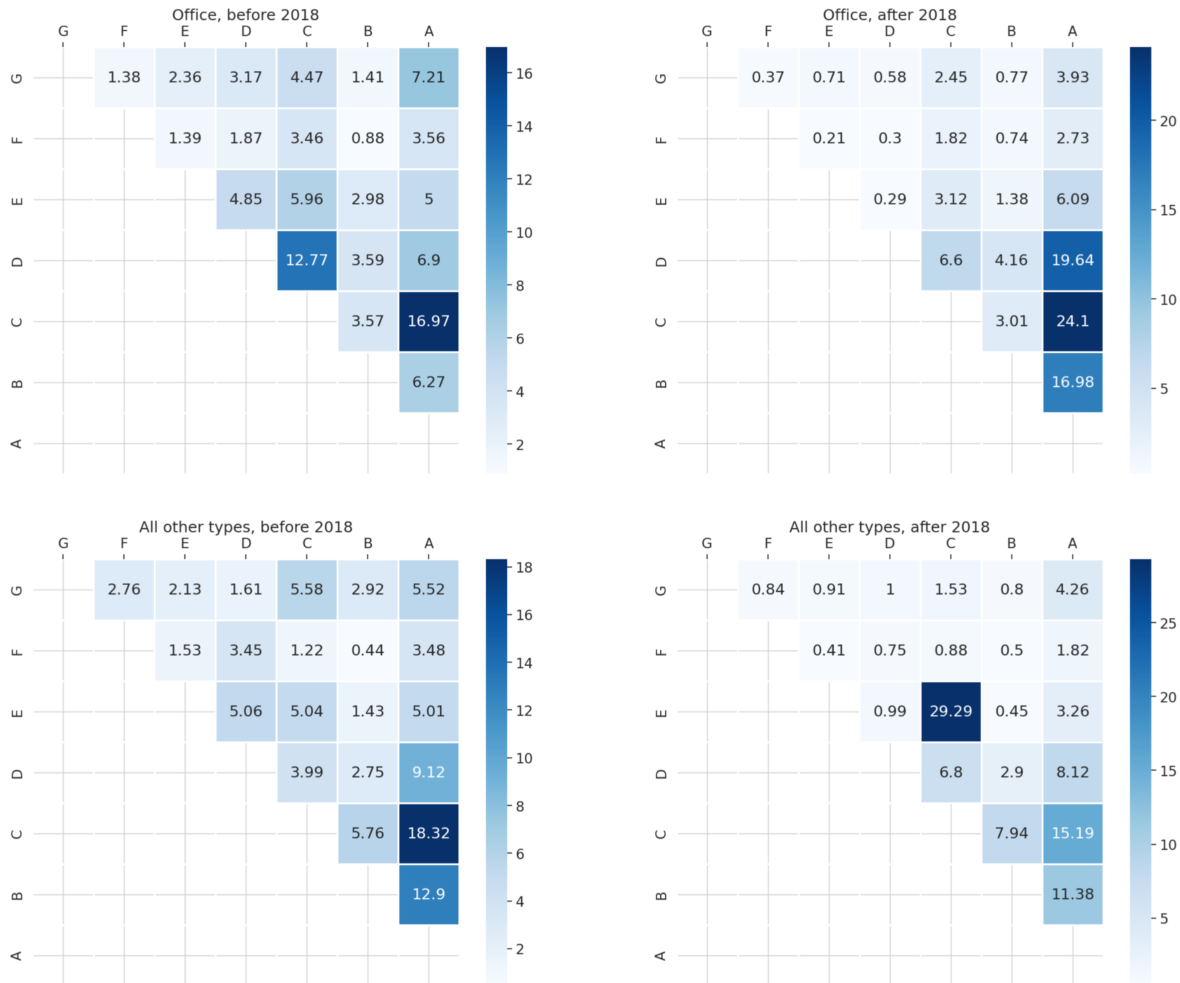

Figure 3: Transition matrix of energy label updates Office (top row) compared with other building types (bottom row) before (left) and after (right) the policy announcement. The number in each grid indicates the percentage of the total market stock (by square meter) of a certain transition (i.e. C to A).

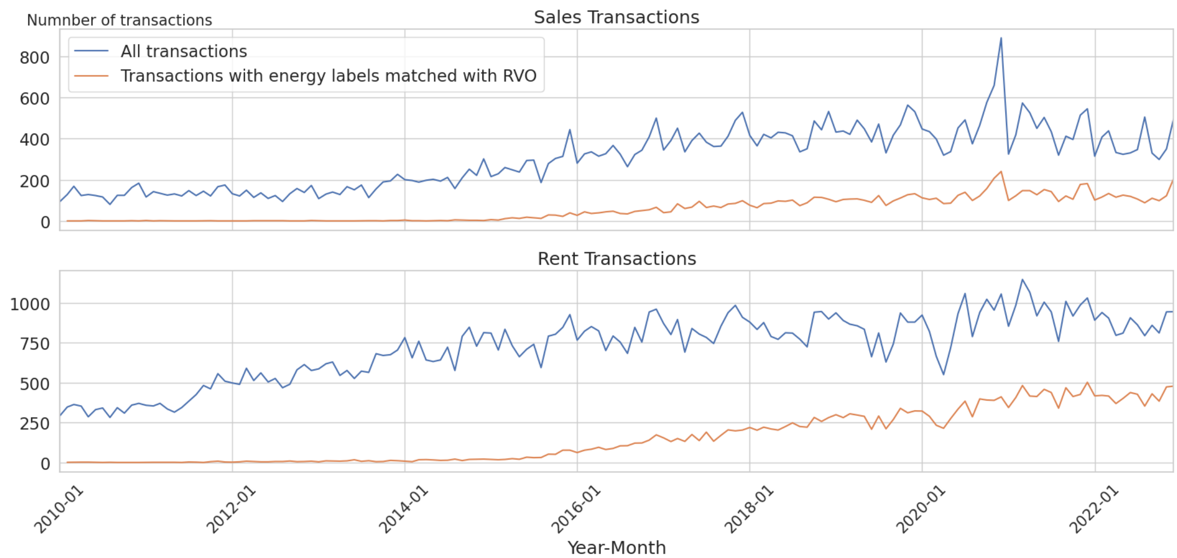

Figure 4: Number of transactions in each month from 2010 to 2022. The x-axis is the timeline from January 2010 to December 2022, the y-axis is the number of transactions. The blue line shows the number of transactions in the NVM dataset for each month, and the orange line shows the number of transactions in which the building has an energy performance certificate

Appendix

A The baseline price effect of the energy label

The following presents the basic relationship between energy labels and property prices or rental rates, both expressed in logarithmic terms per square meter (m^2). As a first step, we exclude the interaction terms in Equation 2 and just evaluate the overall effect of energy labels, comparable to Kok and Jennen (2012). For simplicity, we ignore possible omitted variable bias here, as our dataset lacks detailed hedonic characteristics such as amenities, the number of floors, and street-level location. It is possible that tenants prioritize these property features over energy labels when making rental decisions, or that these features are correlated with our measures of energy performance. The analysis is separated into rent transactions (Columns 1-2) and sales transactions (Columns 3-4).

Column (1) and (3) use the energy index as as proxy for energy efficiency, while Column (2) and (4) use a binary variable indicating if the energy label is above C, therefore in compliance with the label-C regulation. The results suggest that commercial buildings with better energy performance, as captured by a lower energy index or an energy label of C or higher, are associated with higher levels in the rental market. We find a rent difference for the ”compliant” office buildings, of 4.6%, is slightly lower than the ”green premium” documented over the 2005-2010 period (at 6.5% by Kok and Jennen (2012)).

For the sales market, the coefficient for the Energy Index in Column (3) is -0.032 ($p < 0.05$), suggesting that a one-unit increase in the Energy Index corresponds to a 3.2% decrease in the sales price per square meter. In Column (4), the coefficient for the Energy Label above C is 0.039 ($p < 0.05$), indicating that properties with energy labels of C or higher have a 3.9% price premium compared to buildings with an energy label below C. There is no existing research in the Netherlands to compare these point estimates with, but research on the U.S. office market typically shows somewhat higher "green premiums," with the caveat that most studies exploit green certification (e.g. BREEAM or LEED) rather than more specific measures of energy efficiency.

Of course, the results here may be affected by omitted variable bias, given that the assignment of better energy labels might not be endogenous, and any reduced-form model suffers from omitted variable bias.

	Dependent variable: log(price)					
	Sale	Sale	Sale	Rent	Rent	Rent
	(1)	(2)	(3)	(4)	(5)	(6)
Energy Index	-0.032**			-0.057***		
	(0.015)			(0.010)		
Energy Label above C		0.038**			0.046***	
		(0.018)			(0.010)	
BREEAM Certificate			0.106			0.365***
			(0.365)			(0.053)
Building Age	0.002***	0.002***	0.002**	0.004***	0.004***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Area: $< 100m^2$	0.407***	0.407***	0.407***	0.322***	0.322***	0.323***
	(0.029)	(0.029)	(0.029)	(0.013)	(0.013)	(0.012)
Area: $500 - 1000m^2$	-0.356***	-0.357***	-0.357***	-0.297***	-0.299***	-0.301***
	(0.017)	(0.017)	(0.017)	(0.016)	(0.016)	(0.016)
Area: $1000 - 2000m^2$	-0.564***	-0.564***	-0.566***	-0.397***	-0.398***	-0.401***
	(0.023)	(0.023)	(0.023)	(0.028)	(0.028)	(0.027)
Area $2000 - 5000m^2$	-0.781***	-0.780***	-0.785***	-0.432***	-0.433***	-0.437***
	(0.034)	(0.034)	(0.035)	(0.033)	(0.033)	(0.033)
Area $5000 - 10000m^2$	-1.052***	-1.050***	-1.057***	-0.474***	-0.475***	-0.503***
	(0.055)	(0.055)	(0.055)	(0.058)	(0.058)	(0.059)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7762	7762	7762	22506	22506	22506
R^2	0.471	0.471	0.471	0.388	0.387	0.388
Adjusted R^2	0.464	0.464	0.463	0.385	0.384	0.385
Residual Std. Error	0.549	0.549	0.549	0.477	0.477	0.477
F Statistic	658.245***	700.714***	699.661***	995.612***	1065.374***	981.368***
Note:						*p<0.1; **p<0.05; ***p<0.01

Table 5: Baseline capitalization of energy efficiency

We further compare the baseline price effect of energy performance certificates (including energy index, energy label, and BREEAM certificate) before and after the policy announcement.

B Energy label updates

In previous sections, we used the difference in the rating of the energy label to evaluate the magnitude of updates, which is based on the assumption that each incremental change in the energy label represents a uniform challenge, regardless of the initial energy label.

As a robustness check, we employ an ordinal logistic regression model. This approach is particularly suited for ordered categorical outcomes, such as the progression of energy labels from G to A. We explore 2 scenarios: 1) for all energy label updates, we categorize them into 3

	Dependent variable: log(rent)					
	Before	Before	Before	After	After	After
	(1)	(2)	(3)	(4)	(5)	(6)
Energy Index	-0.079***			-0.048***		
	(0.017)			(0.011)		
Energy Label above C		0.059***			0.044***	
		(0.022)			(0.011)	
BREEAM Certificate			0.388***			0.334***
			(0.082)			(0.048)
Building Age	0.004***	0.004***	0.004***	0.004***	0.004***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Area: $< 100m^2$	0.308***	0.308***	0.310***	0.328***	0.327***	0.327***
	(0.017)	(0.017)	(0.017)	(0.012)	(0.012)	(0.012)
Area: $500 - 1000m^2$	-0.282***	-0.285***	-0.289***	-0.300***	-0.302***	-0.303***
	(0.026)	(0.026)	(0.026)	(0.018)	(0.018)	(0.018)
Area: $1000 - 2000m^2$	-0.321***	-0.321***	-0.327***	-0.429***	-0.431***	-0.433***
	(0.044)	(0.045)	(0.044)	(0.027)	(0.027)	(0.027)
Area $2000 - 5000m^2$	-0.324***	-0.325***	-0.334***	-0.473***	-0.474***	-0.476***
	(0.052)	(0.053)	(0.050)	(0.033)	(0.033)	(0.033)
Area $5000 - 10000m^2$	-0.182*	-0.188*	-0.239**	-0.615***	-0.616***	-0.632***
	(0.098)	(0.096)	(0.094)	(0.056)	(0.056)	(0.059)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6396	6396	6396	16110	16110	16110
R^2	0.334	0.332	0.334	0.420	0.419	0.420
Adjusted R^2	0.323	0.321	0.323	0.416	0.416	0.416
Residual Std. Error	0.508	0.509	0.508	0.462	0.462	0.462
F Statistic	324.765***	326.822***	385.001***	1211.357***	1355.674***	1324.370***
Note:						*p<0.1; **p<0.05; ***p<0.01

Table 6: Baseline capitalization of energy efficiency: before and after policy announcement (rent)

	Dependent variable: np.log(sale)					
	Before	Before	Before	After	After	After
	(1)	(2)	(3)	(4)	(5)	(6)
Energy Index	-0.094***			-0.002		
	(0.021)			(0.018)		
Energy Label above C		0.087**			0.016	
		(0.034)			(0.018)	
BREEAM Certificate			-0.278			0.246
			(0.293)			(0.515)
Building Age	0.005***	0.005***	0.004**	0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Area: $< 100m^2$	0.375***	0.379***	0.377***	0.421***	0.421***	0.421***
	(0.050)	(0.051)	(0.051)	(0.034)	(0.033)	(0.033)
Area: $500 - 1000m^2$	-0.367***	-0.368***	-0.374***	-0.347***	-0.347***	-0.347***
	(0.025)	(0.025)	(0.025)	(0.022)	(0.022)	(0.022)
Area: $1000 - 2000m^2$	-0.565***	-0.568***	-0.578***	-0.553***	-0.553***	-0.553***
	(0.036)	(0.037)	(0.036)	(0.028)	(0.028)	(0.028)
Area $2000 - 5000m^2$	-0.727***	-0.725***	-0.739***	-0.812***	-0.811***	-0.812***
	(0.044)	(0.044)	(0.045)	(0.042)	(0.042)	(0.042)
Area $5000 - 10000m^2$	-1.063***	-1.061***	-1.074***	-1.037***	-1.035***	-1.040***
	(0.083)	(0.083)	(0.082)	(0.075)	(0.075)	(0.075)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2593	2593	2593	5169	5169	5169
R^2	0.473	0.472	0.470	0.469	0.469	0.469
Adjusted R^2	0.451	0.450	0.447	0.458	0.458	0.458
Residual Std. Error	0.570	0.571	0.572	0.536	0.536	0.536
F Statistic	471.184***	452.874***	441.154***	809.100***	808.294***	835.183***
Note:						*p<0.1; **p<0.05; ***p<0.01

Table 7: Baseline capitalization of energy efficiency: before and after policy announcement (sale)

cases: ”downgrade” (the new energy label is worse than the previous one), ”unchanged”, and ”upgrade” (the new energy label is better than the previous one); 2) focus on the buildings with below-C label, we categorize them into 4 cases: ”downgrade”, ”unchanged”, ”upgrade below C” (the new energy label is improved, but still falls under level C), and ”upgrade above C”. The model is formalized as follows:

$$\log\left(\frac{P(Y>j)}{P(Y\leq j)}\right) = \alpha_j + \beta_1 AfterAnnouncement_t + \beta_2 Type_i + \beta_3(AfterAnnouncement * Type)_{i,t} + \beta_4 X_{i,t} + \mu_i + \varepsilon_{i,t} \tag{3}$$

for $j = 1, 2, \ldots, J-1$, where J denotes the total number of label update cases (3 for scenario (1) and 4 for scenario (4)), Y represents the ordinal outcome variable for the energy label updates. For example, $P(Y \leq 1)$ denotes the probability that the energy label update falls into the first case (downgrade). α_j is the log-odds of Y when all other explanatory variables are at their reference level, β_1, β_2, β_3, and β_4 are the coefficients for the model explanatory variables, and μ_i captures the unobserved heterogeneity at the building level.

- $AfterAnnouncement_t$ signifies a binary indicator for observations recorded after the policy announcement, to capture the policy impact.
- $Type_i$ reflects the building type, incorporating the structural characteristics that may influence energy efficiency improvements.
- $X_{i,t}$ encompasses additional covariates such as building age, size, and geographical location, which are presumed to affect the upgrade of the energy label.
- μ_i accounts for random effects or error terms, accommodating unobserved factors specific to each building that might affect the energy label upgrade outcomes.

The coefficient of interest is β_3, which captures the causal effect of the policy announcement. Holding all other variables constant, the value of β_3 can be interprete as follows: for office buildings after the policy announcement, the odds of being more likely to upgrade (i.e., upgrade versus unchanged or downgrade) the energy label should be e^{β_3} times that of office buildings before policy announcement. The results are shown in Table 9.

From Table 9, we can still find the positive effect of the policy announcement on upgrading the energy label of office buildings. The estimation result in Column (1) shows that the odds of being more likely to upgrade is $e^{0.231} = 1.259$ times that of office buildings before the policy announcement, which means after the policy announcement, office buildings are more likely to upgrade their energy labels instead of keeping the label unchanged or even downgrade. If we only look at buildings that have a below-C energy label, the estimation result in Column (2) shows an estimate of $e^{0.659} = 1.932$, which means they are twice more likely to upgrade to a better level. The result from robustness checks aligns with the main result in the previous section.

Table 8

	Dependent variable:	
	All buildings	Below-C buildings
	(1)	(2)
AfterAnnouncement*Office	0.231***	0.659***
	(0.086)	(0.136)
Intercept		
downgrade|unchanged	-1.672	-3.6248
unchanged|upgrade	0.8619	
unchanged|upgrade(below C)		-1.4736
upgrade(below C)|upgrade(above C)		-0.5418
Building-level features control	Yes	Yes
Location fixed effect	Yes	Yes
Observations	10,098	4,212
Note:		*p<0.1; **p<0.05; ***p<0.01

Table 9: Estimation result for ordinal logistic regression