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Research article

The spatial dynamics of energy efficiency: EPC impact on retail property values☆

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ABSTRACT

This paper systematically analyzes the effect of energy efficiency on transacted rental and capital values of Dutch retail property assets from 2015–2021. Prior research on Energy Performance Certification (EPC) and energy premiums consistently showed a pricing effect, but recent investigations reveal inconclusive results, particularly when considering non-residential properties. Leveraging a unique dataset of 1015 lease transactions and 478 sale transactions, this study provides one of the first estimates of how EPC labels impact retail value. We utilize ordinary least squares (OLS) regression, considering characteristic retail determinants such as footfall, catchment area type, and retail type, among others. This study finds a premium of 11 percent for rental transactions with Label C or higher on a price per square meter basis. Capital premiums for energy-efficient transactions are more marginal and complex, particularly when accounting for data limitations such as geographic distribution. The nexus between sustainability and financial benefits incentivizes investors and policymakers to embrace energy-efficient measures. Pioneering spatial analyses of EPCs in the retail sector, this paper offers insights for informed policy-making amid geographic variations. In the era of transparency, this research provides empirical evidence to drive responsible investments in energy-efficient retail, shifting from risk management to stakeholder benefits and improved capital efficiency.

1. Introduction

The building sector is currently responsible for 36 percent of total global energy consumption — 30 percent is used during the building's operation phase and the remaining 6 percent for construction-related activities (UNEP, 2022). Given the escalating concern for unbridled energy consumption, there has been an emphasis on, and policy redirection towards cementing the role of energy labels to align with broader carbon neutrality targets for building sustainability (Andaloro et al., 2010) and to disseminate energy performance information to market participants.

These energy-efficient features can subsequently be incorporated into rental or capital value. While the environmental benefits of investing in energy-efficient real estate yield tangible and measurable effects, its financial impacts and returns are a part of the ongoing literary investigation. Research on EPCs and energy premiums consistently show a pricing effect, but this relationship becomes more complex when examining non-residential properties partially due to constraints of available data (Dalton and Fuerst, 2018). Furthermore, while much of the literature around energy premiums focus on the US and the UK market, the Netherlands outperforms both the US and the UK in ESG ratings, indicating a more attractive ecosystem for sustainable investments (Lopez-de Silanes et al., 2020). This is likely due to the regulatory framework that mandates comprehensive ESG disclosures, making research into the dynamics of energy premiums particularly valuable. The European Commission (2013) published a wide-scale report, studying several different European markets regarding the effects of EPC labeling on sales and rent transactions. The scarcity of data, particularly in the retail sector, emerged as a significant barrier in all examined cities, impeding effective policy research, monitoring, and evaluation. Consequently, all the examined case studies neglected to adequately control for location characteristics, opening it up to critique as the scope lacked comprehensive and consistent control variables across different countries (Akhtyrska and Fuerst, 2024). The challenge is not unique to the EU; US researchers similarly cite the proprietary nature of retail data as a major obstacle, often preventing them from accessing the historical data necessary to analyze the connections between energy efficiency and financial performance.(Zhu et al., 2023).

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This paper systematically analyzes the sustainability dimension energy efficiency, on economic outcomes in the Dutch marketplace. A considerable amount of research has focused on residential and office properties, but hedonic studies on retail properties are very embryonic when compared to other sectors. This is partly attributed to the lack of, and confidentiality around, retail transaction data, coupled with an insufficient exploration of retail value determinants. The non-residential sector represents 25 percent of the global building stock, with retail properties covering the highest floor surface area in Europe at 28 percent and consuming 28 percent of non-residential energy (Economidou et al., 2011). In the Netherlands alone, retail properties span a total area of 27 million m^2 (Helgesen and Task, 2014). Despite their significant contribution to global emissions and energy consumption, retail properties remain understudied, both within the Netherlands and internationally. This study's findings offers insights applicable to Europe and beyond — as energy performance grows in importance for sustainable investments, understanding its economic impact across markets is vital for shaping informed energy policies.

Consistent with prior research, this study employs a set of hedonic models to explore the significance of energy efficiency, denoted by EPC labels. We concentrate on retail properties to explore the relationship between investments in energy efficiency, and the rental and sale prices commanded by these properties. This paper is one of first to study the correlation of EPCs with an energy premium in relation to geo-spatial variables. This research examines rental and sales transactions spanning the period from 2015 to 2021, encompassing notable events such as the COVID-19 crisis and the very early stages of the energy crisis in Europe. Leveraging a unique dataset of 1015 lease transactions and 478 sale transactions created from The Dutch Cooperative Association of Estate Agents and Appraisers (NVM), the Netherlands Enterprise Agency (RVO), and Locatus contributes to a comprehensive cross-section of the retail landscape within the EU.

The following section presents a review of related research. Section 4 presents an in-depth examination of the data sources and methodology employed to assess the energy effects on retail prices. A descriptive analysis of the utilized datasets will be conducted, providing valuable insights into the characteristics and underlying patterns within the data. This analysis serves to establish the foundation for the subsequent modeling and facilitates an initial understanding of the energy efficiency landscape within Dutch retail. Section 5 presents new evidence regarding the rental and capital returns associated with investments in energy-efficient retail buildings followed by a discussion in Section 6. Section 7 is a brief conclusion and implications for policy.

2. Energy labeling

The fundamental rationale behind market-based policy instruments, such as the EPC, lies in their ability to stimulate shifts in consumer behavior through the provision of accurate and standardized information (Davis et al., 2015). The Energy Performance of Buildings Directive (EPBD) is the main EU legislative instrument to promote energy efficiency within the built environment — aiding in the decarbonization of existing and new building stock by implementing certification when a property is transacted. Energy labeling, in it of itself, is not the end goal but rather as an essential step to foster an ecosystem of innovation and change for enhanced energy performance of buildings (Hinnells, 2008).

Two main categories of environmental certification exist as performance controls. One category is focused solely on energy performance such as EPCs and Energy Star (an equivalent in the United States). The Energy Index (EI) was introduced alongside EPCs to implement the EPBD in the Netherlands. It is expressed as a numerical indicator, correlating to an EPC grade where lower EI values indicate higher energy efficiency. The specific EI ranges corresponding to different EPCs are depicted in Table 5 in the Appendix. The other category revolves around voluntary eco-certification, characterized by its geographical specificity and alignment with varying environmental agendas. Leadership in Energy, Environmental Design (LEED), and Building Research Establishment Environmental Assessment Method (BREEAM) are (inter)nationally the most used outside of energy performance (Brown and Watkins, 2015). Across Europe, EPC labels are the most common measurement for sustainability; as energy certificates become mandatory for property transactions, they are expected to generate a substantial amount of data over time. Additionally, energy performance was selected as the metric of choice due to its inherent measurability and causality.

2.1. The role of regulations

Fig. 1 illustrates a timeline of environmental certification development and adoption worldwide for commercial properties. More than 3.9 million energy labels, under EPBD, have been issued within the Netherlands for non-residential properties since 2008. EPC labels are based on energy performance assessments and label grades vary from G, for particularly inefficient properties, to A++++ for highly efficient properties. The Dutch national government has set ambitious targets to regulate and even halt operations for office buildings transacted below an EPC grade label of C (Colliers, 2021). And while huge strides have been made in the residential sector due to the EPBD, building improvements in the commercial property sector lag and have not, on a large scale, taken off.

At the EU level, a range of policies and initiatives have been developed to address energy-related challenges — one significant framework is the 'Clean Energy Package', established in 2018 which aims to ensure secure, sustainable, competitive, and affordable energy for all EU citizens. This strategy encompasses eight individual legislation papers, among which the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED), the Renewable Energy Directive (RED), and the Governance Regulation (GR) hold particular importance (BPIE, 2022). Alongside the Clean Energy Package, the European Commission introduced the European Green Deal in 2019 as a strategic plan to fulfill the objectives outlined in the Paris Agreement. The European Green Deal includes a minimum of 55 percent reduction in greenhouse gas emissions from 1990 levels, a 32 percent share for renewable energy, and a 32.5 percent improvement in energy efficiency across sectors by 2030. The ultimate goal is to achieve net-zero greenhouse gas emissions by 2050. Given that buildings in the EU account for around 40 percent of total energy consumption and 36 percent of GHG emissions, the building sector plays a significant role in the attainment of sustainability goals for 2030 and 2050. Implementing energy retrofit measures in these buildings has the potential to result in a substantial reduction of 5–6 percent in the EU's energy consumption and a 5 percent decrease in carbon emissions (European Commission, 2020). However, the current average retrofit rate for the existing building stock remains below 1 percent per year.

2.2. The role of retail

Of the existing 100,000+ retail properties in the Netherlands, only 26 percent currently comply with an energy label of C or above (Colliers, 2021); a remarkable 68 percent of retail properties lack any energy label, highlighting the colossal challenge that lies ahead. In a study utilizing data from the Energy Research Center of the Netherlands, Colliers (2021) discovered that if energy labels were sought for all non-labeled retail properties, it is estimated that less than a quarter of these properties would attain an energy label of C or higher. In contrast, approximately 50 percent of office properties would meet the same requirements. Enhancing the energy performance of retail buildings through investments in energy retrofits and regulatory changes can significantly contribute to sustainable development goals and reduce energy consumption.

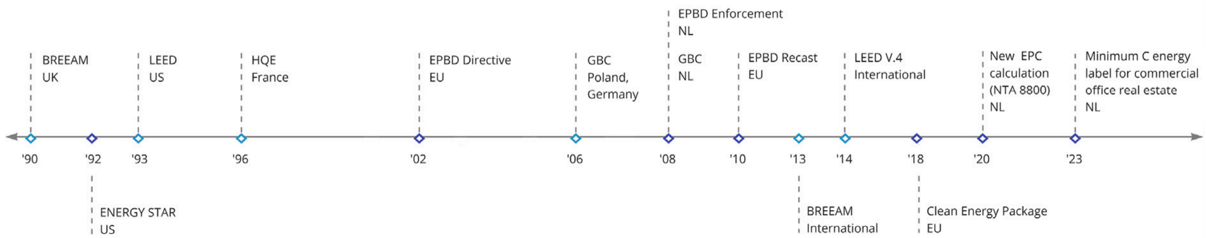

Fig. 1. Evolution of sustainable commercial labeling: a global timeline.

3. Literature review

The introduction of mandatory energy labeling in the different sectors of real estate has sparked increased research activity in this area. Based on empirical evidence, a discernible energy premium is evident within the residential sector with. This can be attributed to the early targeting of the residential sector in policy-making decisions or the closer impact of energy prices on energy poverty and households (Koengkan et al., 2023a). However, when considering all sectors, the emerging body of studies presents a mixed picture (Dalton and Fuerst, 2018). The common thread in existing research, however, is the lament over the unavailability, inaccessibility, and deficiencies of data, which leave room for omitted variable bias and potential endogenous challenges. (McCord et al., 2020).

Highlighting the well-recognized issue of capturing good quality data within real estate, literature on green premiums is predominately focused on the U.S. market, particularly on residential properties. Moreover, much of the eco-certification within the body of literature is not applicable to the Netherlands, such as the LEED program. While the body of work is too large to review meticulously, key insights gained into US, UK, and EU commercial markets are examined, along with a more comprehensive examination of studies focused specifically on the Netherlands.

One of the most important findings from the body of research comes from the random-effects meta-analysis conducted by Dalton and Fuerst (2018) that aggregated 42 global studies to examine the relationship between environmental certification and property transaction prices. They produced rental and sales premiums with weighted mean effects of 6.0 percent and 7.6 percent respectively, when controlling for the broader residential and commercial markets with certification measures of EPC, Energy Star, BREEAM, LEED, Green Mark, NABERS, and mixed certifications. To mitigate the high degree of heterogeneity, further subgroup analysis based on different markets, certification measures, and property types was conducted. The EPC subgroup contained confidence levels of zero and high heterogeneity even within its own subgroup. The variations in property types, locations, and market conditions can all play a role to complicate the ability to draw uniform conclusions. By narrowing the scope to retail properties, our study aims to reduce this heterogeneity and provide more specific insights into the relationship between energy performance and property value in this understudied sector. The commercial property subgroup in the meta-study notably excluded retail properties, highlighting the existing knowledge gap that our research addresses.

3.1. US, UK & the EU

The entirety of the literature around energy and green premiums for American commercial properties focuses on office buildings, with a gaping knowledge gap for the retail sector. All empirical investigations conducted on the office sector in the United States have consistently revealed diverse magnitudes of positive premiums on rental rates, property values, and/or occupancy rates associated with energy-efficient buildings (Miller et al., 2008; Eichholtz et al., 2010; Wiley et al., 2010; Fuerst et al., 2013; Das and Wiley, 2014; Fuerst and Van de Wetering, 2015; Robinson, 2015). Data selection, availability, and omitted variables are acknowledged to be the main contributors to the differences in the results, despite the US exhibiting the highest quality of data in terms of its sample size and number of variables (Dalton and Fuerst, 2018). The earlier studies found large differences in sales prices compared to the rental counterpart (see McAllister, 2009). In addition, the groups of energy efficient and energy inefficient properties exhibit large differences in age, size, and/or vacancy levels.

Chegut et al. (2011) pioneering study on green premiums in Europe focused on UK offices and BREEAM certifications from 2000 to 2009, revealing a 21 percent rental and 26 percent sales premium, with controls for location, property area size, age, storage, amenities, and dummy variables for renovations. Their data encompassed 1171 lease transactions, including 67 BREEAM-certified leases, and 2023 sales transactions, including 70 BREEAM-certified ones. Similarly, the European Commission (2013) examined the impact of EPC labeling on sale and rental transactions across eight European cities. The limited availability of data emerged as a notable finding, highlighting the need for monitoring and evaluation efforts. Consequently, all the examined case studies neglected to adequately control for location characteristics, opening it up to critique as the scope lacked comprehensive and consistent control variables across different countries. Nonetheless, the study covered diverse regions, including France (Marseille and Lille), Ireland, Belgium, the UK (Oxford and surroundings), and Austria (Vienna), consistently showing a premium effect across varied climates and urban–rural settings.

Fuerst and McAllister (2011) examined the impacts of EPCs on London's retail, office, and industrial real estate properties – a first for the retail sector – where no evidence of a price premium could be observed in any of the building categorizations. For the hedonic model, a total of 293 retail transactions, 226 office transactions, and 173 industrial transactions from 2010 were utilized. Control variables included BREEAM certification as an added *green* effect on top of the EPC labels along with vacancy rates, weighted credit risk scores, rentable area size, region dummies, and building segment dummies. The authors explained the absence of statistical significance, suggesting that the small sample size of 708 observations and the fact that only one property in their dataset achieved an EPC A rating, might have contributed to this outcome. This finding further underscores the existing challenges related to data deficiencies, particularly within the retail sector. More recent studies have focused on the introduction of Minimum Energy Efficiency Standards (MEES) in the office commercial market (Akhtyrska and Fuerst, 2024). They found that MEES policies led to a measurable rental reduction of 6–8 percent for affected office units, with a weakly significant 4.4 percent rental discount observed for EPC E-rated offices, possibly due to market expectations of future regulatory expansions. This underscores the evolving impact of energy efficiency regulations on commercial property markets and provide a clearer signal of policy impacts in an environment with fewer pricing regulations than residential markets.

3.2. The Netherlands

The study conducted by Brounen and Kok (2011) in the Netherlands examined the economic implications of EPC labels on the residential market, using 177,000 transactions for 2008 to 2009. They found the adoption of EPCs to be based on economic and political behavior (due to geographic variation) and market signaling along with the capitalization effects of energy labeling. Neighborhoods with densely situated property types housing low-income residents who are politically aligned towards climate issues exhibited a propensity towards adopting EPC labeling. Neighborhood control variables included housing density, time-on-market, and monthly household income. The energy premium they observed varied from 10 percent for A-rated properties when the dwelling was sold, to a discounting effect of 5 percent for G-rated properties, when benchmarked against D-rated properties.

In more recent studies conducted within the Netherlands, Chegut et al. (2016) analyzed 17,835 sale transactions of EPC labels and their effects on the Dutch affordable housing market over the period 2008–2013. A price premium of 2.0 to 6.3 percent was found when compared to otherwise similar homes with low energy efficiency. Murphy (2014) took a different approach to determining a price effect for energy efficiency and drew on data from ex-ante and ex-post assessments of the EPC label. A survey was conducted to investigate the influence of EPCs on Dutch private dwelling purchasers and found that EPCs did not heavily sway homeowners' buying decisions, especially for pre-purchase.

To date, only one conference paper addresses energy premiums in the retail market. Op't Veld and Vlasveld (2013) examined the EPC effects on a single retail portfolio comprising of only 128 properties. They found energy-efficient retail to initially command a higher income of 0.53 percent, but after controlling for various factors such as center size, catchment area, and adjusted property size, the energy premium was insignificant. The data used in this study, while is of high quality, is unfortunately very limited and does not contain sufficient transaction numbers to be convincing. This once again, highlights the secular issue of data for all hedonic modeling of this nature.

Aroul and Rodriguez (2017) raise a compelling argument regarding the generalizability of the findings when analyzing energy performance since attitudes (along with price premiums) differ vastly with regard to green amenities across different markets. This suggests that the effects observed in the office and residential markets may not apply to the retail sector and that these energy premiums, very much remain a behavioral issue. It is further exacerbated in the retail sector since it is a very customer-driven classification that influences the shopping experience and spending behavior. Additionally, the lack of location variables in existing research limits our understanding of energy performance in broader market contexts, particularly in retail (European Commission, 2013). These limitations directly inform our methodology, as we address the gaps by incorporating a sufficient number of rental and sale observations, energy labeling but also geographic data, retail typology, and surrounding population data. Offering new insights into the intersection of energy efficiency and its pricing effect in Dutch retail.

This paper addresses these gaps by examining the relationship between energy labeling, location, and pricing effects in Dutch retail, offering new insights into the intersection of energy efficiency and its pricing effect.

4. Methodology and data

While there are plausible *a priori* reasons to hypothesize a positive correlation when measuring a price differential between energy-efficient and energy-inefficient properties, this section presents the hedonic price models to measure these financial effects along with the proprietary datasets used for EPC certification and rental and sale retail transactions within the Netherlands. Hedonic modeling is a method used to estimate the impact of various factors (like EPCs) on property prices by isolating their individual contributions. Following existing literature on green building economics, this research employs multi-variant OLS regression, a commonly used technique to analyze the impact of rent determinants in real estate research (Eichholtz et al., 2010; Kok and Jennen, 2012; Eichholtz et al., 2013; Porumb et al., 2020; van Overbeek et al., 2024). The log-linear model was chosen due to its ability to capture the partial effect of energy performance, which is expected to be minor compared to factors like location or age (Fuerst and Van de Wetering, 2015). Other methods, such as fixed effects and time series, were not selected because our retail data lacks the variation and panel data required for these approaches. Fixed effects may not adequately capture energy premiums, and time series analysis focuses more on trends over time, which is not the core of this research.

4.1. Methodology

The price of a unique retail property is the sum of the implicit values of all rent determinants, as shown in Eq. (1), and all sale determinants, as shown in Eq. (2). These semi-log equations estimate the dependent variable, price per square foot, for retail building i in cluster n. The β_n are vectors of parameters to be estimated, while ϵi represents the random error and stochastic disturbance term. The weighting assigned to each variable reflects its overall contribution to the price, enabling a dollar-weighted model on price premiums (Rosen, 1974).

To accurately isolate the effect of a good EPC certification and avoid overestimating its impact, this paper follows previous studies and controls for rent determinants that are proven to have a significant effect on retail prices in the current body of literature (Sirmans and Guidry, 1993; Mejia and Benjamin, 2002; Rosiers et al., 2005; Hui et al., 2007; Hardin et al., 2002; Hardin and Wolverton, 2001; Nase et al., 2013). Four major descriptor series that influence the prices of retail properties were identified — they are geographic regions, retail positioning, physical characteristics, and transaction type form the basis of the models. A bi-directional stepwise regression was conducted to optimize variable selection, focusing on statistical significance and simultaneity bias for inclusion. An overview of the control variables can be found in Table 6 in the Appendix.

4.1.1. Rental transactions

The semi-log regression rental function, incorporating a complete list of independent variables, is presented in Eq. (1):

$$log Rent = \beta_0 + \beta_1 T + (Ln)\beta_2 EI + \beta_3 LOC + \beta_4 A + \beta_5 RT + \beta_6 SEGM + (Ln)\beta_7 POP + \beta_8 AGE + \beta_9 V + \epsilon i \tag{1}$$

In which:

R = rent price
β_0 = intercept
T = transaction year
EI = energy index
LOC = 4-digit postcode
A = location typology
RT = retail typology
$SEGM$ = segment class
POP = the number of residents in the area
AGE = age
V = vacancy
ϵ_i = observed statistical error

4.1.2. Sale transactions

Similarly, the semi-log regression sale function is as follows in Eq. (2):

$$log Sale = \beta_0 + \beta_1 T + \beta_2 EI + \beta_3 LOC + \beta_4 A + \beta_5 RT + \beta_6 SEGM + \beta_7 POP + \beta_8 AGE + \beta_9 V + \epsilon i \tag{2}$$

In which:

S = sale price
β_0 = intercept

T = transaction year
EI = energy index
LOC = 4-digit post code
A = location typology
RT = retail typology
$SEGM$ = segment class
POP = number of residents in the area
AGE = age
V = vacancy
ϵ_i = observed statistical error

4.2. Data

Hedonic studies on retail property are still embryonic, this is partially due to the confidentiality around retail transactions (Rosiers et al., 2005). This paper employs a combination of three different datasets representing a cross-section of the retail landscape. Rental and sales transaction data from NVM cover approximately 75 percent of all recorded property transactions in the Netherlands. The initial database was purged based on the removal of missing observations, erroneous data entries, and property types outside of the retail function. This is subsequently merged with the data set from RVO comprising of full addresses, EPC data, and floor area. An address-matching exercise was performed to align the EPC scores with the NVM data. Lastly, a retail-specific database, extracted from Locatus, was further stratified to provide information on the catchment area, retail type, tenant, and type of locale the property lies within. Locatus is a Dutch research firm that collects and constructs property-level data points on all retail and consumer-oriented service companies in the Benelux region. Outliers, that have a substantial impact on the estimated regression coefficients have been removed using Cook's Distance measure. It was used to identify and remove outliers in the transaction prices and square meterage variables; 57 transactions were removed from the rental dataset and 17 transactions from the sale dataset. A final address matching exercise was performed to create a unique dataset encompassing 1015 lease properties and 478 sale properties, complete with EPC label, transaction price, size, location, and various building and retail hedonic characteristics.

Data analysis consists of two main steps: first, to see whether there are statistical differences between energy-efficient properties and energy-inefficient properties, the groups have been compared using a t-test for the normally distributed variables and a Mann–Whitney test for the not-normally distributed variables. A summary of the descriptive statistic for rental and sales data can be found in Tables 1 and 2. The corresponding count statistics can be found in Tables 7 in the Appendix. Second, the two unique datasets have been examined with two distinct OLS regression models in both rental and sale transactions. The remaining variables were tested for normality through a Kolmogorov–Smirnov test with all parameters normalized via a natural log transformation in line with previous research (Walker, 1989; Porumb et al., 2020; van Overbeek et al., 2024). Multicollinearity was assessed through Variance Inflation Factors, heteroscedasticity, analyzed through a Breusch–Pagan test, as well as identification and non-linear relationships that could significantly influence the gradient of the regression line. To align with the national Dutch 2050 targets, properties are categorized into "High EPC" (energy label C or higher) and "Low EPC" (energy label D or below) groups. For clarity, throughout the paper, blue will represent high EPC properties, while orange will indicate low EPC properties.

4.2.1. Descriptive statistics- Rental transactions

Table 1 depicts the quantitative distinction between retail spaces with a high EPC label and a low EPC label. The sample rental properties are diverse in age and type with buildings from 1850 to 2020, covering high-street properties as well as neighborhood centers and shopping malls. The median EI score falls within label A for the higher group and label D for the lower group.

4.2.2. Descriptive statistics- Sale transactions

A summary of the descriptive statistics for sale transactions is presented in Table 2. The sample sale properties are diverse in age and typology with one particular property dating back to 1600 in Delft city center. The properties with high EPC labels, on average, tend to be younger in age and have lower footfall numbers. This finding is consistent with the nature of high-street retail in the Netherlands, where older properties are more prevalent.

5. Results

5.1. Rental transactions

Fig. 2 highlights the presence of distinct market structures and segmentation on a municipality level, which contribute to variations in rental pricing. Retail location typologies are typically classified into city centers, regional centers, and district centers. These structural characteristics exhibit specific spatial concentrations, resulting in a complex mosaic of market compositions. The observations in the rental dataset, including both high and low EPC labels, indicate a random distribution across the Netherlands. This suggests that the sample is representative of retail real estate properties throughout the country. The number of transactions place a clear emphasis on the Randstad areas in the Netherlands, including prominent municipalities such as Groningen, and Maastricht; this is logical since a significant proportion of retail spaces are situated within these regions.

Table 3 reports the results of the OLS regression model on the natural log of rent per m^2, corrected for heteroskedasticity. The results are organized by the four descriptor series, following a stepwise approach. Model (1) reports a basic model relating rent to transaction year and EI; the coefficient of EI represents the impact of a higher EPC grade on the rental price. The adjusted R2 is insignificant.

In model (2), the estimated coefficient for EPC ratings reduces slightly at 8.5 percent in retail rents but grows in significance to the 0.05 level. The other variables of interest are the added postcodes (location fixed effects) and location typology that enhanced the regression's explanatory power. Rent in "city centers" is over 62 percent higher than that of a "small regional center", about 10 percent higher than that of a supporting "city district center", and almost 50 percent higher than that of a "large regional center".

In model (3) the variables measuring retail positioning are added to the model. The results indicate that there is a substantial premium associated with a higher building segment at the highest significance level. Population within a 5 km radius is insignificantly different from zero however, there is a substantial premium associated with population within a 10 km radius. In contrast to the initial expectation that "fashion and luxury" retail typology would yield higher rents, "daily use" retail outperforms it by 27 percent at the highest level of significance. A highly significant rent premium of 12 percent is associated with the EI in this regression.

Model (4) adjusts for the age range and vacancy of the retail property. However, during the step-wise process, age ranges were systematically eliminated due to the lack of influence. The relatively lower R-squared values suggest that while the model captures some key factors, there are likely additional unobserved variables influencing retail property rents. Vacancy in rental retail properties exhibits roughly the expected 15 percent discounting effect. A highly significant rent premium of 11 percent is associated with the EI in this regression.

5.2. Sale transactions

Fig. 3 provides a geographical overview of both high and low EPC retail properties, alongside a comprehensive representation of total sales transactions at the municipal level. Although the observations in the dataset are randomly distributed throughout the Netherlands, there is a noticeable disparity in the number of observations between

Table 1
Descriptive statistics high vs. low EPC label — rental transactions.

Descriptive statistics		N	Median	Standard deviation	Significant difference	T-test or Mann–Whitney
Energy label variable						
Energy Index	High EPC	625	50	10.40	Yes++	0.17
	Low EPC	390	125	37.17		
Retail variables						
Footfall	High EPC	625	5700	5522.88	Yes++	5.40 ***
	Low EPC	390	7700	6797.42		
Population within 5 km	High EPC	625	76,483	98,123	No++	0.01
	Low EPC	390	83,912	106,369		
Population within 10 km	High EPC	625	165,5860	197,731	No++	2.23 **
	Low EPC	390	215,484	205,064		
Building variables						
Age (Years)	High EPC	625	70	67.73	Yes++	1.41
	Low EPC	390	93	74.66		
Size of transaction (m^2)	High EPC	625	120	97.51	No++	−7.25 ***
	Low EPC	390	116	103.76		
Lease rent (€/m^2)	High EPC	625	200	190.22	No++	40.45 ***
	Low EPC	390	215	74.54		

*Significant at the 10% level **Significant at the 5% level ***Significant at the 1% level.
Based on a + t-test ++ Mann–Whitney test.

Table 2
Descriptive statistics high vs. low EPC label — sale transactions.

Descriptive statistics		N	Median	Standard deviation	Significant difference	T-test or Mann–Whitney
Energy label variable						
Energy Index	High EPC	220	50	11.71	Yes+	1.72*
	Low EPC	258	125	36.10		
Retail variables						
Footfall	High EPC	220	4600	4636.38	Yes++	5.78 ***
	Low EPC	258	5050	5415.66		
Population within 5 km	High EPC	220	48,429	72,541	Yes++	−1.58
	Low EPC	254	64,862	70,617		
Population within 10 km	High EPC	220	119,780	153,573	No++	−0.17
	Low EPC	258	123,630	141,487		
Building variables						
Age (Years)	High EPC	220	94	46.96	No++	−2.19 **
	Low EPC	258	98	84.26		
Size of transaction (m^2)	High EPC	220	164	155.44	No++	−2.50 **
	Low EPC	258	173	182.12		
Sale Value (€/m^2)	High EPC	220	1991.87	3.691.35	No++	31.53 ***
	Low EPC	258	2126.42	1995.50		

*Significant at the 10% level **Significant at the 5% level ***Significant at the 1% level.
Based on a + t-test ++ Mann–Whitney test.

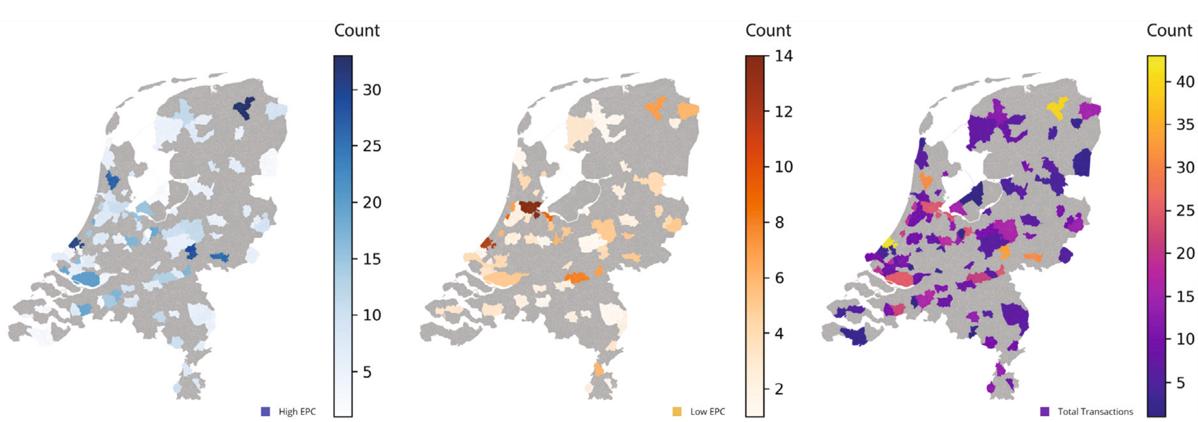

Fig. 2. Map of the Netherlands illustrating the spatial distribution of rental retail transactions across municipalities from 2015 to 2021.

Table 3
Market rent OLS regression results.

	(1) Energy	(2) Geographic	(3) Retail	(4) Physical
Energy index	0.1081**	0.0854***	0.1230***	0.1144***
	(0.0466)	(0.0204)	(0.0391)	(0.0390)
2015 dummy	–	–	–	–
2016 dummy (1 = yes)	−0.0142	0.0262	0.0370	0.0275
	(0.0956)	(0.0813)	(0.0806)	(0.0802)
2017 dummy (1 = yes)	0.0661	0.0926	0.0931	0.0733
	(0.0953)	(0.0881)	(0.0786)	(0.0780)
2018 dummy (1 = yes)	0.0859	0.0992	0.0924	0.0738
	(0.0938)	(0.0901)	(0.0794)	(0.0788)
2019 dummy (1 = yes)	0.0336		0.0466	0.0340
	(0.1008)	(0.1001)	(0.0840)	(0.0836)
2020 dummy (1 = yes)	0.0360	0.0077	−0.0214	−0.0202
	(0.1033)	(0.0991)	(0.0871)	(0.0868)
2021 dummy (1 = yes)	−0.0552	0.2310	0.2122**	0.1921*
	(0.1021)		(0.1056)	(0.1048)
Location fixed effects	N	Y	Y	Y
Location typology:				
City center (1 = yes)		0.6230***	0.3177***	0.3158***
		(0.0624)	(0.0666)	(0.0661)
Regional center -Large (1 = yes)		0.1340**	0.1362**	0.1154**
		(0.0606)	(0.0568)	(0.0565)
Regional center -Small		–	–	–
City district center (1 = yes)		0.5267***	0.1621***	0.1572***
		(0.1239)	(0.1249)	(0.1247)
Retail typology:				
Fashion & Luxury			–	–
Daily use (1 = yes)			0.2689***	0.1840***
			(0.0653)	(0.0673)
Free time (1 = yes)			−0.1808**	−0.2612***
			(0.0802)	(0.0818)
In & around the house (1 = yes)				−0.1434**
				(0.0577)
Leisure (1 = yes)			0.1907	−0.0985*
			(0.1092)	(0.0591)
Segment:				
A1 (1 = yes)			0.5854***	0.5796***
			(0.0946)	(0.0939)
A2 (1 = yes)			0.3717***	0.3461***
			(0.0898)	(0.0891)
B1 (1 = yes)			0.2324***	0.2217***
			(0.0829)	(0.0823)
B2 (1 = yes)			0.0194	0.0088
			(0.0825)	(0.0821)
C			–	–
Population within 5 km			0.0057	0.0259
			(0.0511)	(0.0543)
Population within 10 km			0.3048***	0.2253***
			(0.0493)	(0.0529)
Vacancy dummy (1 = yes)				−0.1559***
				(0.0370)
Constant	4.9369***	4.6287***	0.8917**	1.7102***
	(0.1815)	(0.1427)	(0.3726)	(0.4253)
R-squared	0.0286	0.3684	0.4360	0.4494
R-squared Adj.	0.0219	0.3370	0.4067	0.4172
N	1015	1015	1015	1015

Standard errors are in brackets.
* Significant at the 10% level ** Significant at the 5% level *** Significant at the 1% level.

the rental and sales data. Sales transactions are disproportionately concentrated in smaller regional centers like Oldenzaal, Purmerend, and Roermond, rather than the more prominent Randstad cities. This may indicate the possibility of geographic data bias, despite the dataset's extensive coverage of different location typologies.

Table 4 reports the results of the OLS regression model on the natural log of sale prices per m^2. Model (1) reports a basic model relating sale values to transaction years and EI; this regression, based upon 478 observations has an insignificant adjusted R2. Interestingly, in the first model, the only variable that demonstrates statistical significance is the 2020 dummy. This variable indicates a significant, 50 percent decline in sale values compared to 2015 which can be partially attributed to the impact of the COVID-19 pandemic. However, it is noteworthy that the EI variable has a very small effect of 0.07 percent

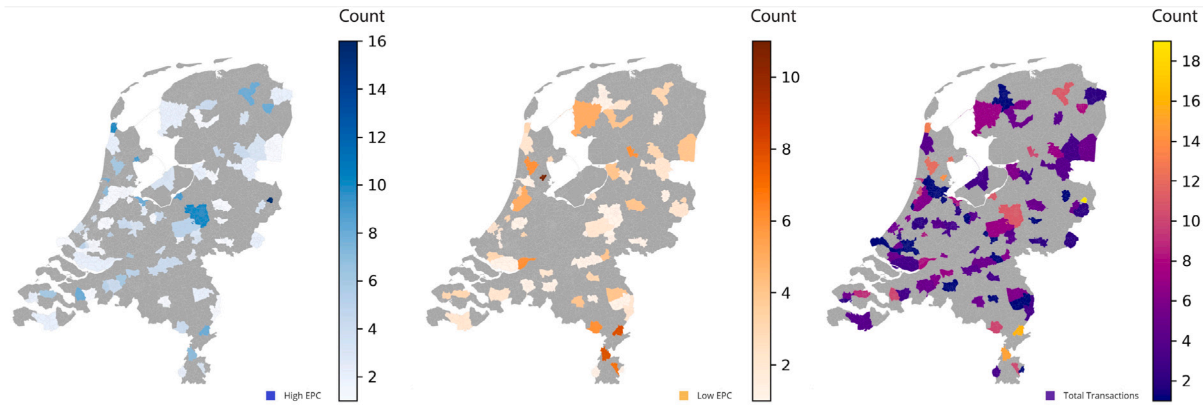

Fig. 3. Map of the Netherlands illustrating the spatial distribution of sale retail transactions across municipalities from 2015 to 2021.

with zero significance. This suggests that there is a need for additional explanatory variables and more comprehensive control factors for a robust regression analysis. Model (2), controls for important geographic proxies such as postcodes (location fixed effects) and location typologies. Properties located within "city centers" command higher rents compared to "small regional centers" at the 0.05 significance level. The other location typologies did not meet the criteria for inclusion during the stepwise elimination process. The estimated coefficient for EPCs is still negligible at 0.08 percent and remains statistically insignificant.

In model (3) retail positioning variables to distinguish retail typologies, segment classes, and populations within the area are added. The estimated coefficient for EI jumps in significance at the 0.10 level but the coefficient still remains less than 1 percent. Similar to the rental model, the "daily use" retail typology yields higher sale prices compared to the expected top performer: "fashion and luxury", exhibiting a premium of 18 percent at the 0.05 significance level. The analysis reveals that the population within a 10 km radius has a greater impact on sale prices compared to the population within a 5 km radius once again. Furthermore, in the segment category, A2 properties exhibit higher premiums at a higher level of significance even when compared to A1 buildings.

In model (4) where all control variables are included, the estimated coefficient of EI indicated a sale price premium of 0.1 percent but is insignificantly different from zero. Building age classification and vacancy dummies were adjusted for in model (4). The results reveal a significant discounting effect for newer buildings, highlighting the complexity of location factors. Notably, in the Netherlands, large city centers with renowned historical high streets command higher rents and hold significant consumer value, emphasizing how location and historical significance shape the distribution of these retail properties. Vacancy levels in sold retail properties were found to have a stronger negative correlation with prices, showing a 26 percent decrease in prices at the highest significance level.

6. Discussion

The findings suggest that the relationship between EPC labels, and rental and sale prices are complex and multifaceted. Rental transactions with higher EPC certifications show a premium of approximately 11 percent on a price per m^2 basis and the spatial distribution of these transactions reflects the broader retail landscape across the country. These results are not only intuitive, but also align with previous research by Eichholtz et al. (2010) in the US office sector, Chegut et al. (2011) in the UK office sector, and Chegut et al. (2016) in the Dutch housing market with a caveat that it is difficult to compare between sectors and regions. The lower R-squared values observed in the rental analysis may be attributed to several factors, including the presence of omitted variables, which are common in hedonic modeling. In particular, the behavioral dynamics of the retail sector present unique challenges (Koengkan and Fuinhas, 2022). Unlike office or residential markets, retail property values are influenced by consumer preferences, tenant mix, and shopping experiences, making pricing decisions more subjective. This behavioral element is difficult to quantify and may contribute to the unexplained variance in the model. This suggests that while some factors may be missing, the energy rental premium is still meaningful since it is statistically significant and aligns with prior research.

Sale values of energy-efficient transactions are more marginal and complex, particularly when accounting for data limitations such as geographic distribution. The spatial analysis emphasizes the importance of traditional retail location factors where regional market differences play a significant role. Although the sale observations are distributed randomly throughout the Netherlands, they are disproportionately concentrated in smaller regional centers rather than the more prominent Randstad cities, where a higher volume of retail properties exists. While geographic concentration can affect our results, we control for location in two different ways to minimize confounding effects, though cross-sectional dependence remains a common challenge in such models (Koengkan et al., 2023b). These "smaller regional centers" serve wider catchment areas, attracting shoppers from nearby towns and rural regions with a variety of daily goods and services (Colliers, 2021). The ideal distance is unknown so as a result, the "population within 10 km" determinant has potentially a more significant impact on sale prices, explaining why the A1 segmentation did not yield a notable price effect. In these suburban and rural areas, retail sale values are driven less by energy efficiency and more by catchment qualities. The analysis also reveals a more consistent relationship between EPC labels and rental premiums compared to sale premiums. This difference can stem from market dynamics, as the rental market reflects immediate consumer preferences, making it more sensitive to energy efficiency. Tenants are likely to prioritize lower utility costs, which can directly influence their willingness to pay higher rents for energy-efficient properties (Das and Wiley, 2014). Retail property buyers appear to prioritize location and catchment area as a price driver; rendering the age-old adage defining the three most important determinants of retail property valuation: location, location, location, to be true.

While the data used in this study represents the best available information at the time, it is essential to recognize its limitations and continue to seek more comprehensive and high-quality data sources for future research. Both rental and sale models exhibit limitations due to a lack of data, notably the absence of certain determinants related to energy-efficient features, such as operational expenditures and specific building property features. Some factors, such as temporary vacancies, the floor discounting effect, and specific details related to materials or building characteristics, were not included in the analysis due to unavailability of data. For example, the effective price of a −1 level

Table 4
Market sale OLS regression results.

	(1) Energy	(2) Geographic	(3) Retail	(4) Physical
Energy index	0.0007	0.0008	0.0013*	0.0010
	(0.0007)	(0.0006)	(0.0006)	(0.0005)
2015 dummy	–	–	–	–
2016 dummy (1 = yes)	−0.2281	0.1044	0.0961	0.0789
	(0.1934)	(0.1992)	(0.1976)	(0.1883)
2017 dummy (1 = yes)	−0.2409	−0.0389	−0.0402	−0.0408
	(0.1833)	(0.1892)	(0.1864)	(0.1772)
2018 dummy (1 = yes)	−0.1131	0.1482*	0.1690**	0.1712**
	(0.1816)	(0.1890)	(0.1864)	(0.1779)
2019 dummy (1 = yes)	−0.2424	0.0002	0.0079	−0.0643
	(0.1935)	(0.1935)	(0.1883)	(0.1800)
2020 dummy (1 = yes)	−0.4919***	−0.1075	−0.0807	−0.0166
	(0.1796)	(0.1853)	(0.1837)	(0.1751)
2021 dummy (1 = yes)	−0.0398	0.2877***	0.1379***	0.1338***
	(0.1722)	(0.1815)	(0.2967)	(0.2872)
Location Fixed Effects	N	Y	Y	Y
Location typology:				
Regional center -Small		–	–	–
City center (1 = yes)		0.3445	0.2777	0.4841**
		(0.6025)	(0.6058)	(0.2288)
Retail typology:				
Fashion & Luxury			–	–
Daily use (1 = yes)			0.4124***	0.2495**
			(0.1191)	(0.1200)
Free time (1 = yes)			−0.3502**	−0.2806*
			(0.1615)	(0.1643)
In & around the house (1 = yes)			−0.2467**	−0.3525***
			(0.1143)	(0.1160)
Leisure (1 = yes)			−0.0341*	−0.0985*
			(0.1883)	(0.1859)
Segment:				
A1 (1 = yes)			0.0142	0.1620
			(0.1755)	(0.1681)
A2 (1 = yes)			0.3394**	0.2786*
			(0.1671)	(0.1611)
B1 (1 = yes)			0.0980	0.1600**
			(0.1549)	(0.1497)
B2 (1 = yes)			0.0680	0.0733
			(0.1493)	(0.1424)
C			–	–
Population within 5 km			−0.1016	0.0172
			(0.1700)	(0.1645)
Population within 10 km			0.2598***	0.1475**
			(0.0564)	(0.0576)
Age:				
<10 years				−2.3258***
				(0.4644)
11–30 years				−0.3842**
				(0.1666)
31–50 years				−0.2145
				(0.1459)
50+ years				–
Vacancy dummy (1 = yes)				−0.2624***
				(0.0800)
Constant	7.8461***	7.6457***	7.5458***	6.5061***
	(0.1759)	(0.0766)	(0.0788)	(0.6505)
R-squared	0.0460	0.4451	0.4852	0.5279
R-squared Adj.	0.0318	0.3943	0.4342	0.4823
N	478	478	478	478

Standard errors are in brackets.
* Significant at the 10% level ** Significant at the 5% level *** Significant at the 1% level.

is not the same as a ground or +4 level. To improve the accuracy of future research, it is recommended to incorporate additional variables, consider a larger and more diverse sample size, and expand the geographical distribution. In relation to retail determinants, brand presence and anchor tenants are factors that could not be incorporated into our models. Further qualitative research, including survey data, is therefore essential to advancing the energy transition in retail buildings and gaining deeper insights into this understudied sector for the Netherlands. Such research can address the discrepancies and “noise” in the data that reflect real-world complexities. In an ideal world, where data is plentiful and accurately measured, we might have clearer answers.

To address this, emphasis should be placed on data quality within real estate. By implementing comprehensive guidelines for data collection, processing, and reporting, policymakers can enhance the credibility of information and contribute to a more robust data landscape. To facilitate the energy transition, we recommend to implement continuous development programs and regulations for real estate agents and appraisers to emphasize the significance of energy certifications. This approach will not only promote a deeper understanding of energy efficiency's value in property transactions but also foster a culture of accountability and expertise within the industry. Equipping stakeholders with insights into the financial implications of energy retrofits not only fulfills the initial goals of the EU Directive, but also contributes to reduced overall energy consumption in the built environment.

A binding legislation has been introduced for the office market, yet similar measures are not yet in place for the retail sector. We propose enacting similar legislation for the retail sector; the absence of concrete pathways and legislative pressure to achieve long-term, energy efficiency targets means that there is little incentive for stakeholders to prioritize energy-efficiency to achieve the 50–60 percent energy reduction in the sector by 2050 (DGBC, 2023). However, when setting intermediary energy targets to align with national and international climate goals, there is a risk that property developers and investors may prioritize simply meeting the minimum requirements of upcoming regulations. In fact, investors are often criticized for *herd behavior* and making allocation decisions in a "reactionary" manner — shifting capital towards recently successful asset classes without adequately assessing future potential (Geltner, 2006). This narrow focus could significantly undermine efforts to maximize the operational efficiency and exchange value of properties; efforts that are ultimately crucial in driving policy regulations.

Furthermore, raising consumer awareness about the energy performance of retail stores is essential given the significant influence of consumer behavior on retail value. To effectively educate consumers, real estate developers, investors, and policymakers alike should focus on making information about EPCs practical and easily understandable. This can be achieved through visual indicators, similar to higher LEED certifications on building facades. Disclosing retail energy data in this way would not only promote transparency but also foster the development of an energy-literate society. Additionally, it is important to recognize that building a carbon- and energy-literate society requires mastering new skills and information and efforts must be made to simplify technical information for a diverse audience. We recommend national communication campaigns to support and amplify EPC education, particularly during the early stages of implementing retail C-labeling schemes, as these efforts are crucial for long-term success.

7. Conclusion

This paper presents one of the first systematic analyses of the financial implication and spatial distribution of energy efficiency using the Dutch retail market as a laboratory, by analyzing historical rental and sale transactions from 2015 to 2021. The findings demonstrate a clear positive relationship between energy efficiency and financial performance in the rental market, aligning with the EU's carbon reduction goals by highlighting how sustainable buildings can contribute to lower energy consumption. Sale premiums for energy-efficient properties are more marginal due to geographic data limitations. This study also stands out as one of the first to conduct spatial analyses of EPCs for the retail sector, providing valuable insights for informed policymaking while considering geographic variation. By addressing data gaps and promoting energy-efficient investments, this research supports the broader objectives of the European Green Deal, paving the way for more sustainable development, disseminating energy performance information to market participants, and reducing the energy consumption of retail properties.

Table 5
EPC categories and the corresponding energy indices under NTA 8800.
Source: Adapted from RVO (2019).

Energy performance label	Category
A+++++	Energy Index ≤ 10 kWh/m^2 year
A++++	10 < Energy Index ≤ 20 kWh/m^2 year
A+++	20 < Energy Index ≤ 30 kWh/m^2 year
A++	30 < Energy Index ≤ 40 kWh/m^2 year
A+	40 < Energy Index ≤ 50 kWh/m^2 year
A	50 < Energy Index ≤ 75 kWh/m^2 year
B	75 < Energy Index ≤ 100 kWh/m^2 year
C	100 < Energy Index ≤ 125 kWh/m^2 year
D	125 < Energy Index ≤ 150 kWh/m^2 year
E	150 < Energy Index ≤ 175 kWh/m^2 year
F	175 < Energy Index ≤ 200 kWh/m^2 year
G	Energy Index > 200 kWh/m^2 year

Looking ahead, regulatory efforts should prioritize concentrated data collection and enhancing energy literacy, particularly given that only 26 percent of the 100,000+ retail properties in the Netherlands currently meet an energy label of C or above. The staggering 68 percent of retail properties without any energy label underscores the colossal challenge that lies ahead. Specific policy actions, such as the implementation of mandatory EPC regulations for retail properties — drawing lessons from the Dutch office sector, where the national government has established ambitious targets to regulate and potentially halt operations for office buildings with EPC grades below C — and supporting national campaigns to raise awareness about energy literacy, are essential to driving the energy transition in the Netherlands. Next steps in research should focus on addressing the remaining gaps in better understanding the supply of energy-efficient buildings, including the incremental costs associated with their construction. Understanding the extent and changes over time in these variations due to the introduction of substitute or complementary sustainable building products and regulations remains limited. Expanding this type of spatial analysis across the EU could help policymakers set clearer intermediary targets with geographic variation in mind, while promoting consistent, data-driven regulatory frameworks. By ensuring that policies reflect both the environmental and financial benefits of energy-efficient practices, this paper supports the EU's broader carbon reduction goals, underscoring the real potential for the retail sector to steer the real estate industry toward a more sustainable future.

CRediT authorship contribution statement

Jia Jasmine Zhang: Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Hauke Ward:** Writing – review & editing, Validation, Supervision, Conceptualization. **Queena Qian:** Writing – review & editing, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

See Tables 5 and 6.

Appendix B

B.1. Rental regression model (count)

See Table 7.

Table 6
Control variable overview.

Control variable	Description
Energy index	The energy performance of the transacted property in a numeric format from 0 to 200+.
Energy performance label	The energy performance of the transacted property in a categorical format from A+++++ to G.
Rental price	The transaction rent per square meter of lettable floor area retail space.
Sale price	The transaction sale value per square meter of lettable floor area retail space.
Transaction year	The specific year in which a property was sold or rented out to a tenant and/or owner.
4-digit post code	The specific neighborhood or a part of a larger city: the first two digits of the postal code indicate the region, and the last two digits indicate the specific neighborhood within that region.
Location typology:	The retail locations are categorized into three primary types, depending on their function: 'City & Town Centres', 'Supportive Centres', and 'Residual Centers' per Locatus categorization. However, it is worth noting that the last type, 'Residual Centers', was not found in the dataset.
City center	Pertaining to the most important retail areas in the Netherlands, the vicinity must host over 400 shops; falls under the 'City & Town Centres' group of which the inner cities of Amsterdam, Rotterdam, the Hague, and others are a part.
Regional center- Large	Refers to the primary commercial hub of a town or city, typically hosting between 200 to 400 shops in the retail sector; falls under the 'City & Town Centres' group. Examples of such areas include Delft Center and Bussum Center.
Regional center- Small	Similar to the Large Regional center, this category refers to the primary commercial hub of a town or city but only hosts 100 to 200 shops; falling under the 'City & Town Centres' group. Examples are Franeker Center or Putten Center.
City district center	This typology is characterized by its systematic development and is always an extension of a city or town center; falling under the 'Supportive Centres' group Examples of such centers include Amsterdam-Osdorpplein and Nijmegen-Dukenburg and contain 50 to 100 points of sale.
Retail typology:	The umbrella term encompassing multiple industries that share similar characteristics per Locatus categorization.
Fashion & Luxury	Retail spaces specializing in clothing, accessories, and luxury goods
Daily use	Retail spaces focused on everyday necessities and convenience products, including grocery stores but excluding the hotel, restaurant, and catering (HORECA) sector.
Free time	Retail spaces catering to recreational and entertainment products, such as books, hobbies, and electronics.
In & around the house	Retail spaces related to home improvement, furniture, and interior decor.
Leisure	Retail spaces offering services and products for leisure activities, such as sports equipment, travel, and entertainment.
Segment:	Determined by the ratio between the maximum footfall number of a retail area and the footfall number of a specific outlet (percentage of the busiest counting point). This concept is based on the division established by Drs. E.J. Bolt Bolt (2003) in his book titled *Winkelvoorzieningen op waarde geschat.*
A1	75 to 100 percent.
A2	50 to 74 percent.
B1	25 to 49 percent.
B2	10 to 24 percent.
C	5 to 9 percent.
Footfall	On an average Saturday, the footfall of a property is determined by visiting 24 different counting points where footfall counters record data for 5 min, four times a day. These footfall countings are carried out twice a year at various locations by Locatus. To ensure accuracy, the results are then compared with the transaction numbers of several anchor stores, which helps generate reliable footfall figures for an average Saturday. This value is not used directly in the model due to multicollinearity but rather as a calculation for the Segment class, above.
Population within 5 km	The number of residents living within a walking time of 5 km.
Population within 10 km	The number of residents living within a walking time of 10 km.
Age	The age of the property is defined as the number of years elapsed since its construction year. The categorical division aligns with typical construction eras, helping to capture the characteristics and building standards prevalent during different periods.
<10 years	This category includes buildings that are relatively new; they are likely to benefit from the latest construction technologies and energy-efficient design practices.
11–30 years	These properties include buildings that first started to emphasize the sustainability and energy efficiency in building design and construction. This time period also corresponds to a focus on urban renewal and regeneration projects.
31–50 years	These properties may have been built during a time when energy efficiency was not a primary concern, and build in a haste given the context of the Netherlands (Berghauser Pont and Haupt, 2007). Many of these buildings can benefit from energy-efficient upgrades or retrofits.
50+ years	Buildings in the category belong to an era when energy efficiency was not a central consideration in construction and have reached their designed lifespan. Some of these properties may have historical or architectural significance, which could influence their market value.
Vacancy	A binary variable to indicate if the building is vacant at the time of survey by Locatus. (1 = yes)

Note: This table only presents the statistically significant variables found in both models.

Table 7
Rent model count statistics.

Descriptive statistics	Description		Count
Geographic regions variables			
Segment	A1	High EPC	85
		Low EPC	77
	A2	High EPC	88
		Low EPC	71
	B1	High EPC	232
		Low EPC	118
	B2	High EPC	172
		Low EPC	101
	C	High EPC	48
		Low EPC	23
Location typology	City center	High EPC	190
		Low EPC	115
	Regional center- Large	High EPC	183
		Low EPC	138
	Regional center- Small	High EPC	189
		Low EPC	109
	City district center	High EPC	15
		Low EPC	11
	District center- Large	High EPC	34
		Low EPC	13
	Inner Urban Shopping Area	High EPC	9
		Low EPC	3
	Big Box Retail Park	High EPC	5
		Low EPC	1
Retail positioning variables			
Vacancy	(1 = yes)	High EPC	207
		Low EPC	125
Retail typology	Fashion & Luxury	High EPC	167
		Low EPC	144
	In & around the house	High EPC	58
		Low EPC	32
	Daily use	High EPC	28
		Low EPC	33
	Services	High EPC	60
		Low EPC	26
	Free time	High EPC	29
		Low EPC	10
	Leisure	High EPC	24
		Low EPC	7
	Catering	High EPC	10
		Low EPC	
	Detail other	High EPC	17
		Low EPC	8
	Other	High EPC	22
		Low EPC	5

B.2. Sale regression model (count)

See Table 8.

Table 8
Sale model count statistics.

Descriptive statistics	Description		Count
Geographic regions variables			
Segment	A1	High EPC	10
		Low EPC	32
	A2	High EPC	44
		Low EPC	40
	B1	High EPC	89
		Low EPC	103
	B2	High EPC	58
		Low EPC	60
	C	High EPC	14
		Low EPC	14
Location typology	City center	High EPC	29
		Low EPC	45
	Regional center- Large	High EPC	69
		Low EPC	96
	Regional center- Small	High EPC	101
		Low EPC	93
	City district center	High EPC	3
		Low EPC	3
	District center- Large	High EPC	13
		Low EPC	17
Retail positioning variables			
Vacancy	(1 = yes)	High EPC	80
		Low EPC	79
Retail typology	Fashion & Luxury	High EPC	52
		Low EPC	83
	In & around the house	High EPC	13
		Low EPC	29
	Daily use	High EPC	22
		Low EPC	21
	Services	High EPC	15
		Low EPC	17
	Free time	High EPC	11
		Low EPC	9
	Leisure	High EPC	5
		Low EPC	8
	Detail other	High EPC	11
		Low EPC	4
	Other	High EPC	6
		Low EPC	4

(*continued on next page*)

Table 8 (*continued*).

Data availability

The authors do not have permission to share data.

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