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Does the energy transition reinforce urban inequality? Evidence from geolocated Energy Performance Certificates and housing transactions from Warsaw metropolitan area

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Extended abstract

1. Introduction and motivation

The decarbonisation of the building sector has become a central pillar of the European energy transition. Buildings account for approximately 40% of final energy consumption and 36% of greenhouse gas emissions in the European Union (European Commission, 2020), making them a primary target of climate policy. Energy efficiency improvements are widely recognised as one of the most cost-effective strategies to reduce emissions and enhance economic resilience (IEA, 2024). In this context, Energy Performance Certificates (EPCs) were introduced to increase transparency, inform consumers and stimulate investments in energy-saving technologies.

Although EPCs are primarily designed as environmental policy instruments, they are structurally embedded in housing markets. Certificates are typically required at the point of sale or rental, linking energy performance information directly to property transactions. As a result, EPCs may influence not only environmental outcomes but also spatial economic processes. Beyond their technical function, they can be interpreted as measurable indicators of modernization, investment and local development dynamics.

While existing research has examined EPCs in environmental and technical terms (Pasichnyi et al., 2019) and has identified price effects through hedonic modelling (Fuerst et al., 2016; Marmolejo-Duarte & Chen, 2022; Ou et al., 2025), considerably less attention has been devoted to their metropolitan spatial consequences. In particular, little is known about whether the energy transition interacts with housing markets in ways that reinforce or reshape urban inequality.

This paper addresses this gap by examining whether energy efficiency improvements are capitalised into housing prices in ways that contribute to socio-spatial stratification. The focus is on the

Warsaw Metropolitan Area, a rapidly growing Central and Eastern European capital characterised by strong development dynamics and pronounced centre–periphery differentiation.

2. Theoretical framework

The analysis is grounded in urban economics and regional science. Bid-rent theory and spatial equilibrium models suggest that housing prices reflect a bundle of attributes, including accessibility, amenities and structural quality (Duranton & Puga, 2004). Energy efficiency may be conceptualised as an additional quality dimension, potentially capitalised into prices through lower operating costs, improved comfort and signalling effects regarding building standards. However, capitalization mechanisms are unlikely to be spatially uniform. In high-demand central districts, where housing markets are competitive and price levels elevated, additional quality attributes such as superior energy performance may command stronger premiums. In peripheral or socio-economically weaker areas, willingness or capacity to pay for energy-efficient features may be more constrained.

Energy efficiency also intersects with debates on spatial inequality and energy justice. Buildings with higher energy performance offer lower utility costs and improved living conditions, representing an important dimension of welfare. If modernization and energy-efficient construction are concentrated in already advantaged neighbourhoods, the transition may inadvertently reinforce existing socio-spatial disparities. Moreover, improvements in building energy performance may display spatial spillover effects.

Studies on diffusion processes suggest that modernization tends to cluster and propagate through proximity mechanisms (Kok et al., 2012; Egner & Klöckner, 2021). Such dynamics may align energy-efficient investments with broader patterns of urban renewal and redevelopment, potentially overlapping with gentrification processes. Within this framework, energy performance indicators are treated not merely as technical metrics but as spatial markers of urban transformation embedded within metropolitan housing markets.

3. Data

The empirical analysis combines three high-resolution spatial datasets for the Warsaw Metropolitan Area. First, a geolocated database of Energy Performance Certificates issued between 2015 and 2025 is utilised. The dataset includes detailed indicators of estimated primary and final energy demand, carbon emissions and renewable energy shares, along with building-level addresses. The records have been cleaned and geocoded, enabling precise spatial analysis at the micro level. Second, transaction-level data from the Polish Real Estate Price Register (Rejestr Cen Nieruchomości) are incorporated. This public register contains notarized information on property transactions, including sale price, floor area, floor level and exact location. The use of transaction prices, rather than asking prices, ensures that the analysis reflects realised market behaviour. Third, grid-level demographic data are

employed to capture neighbourhood characteristics, including population density and age structure. These contextual variables allow examination of how energy modernization relates to broader socio-spatial patterns. The integration of these datasets enables building-level linkage between energy performance and transaction prices within their precise spatial environment.

4. Research Questions and Hypotheses

The study addresses three main research questions:

1. Is energy efficiency capitalised into housing transaction prices?
2. Are high-energy-performance buildings spatially concentrated in already high-value neighbourhoods?
3. Does the price premium associated with energy efficiency vary across the metropolitan structure?

Based on urban economic theory and previous empirical findings, the following hypotheses are formulated:

H1. Better energy performance (lower primary energy demand) is associated with higher transaction prices per square meter.

H2. High-energy-performance buildings are spatially clustered in neighbourhoods characterised by higher average housing prices and stronger development dynamics.

H3. The capitalization effect of energy efficiency is stronger in already high-value areas, reinforcing existing price gradients.

These hypotheses connect environmental modernization with mechanisms of spatial stratification and housing market differentiation.

5. Methodology

The empirical strategy combines hedonic price modelling with spatial econometric techniques. A baseline hedonic regression is estimated with the logarithm of transaction price per square meter as the dependent variable. Explanatory variables include building characteristics, time controls and energy performance indicators. District-level fixed effects are introduced to account for unobserved heterogeneity. Given the spatial interdependence of housing markets, spatial lag or spatial error specifications are employed to address local price spillovers. This approach ensures consistent estimation of the energy performance premium. In addition, exploratory spatial data analysis is conducted to identify clusters of high energy performance and high price levels. Local indicators of spatial association are used to examine whether energy-efficient buildings co-locate with high-value

neighbourhoods. Interaction terms between energy performance and neighbourhood price levels are introduced to test whether the price premium varies across the metropolitan hierarchy.

6. Expected Results and Contribution

It is anticipated that energy efficiency will be positively associated with housing prices, consistent with prior studies. However, the distribution of high-performance buildings is expected to be uneven across space, with concentration in central districts and rapidly developing suburban areas. If these patterns are confirmed, the findings would suggest that the energy transition interacts with housing markets in ways that may reinforce existing socio-spatial hierarchies. Energy modernization could enhance the attractiveness and value of already dynamic areas, potentially intensifying affordability pressures. The study contributes to the literature by integrating environmental policy analysis with metropolitan housing market dynamics. It demonstrates how building-level energy indicators can serve as empirical tools for analysing urban transformation and spatial inequality at a fine-grained scale.

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