

Energy Efficiency and House Prices in England: A Repeated-Sales Analysis Using SAP Energy Efficiency Scores.

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Executive Summary

Residential energy efficiency is increasingly important in both housing economics and climate policy because it can reduce household energy costs, affect carbon emissions, and influence the value of housing assets. However, the extent to which improvements in energy performance are reflected in house prices is still unclear. This dissertation examines whether improvements in residential energy efficiency are capitalised into house prices in England, using matched Energy Performance Certificate data and Land Registry Price Paid Data. The analysis focuses on the continuous Standard Assessment Procedure (SAP) score as the primary measure of energy efficiency, allowing the study to examine the marginal pricing of energy performance rather than relying exclusively on discrete EPC bands. The empirical strategy implements a repeated-sales framework, comparing the same property over time to control for time-invariant unobserved characteristics. The final repeated-sales regression sample contains 28,737 pairs. The findings indicate a consistent positive relationship between improvements in SAP scores and within-property house price growth. In the preferred specification, a 10-point SAP improvement is associated with about 5.7% higher within-property sale-price growth. This relationship remains positive and statistically significant across several robustness checks, including alternative sample restrictions and specification changes. Overall, the findings indicate that residential energy efficiency is capitalised into house prices and that the repeated-sales approach provides more credible evidence than cross-sectional models in this context.

AI Statement

I acknowledge the use of generative AI in the literature search and code development in this paper. However, the work reported remains my own.

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Chapter 1. Introduction and motivation

Homes with better energy efficiency use less energy, cost less to heat and typically generate lower carbon emissions. They may also be at lower risk of underheating and less exposed to future retrofit or regulatory costs. If households value these benefits, standard economic theory suggests they may be reflected in property prices. This makes residential energy efficiency an important issue in both housing economics and climate policy. In the UK, housing, fuel, and power account for around 18% of average household spending (ONS, 2025), and residential buildings account for 13.9% of total UK emissions (DESNZ, 2026). Energy efficiency has also become more relevant as governments increasingly seek to reduce residential emissions through policies such as minimum energy efficiency standards, retrofit targets, and stricter disclosure requirements. The financial benefits of energy-efficient homes are increasingly evident: the average new-build home, typically rated Energy Performance Certificate (EPC) A or B, can have energy costs up to 27% lower than older homes rated F or G (HBF, 2025). Determining whether these advantages are capitalised into house prices is therefore key for understanding household incentives and for assessing the wider economic rationale for energy efficiency improvements.

This dissertation is grounded in hedonic pricing theory. According to Rosen's (1974) framework, a house is treated as a bundle of characteristics, with its market price reflecting the implicit value buyers assign to each attribute. Alongside location, size, and quality, energy efficiency can therefore be understood as a housing characteristic that may be valued in the market. If buyers value lower expected energy bills and the wider benefits of efficient homes, demand for energy-efficient properties should be higher. Where housing supply is relatively constrained, this stronger demand is often capitalised into higher sale prices rather than being accommodated through large supply responses. Considering this, the expected relationship between energy efficiency and house prices reflects the interaction of demand for desirable housing characteristics and the limited supply of comparable dwellings. However, this premium may be weakened if buyers have imperfect information, lack confidence in EPC ratings, or undervalue future savings.

This dissertation examines whether residential energy efficiency is capitalised into house prices in England by using matched EPC data and Land Registry Price Paid Data (PPD). The official methodology for measuring energy efficiency is the Standard Assessment Procedure (SAP) score, which is then used to produce an EPC rating.

This dissertation focuses on SAP scores, which provide a continuous measure of energy efficiency, enabling the study to estimate the marginal relationship between energy efficiency and house prices rather than restricting the analysis to discrete EPC bands. The initial approach considered a broad, all-sales hedonic model. However, the resulting cross-sectional estimates proved sensitive to specification choices. Thus, the preferred empirical strategy utilises a repeated-sales framework, which compares the same property over time and therefore better controls for time-invariant unobserved dwelling characteristics.

This dissertation offers three main contributions. It provides recent evidence from England during a period of rising energy costs, while using SAP scores to capture energy efficiency more precisely than EPC bands. Finally, it shows the empirical advantages of a repeated-sales approach over cross-sectional hedonic models for identifying the effect of energy efficiency on house prices.

Chapter 2. Literature Review

2.1 Hedonic pricing and why energy efficiency should capitalise into prices

Much of the empirical literature reviewed in this chapter is grounded in hedonic pricing theory. In Rosen's (1974) framework, housing prices reflect the value buyers attach to different dwelling characteristics, including potentially energy efficiency.

A second relevant framework is cost-benefit reasoning through capitalisation theory. If a more energy-efficient home has a higher purchase price, buyers will compare this additional upfront cost with the expected future benefits of ownership. These benefits may include lower energy bills, greater thermal comfort and reduced exposure to future retrofit or regulatory costs. Some of these benefits are monetised directly through lower bills, while others, such as reduced risk of underheating and lower future compliance costs, are not traded directly in markets but may still enter willingness-to-pay calculations. In principle, a buyer should be willing to pay a premium for energy efficiency where the discounted present value of these expected benefits exceeds the additional cost. This provides the economic rationale for expecting energy efficiency to be positively associated with house prices.

UK residential buildings are a significant source of emissions, largely because most home heating remains fossil-fuel-based. In 2024, the buildings sector accounted for 21% of the

UK's territorial greenhouse gas emissions, most of which was from residential fuel combustion (DESNZ, 2024). Improving energy efficiency means that a home requires less energy to deliver the same amount of warmth and energy services. This reduces household energy demand and, in turn, lowers energy bills. Because home heating in the UK still relies heavily on fossil fuels, lower energy use also reduces carbon emissions. Energy efficiency, therefore, has both private value, through lower household costs, and social value, through lower emissions and progress towards net-zero objectives. Government policy has repeatedly framed energy-efficiency improvements in precisely these terms, as a way to lower bills and reduce emissions (DESNZ 2023, CCC 2017).

However, the relationship between efficiency and price may be weaker than this simple capitalisation logic suggests. A third relevant framework is the literature on information failure, imperfect information, and the energy efficiency gap. Allcott and Greenstone (2012) argue that households often underinvest in energy efficiency even when it appears privately beneficial, because decisions are affected by imperfect information, inattention, and cognitive bias. In housing markets, buyers may not perfectly observe a property's true energy performance, may not fully understand or trust EPC-based measures, and may therefore misjudge the scale of future energy savings. In addition, housing decisions involve discounting, since buyers compare a higher purchase price today with energy bill savings that accrue over time. If households display present bias or apply a high private discount rate, they may place too little weight on future savings and too much weight on upfront costs. As a result, energy efficiency may be only partially or unevenly capitalised into house prices. This divergence may be greater from a social perspective, because lower emissions generate wider benefits that private buyers do not fully internalise. Also, social time preference may imply a lower social discount rate than the private rate used by households.

2.2 SAP as the market signal in England

In England, the main measure of residential energy efficiency is the SAP, which underpins EPCs. SAP is the UK government's methodology for calculating the energy performance of dwellings, and EPCs must be disclosed when a property is built, sold or let (GOV, 2013). As EPCs provide standardised information to buyers and tenants, they are central to any analysis on whether energy efficiency is reflected in house prices. The domestic EPC regime was fully implemented by 2008, and certificates are generally valid for 10 years (GOV, 2025).

This makes EPCs important not only as a measure of energy performance but also as a market signal. Figure 1 illustrates how SAP scores map into EPC bands in England.

Figure 1: Mapping of SAP scores to EPC energy-efficiency bands in England

SAP Score	EPC Rating
92+	A
81-91	B
69-80	C
55-68	D
39-54	E
21-38	F
1-20	G

Buyers may respond to SAP as a continuous measure of efficiency, or to the discrete A-G EPC band into which that score falls. Therefore, SAP/EPC can affect prices through both energy-efficiency benefits and information disclosure.

EPC/SAP scores are modelled from recorded dwelling characteristics and represent a snapshot at the time of assessment; improvements made later may not be captured, so certificates can be outdated relative to the sale date (Census, 2021). Measurement error is also relevant: repeat EPC assessments for the same dwelling have been shown to yield different scores and even misclassify EPC bands (Creds, 2019). Similarly, evidence comparing EPC-modelled to smart-meter data finds EPCs can overpredict energy use, especially in lower bands (Few et al, 2023). These issues imply potential attenuation bias and timing misalignment in modelling estimates unless matching rules are handled carefully.

2.3 Empirical Evidence: Does energy efficiency affect sale prices?

Early studies generally reported positive price effects for energy efficiency, but many were constrained by small local samples and weak measures for energy performance. DECC (2013) notes that many studies from the 1980s and 1990s were limited to samples of dozens or hundreds of properties, although they still often found positive relationships (Halvorsen and Pollakowski, 1981, Johnson and Kaserman, 1983, Quigley, 1984, Laquatra, 1986, Dinan and Miranowski, 1989, Quigley and Rubinfeld, 1989).

More recent studies use larger datasets and more standardised energy measures. DECC (2013) used a dataset of 325,950 properties sold at least twice between 1995 and 2011, matched sale data to EPC ratings and housing attributes and estimated positive price differentials by EPC band. Relative to band G, they report premiums of around 6% for F/E-rated homes, 8% for D, 10% for C, and 14% for A/B, with larger effects for terraces and flats. This remains one of the most influential pieces of UK evidence and strongly suggests that energy efficiency is indeed capitalised into transaction prices. However, because the analysis is based on discrete EPC bands, it captures average differences across broad categories rather than the marginal pricing of underlying energy performance.

Additional England-focused evidence also supports a positive relationship between energy performance and house prices. Fuerst et al. (2015) analysed EPC ratings and house prices in England. They found that less efficient dwellings sell at a discount relative to EPC band D, with F/E and G-rated homes selling for about 1% less, whereas A/B-rated homes sold for 5% more. This reinforces the broader conclusion that energy performance is reflected in transaction prices, while also illustrating that the size of the premium or discount depends on the band used as the reference category.

Other work suggests that markets price not only EPC bands but also underlying continuous efficiency measures. Aydın et al. (2020) found that a 10% increase in energy efficiency is associated with around a 2.2% increase in dwelling value using an Instrumental Variables (IV) strategy, with results corroborated in repeated-sales estimates, implying that simple Ordinary Least Squares (OLS) may understate the valuation of efficiency.

Related UK evidence also points in the same direction. A BEIS/Cambridge study by Fuerst et al. (2017) reports that B/C-rated dwellings transact at a premium of around 4.7-4.9% per square metre relative to comparable D-rated homes, while F/G-rated dwellings face discounts

of roughly 9-11%. Importantly, the report also finds a positive association between the continuous 0-100 energy-efficiency score and predicted dwelling price. This is especially relevant for this dissertation because it supports the use of a continuous efficiency measure rather than relying only on discrete EPC bands.

A different strand of UK evidence argues that the EPC ratings system can affect prices not just through the underlying energy efficiency, but also because buyers respond to the A-G label assigned to the property. Sejas-Portillo et al. (2020) estimate house prices rise roughly 0.8% to 2.5% when a property just crosses into a higher EPC band, holding the SAP score essentially constant. This is important because it suggests that part of the pricing effect may reflect the label's visibility rather than the underlying continuous efficiency measure. In this context, a regression-discontinuity approach compares properties with very similar SAP scores that lie just on either side of an EPC band threshold. Any discrete price jump at that cutoff can therefore be interpreted as the value of moving into a higher EPC category, rather than the value of a substantial change in underlying energy performance.

More recent studies also highlight potential brown discounts, where inefficient homes are penalised rather than efficient homes rewarded. Ferentinos et al. (2023) studied the introduction of the Minimum Energy Efficiency Standard (MEES) in England and Wales, which restricts the letting of privately rented F and G-rated properties unless exemptions apply. Using a difference-in-differences approach, they estimated that affected properties experienced an average reduction in sale price of about £5k–£9k compared with unaffected properties. This is a clear example of a discount channel: poor energy efficiency can be capitalised negatively when it creates expected compliance costs, future retrofit burdens, or constraints on rental income. At the same time, this design identifies capitalisation of MEES rather than willingness to pay for energy efficiency alone.

Finally, several papers show that average effects may conceal substantial heterogeneity, meaning that the relationship between energy efficiency and house prices differs across properties and market segments. McCord et al. (2020) show that “average” OLS effects can hide important differences: in their quantile regressions, significant EPC capitalisation appears mainly toward the upper end of the conditional price distribution, while lower quantiles often show weak or insignificant effects. They also highlight that very inefficient homes can attract brown discounts in higher price segments, and that potential EPC measures

can be priced differently from current scores, suggesting buyers may distinguish between fixable vs persistent inefficiency. Additionally, Wei & Peiser (2025) argue the “green premium” is not constant over time, implying that the market valuation of energy efficiency may evolve with energy prices, policy developments and broader housing-market conditions.

Overall, the empirical literature points to a positive relationship between energy efficiency and house prices, though it also shows that estimated effects depend on measurement choices, market context, and empirical design.

2.4 Identification challenges and what methods the literature uses to handle them

Identifying the causal effect of energy efficiency on house prices is difficult. The central econometric problem is endogeneity, particularly omitted-variable bias. This arises when energy efficiency is correlated with other determinants of house prices that are not fully observed in the data. In this context, homes with higher energy efficiency may also be newer, better-maintained or recently refurbished. Because these characteristics can raise house prices independently of energy efficiency, a simple cross-sectional regression may attribute too much of the price difference to energy performance itself. As a result, the estimated coefficient on energy efficiency in an OLS hedonic model may not recover the true causal effect, or the pure willingness to pay for energy efficiency alone.

This issue is especially relevant for this dissertation. Initial all-sales hedonic estimates, which used cross-sectional estimations of all transactions, were sensitive to specification choice, suggesting that cross-sectional estimates may be unstable and vulnerable to omitted-variable bias. For that reason, this dissertation adopts a repeated-sales framework as its preferred empirical strategy. By comparing the same property over time, unobserved dwelling characteristics can be better controlled for, providing a more credible basis for estimating whether changes in energy efficiency are associated with changes in sale price.

This does not eliminate all identification problems. Changes that occur between sales can still affect both SAP scores and sale prices, especially renovations undertaken between transactions. Timing issues also matter because EPCs may be outdated as of the sale date and retrofit activity may occur between certification and the transaction. These concerns underscore the importance of matching rules and time controls in practice.

The wider literature uses several strategies to address these challenges. One approach is to exploit within-property variation through repeated sales or property fixed effects, reducing bias from time-invariant unobserved quality. Another is to use regression discontinuity around EPC cutoffs. Sejas-Portillo et al. (2020), for example, use SAP thresholds to isolate the effect of crossing into a higher EPC band, thereby identifying the price impact of the label itself rather than the continuous underlying efficiency measure. A further approach uses policy variation as a quasi-experiment. Ferentinos et al. (2023) exploit MEES to identify the price effects of regulatory exposure and expected compliance costs. Other studies address selection into disclosure directly. Hyland et al. (2013) estimated a Heckman selection model to show that simple results may be biased if properties with advertised energy ratings differ systematically from those that do not. Finally, Aydın et al. (2020) use an IV strategy and argue that OLS may understate the value buyers place on efficiency.

Different empirical strategies identify different effects: repeated-sales models capture within-property changes in energy performance, regression-discontinuity designs isolate EPC band thresholds, and policy-based approaches capture regulatory shocks such as MEES. Given the instability of all-sales hedonic estimates and the risk of omitted variable bias, this dissertation uses a repeated-sales approach.

2.5 Summary and Hypotheses

The literature suggests that residential energy efficiency is often capitalised into sale prices, but the size and even direction of the effect depend on market segment, policy context, measurement choice and identification strategy. Hedonic pricing theory explains why energy efficiency may matter as one characteristic within the bundle of housing attributes. A capitalisation framework suggests that buyers may pay more for efficient homes because of expected future bill savings and related co-benefits. At the same time, information frictions, the influence of EPC labels and policy exposure mean that these price effects may be incomplete, non-linear or heterogeneous.

Against this background, this dissertation uses SAP as a continuous measure of intrinsic energy efficiency and adopts a repeated-sales semi-log framework as its preferred empirical design. This choice is motivated by the need to reduce bias from time-invariant unobserved dwelling characteristics and by the instability of the initial all-sales hedonic estimates.

The primary hypothesis is that improvements in SAP scores are associated with higher growth in within-property sale prices.

H₀: Changes in residential energy efficiency, measured by SAP score, are not associated with within-property house price growth.

H₁: Improvements in residential energy efficiency, measured by SAP score, are positively associated with within-property house price growth.

A secondary hypothesis is that the capitalisation of energy-efficiency improvements is heterogeneous across dwelling types.

Chapter 3. Data and Methodology

3.1 Data sources

This study investigates whether improvements in residential energy efficiency are capitalised into house prices by combining EPC records with Land Registry Price Paid Data (PPD). The EPC data provided information on the energy performance of dwellings, including SAP scores, EPC ratings, floor area, tenure, property type and other dwelling characteristics. The PPD provided transaction-level information on residential property sales, including sale price, sale date and address details.

The raw datasets were very large. The EPC data contained 28,685,721 records, while the PPD data contained 30,906,559 records. Because these files were too large to handle efficiently using a standard in-memory workflow in R, the cleaning and matching pipeline was implemented using DuckDB within R, allowing the data to be queried directly from disk.

3.2 Data cleaning and matching

The first stage of the empirical process involved cleaning address information in both datasets so that the EPC data could be linked to the corresponding house sales. Address fields were standardised by converting them to uppercase, trimming whitespace, and removing punctuation. Matching keys were then created using the postcode and the first line of the address. This produced an initial set of candidate EPC-sale matches.

Because multiple EPC records could be linked to the same transaction, the next step retained only the EPC record closest in time to the sale date. To improve match quality, matched

observations were restricted to cases in which the EPC record was within 1 year of the transaction date. This reduced the risk of attaching an EPC observation that was too far removed from the dwelling's actual condition at the point of sale.

The analysis initially considered a broad all-sales hedonic model on this matched sample, leveraging the larger number of observations and the availability of structural housing controls. However, as discussed later in section 3.5.1, this approach ultimately proved unsuitable, and the analysis moved to a repeated-sales framework.

Under the repeated-sales design, properties were retained only if they appeared in at least two matched-sale observations. Transactions within the same property were then ordered by date and paired sequentially, so that changes in sale price could be compared with changes in SAP score for the same dwelling over time. Additional cleaning removed implausible observations, including sale prices below £80,000, resale gaps below 90 days, and extreme log price changes outside the interval $[-2,2]$. This process reduced the data to a final repeated-sales estimation sample of 28,737 sale pairs.

Table 1: Sample construction and attrition

Stage	Observations
Raw EPC records	28,685,721
Raw price paid records	30,906,559
Cleaned EPC records	28,685,721
Cleaned price paid records	30,852,001
Candidate sale–EPC matches	1,718,048
Best EPC match within 1 year	390,263
Repeated-sales matched observations	60,196
Repeated-sales properties	28,844
Repeated-sales pairs	30,411
Cleaned repeated-sales pairs	28,878
Final trimmed regression sample	28,737

3.3 Variables

The dependent variable in the preferred specification is the change in log sale price between two consecutive sales of the same property:

$$\Delta \log(P_{it})$$

where P_{it} is the sale price of property i at transaction t . Log price changes are used because coefficients can then be taken approximately as percentage effects.

The key independent variable is the change in SAP score:

$$\Delta SAP_{it}$$

where SAP is the official UK measure of dwelling energy efficiency. A higher SAP score indicates better energy performance. The empirical question is therefore whether an increase in SAP between two sales of the same dwelling is associated with stronger within-property price growth. A further explanatory variable is the time between sales, measured in years. This is included because longer holding periods naturally allow more time for cumulative house-price appreciation.

In supplementary specifications, fixed effects are included for the year of the current sale, the year of the previous sale, and the council area. These controls account for broader time effects and local housing-market heterogeneity.

Table 2: Variable definitions

Variable	Definition
d_log_price	Change in log sale price between consecutive matched sales of the same property
d_sap_score	Change in SAP score between consecutive matched EPC-linked sales
years_between_sales	Number of years between the two matched sale transactions
sale_price	Current sale price
prev_sale_price	Previous sale price
sap_score	Current SAP score
prev_sap_score	Previous SAP score
sale_year	Year of current transaction
prev_sale_year	Year of previous transaction
council	Local authority / council area

3.4 Descriptive Statistics

Table 3 reports descriptive statistics for the final repeated-sales sample. The mean log price growth is 0.4149, and the mean SAP improvement is 11.46 points, indicating positive within-property changes in both sale prices and energy efficiency on average. The average gap between sales is 6.26 years, suggesting that the sample is not dominated by very short resale gaps. The mean current and previous sale prices are £575,140 and £376,949, respectively, while the mean current and previous SAP scores are 59.16 and 47.70. The sample therefore shows economically meaningful within-property variation in both prices and energy performance.

Table 3: Descriptive statistics for final repeated-sales regression sample

Variable	Mean	SD	Min	P25	Median	P75	Max
Change in log price (d log price)	0.41	0.33	-1.95	0.21	0.39	0.59	1.99
Change in SAP (d sap score)	11.46	17.17	-43	0	7	20	73
Years between sales	6.26	4.28	0.55	2.26	5.70	10.12	17.39
Current sale price (£)	575,140	477,628	87,000	300,000	460,000	700,000	12,000,000
Previous sale price (£)	376,949	312,546	80,000	203,500	300,000	455,000	11,500,000
Current SAP score	59.16	15.74	3	51	62	70	100
Previous SAP score	47.70	19.42	1	35	49	61	94

Before estimating the regression models, I examined simple correlations and the graphical relationship between the key variables. The pairwise correlation between the change in SAP score and the change in log sale price is 0.28, indicating a positive raw relationship between energy-efficiency upgrades and within-property price growth. The correlation between years between sales and price growth is also positive (0.23), consistent with the idea that longer holding periods allow greater cumulative appreciation. In contrast, the correlation between SAP change and years between sales is close to zero (0.003), suggesting that changes in energy efficiency are not simply driven by longer resale intervals. These correlations are descriptive rather than causal, but they are consistent with the main empirical analysis.

Figure 2: Binned relationship between changes in SAP and within-property price growth

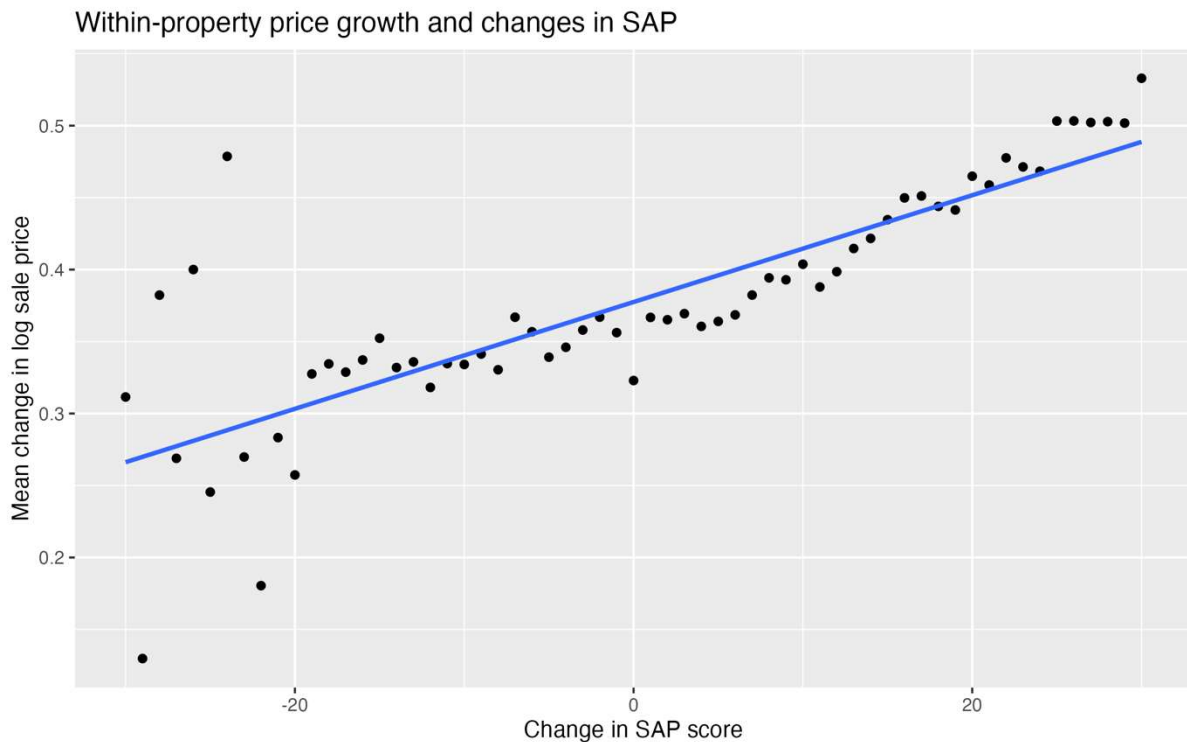


Figure 1 plots the binned relationship between changes in SAP score and mean within-property price growth. The pattern is upward-sloping, consistent with the correlation between changes in SAP and log sale price from the correlation matrix being 0.28. As with the correlations, this figure is descriptive only, but it supports the motivation for the regression analysis.

3.5 Empirical strategy

3.5.1 Initial all-sales hedonic approach

The project initially considered estimating a standard hedonic model on the full matched all-sales sample:

$$\log(P_{it}) = \beta SAP_{it} + X'_{it}\gamma + \lambda_t + \mu_c + \varepsilon_{it}$$

where SAP_{it} is the energy-efficiency score of the property, X_{it} is a vector of observed housing characteristics, λ_t denotes sale-year fixed effects, and μ_c denotes council fixed effects.

This specification was attractive because it retained more observations and allowed direct control for observed structural characteristics such as floor area, room counts, property type, tenure and construction age. However, the estimated SAP coefficient proved highly sensitive to specification choice: in some models it was positive and statistically significant, whereas in

others it became statistically insignificant or changed sign when alternative controls were included. This instability suggested that the cross-sectional relationship between SAP and sale price was difficult to estimate reliably using observed controls alone. This is likely because energy efficiency is closely correlated with other dimensions of dwelling quality, including some that are unobserved. Additional diagnostics for the all-sales hedonic model also pointed in the same direction: a Breusch–Pagan test indicated heteroskedasticity ($p < 0.001$), while a RESET test suggested sensitivity to specification ($p < 0.001$).

3.5.2 Preferred repeated-sales specification

Given these concerns, the preferred empirical strategy is a repeated-sales model estimated in first differences:

$$\Delta \log(P_{it}) = \beta \Delta SAP_{it} + \gamma T_{it} + \lambda_t + \lambda_{t-1} + \mu_c + \varepsilon_{it}$$

Where:

- $\Delta \log(P_{it})$ is the change in the log sale price for property i between two consecutive sales,
- ΔSAP_{it} is the change in SAP score over the same interval,
- T_{it} is the number of years between sales,
- λ_t and λ_{t-1} are current and previous sale-year fixed effects,
- μ_c denotes council fixed effects in selected specifications.

The repeated-sales framework is preferred because it controls for time-invariant dwelling characteristics, including unobserved aspects of location, baseline condition, and other persistent property attributes. Relative to the all-sales hedonic approach, it therefore provides a more credible basis for estimating the relationship between changes in energy efficiency and within-property price growth.

3.5.3 Statistical Inference and Diagnostics

Statistical inference is based on standard errors clustered at the council level, allowing for heteroskedasticity and within-council correlation in the residuals. Coefficient significance is assessed using t-statistics, p-values and 95% confidence intervals. In addition to the main specification, several robustness checks were undertaken, including the inclusion of council fixed effects, restricting the sample to moderate SAP changes, excluding properties resold within one year, and estimating the model on positive SAP changes only.

3.6 Limitations of the data and method

Several limitations should be acknowledged. The repeated-sales sample is selective because it includes only properties that can be matched successfully across EPC and PPD data and that transact at least twice. However, these restrictions were imposed to improve match quality and ensure meaningful results. Some address matching errors may remain despite cleaning and the one-year EPC window. Although the use of standardised address fields, postcode-based matching and retention of the closest EPC record helps reduce this risk. Finally, EPC-based SAP measures are imperfect and may not fully reflect the dwelling's condition at the exact point of sale, but restricting matches to EPCs observed within one year of sale helps limit timing issues. While the repeated-sales design reduces bias from time-invariant unobserved dwelling characteristics, it cannot fully separate SAP changes from other time-varying renovations.

Chapter 4. Results and Robustness

4.1 Main repeated-sales results

This chapter presents the main empirical results on the relationship between improvements in residential energy efficiency and house prices. A Breusch-Pagan test was conducted, which indicated heteroskedasticity ($p < 0.001$), so standard errors were clustered at the council level. Table 4 reports the repeated-sales estimates. Across all specifications, the coefficient on the change in SAP score is positive and highly statistically significant.

In the baseline specification with current and previous sale year fixed-effects and standard errors clustered at the council level, the estimated coefficient on ΔSAP is 0.0055. Adding council fixed-effects changes the estimate only slightly, to 0.0056, suggesting that the main result is not driven by broad differences in housing-market conditions across areas.

Table 4: Repeated-sales estimates of the effect of SAP improvements on house price growth

	(1) Main FE	(2) + Council FE	(3) SAP restricted	(4) Gap ≥ 1 year	(5) Upgrades only
Change in SAP score	0.0055***	0.0056***	0.0045***	0.0057***	0.0070***
	(0.0002)	(0.0002)	(0.0003)	(0.0002)	(0.0002)
Years between sales	0.0288***	0.0285***	0.0299***	0.0230***	0.0243***
	(0.0047)	(0.0048)	(0.0052)	(0.0048)	(0.0057)
Sale year FE	Yes	Yes	Yes	Yes	Yes
Previous sale year FE	Yes	Yes	Yes	Yes	Yes
Council FE	No	Yes	No	Yes	Yes
Clustered SE by council	Yes	Yes	Yes	Yes	Yes
Observations	28,737	28,734	24,796	25,447	18,928
Adj. (R ²)	0.1780	0.1855	0.1356	0.2134	0.2501

*Note: Dependent variable: change in log sale price between consecutive matched sales of the same property. Standard errors clustered at council level in parentheses. Column (3) restricts the sample to $\Delta SAP \in [-30, 30]$; column (4) excludes resale gaps below one year; column (5) includes positive SAP changes only. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

These estimates imply that a one-point increase in SAP is associated with roughly a 0.55% increase in sale price. Using the exact exponential transformation, a 10-point SAP improvement corresponds to a price increase of approximately:

$$100 \times (\exp(0.0055 \times 10) - 1) \approx 5.7\%$$

Suggesting that energy-efficiency improvements are reflected in within-property house price growth. The coefficient on years between sales is also positive and significant, as expected, since longer holding periods allow greater cumulative price appreciation.

The estimates are also precise. For example, in the council-fixed-effects specification, the coefficient on ΔSAP is 0.0056 with a clustered standard error of 0.0002, implying a narrow confidence interval well above zero. Adjusted R² values range from around 0.14 to 0.25 across specifications. While these values indicate that much variation in individual repeat-sale price growth remains unexplained, the estimated effect of SAP improvements is stable and precisely estimated.

4.2 Robustness checks

The positive relationship between SAP improvements and sale prices remains robust across several alternative specifications.

First, adding council fixed effects produces almost no change in the estimated SAP coefficient (0.0055 to 0.0056). This suggests that the baseline result is not driven by broad differences in housing-market conditions across local authorities. Second, restricting the sample to moderate SAP changes, defined as $\Delta\text{SAP} \in [-30, 30]$, reduces the estimated coefficient to 0.0045, but the effect remains highly statistically significant. This implies that the main result is not solely driven by very large, measured changes in SAP. Third, excluding properties resold within one year produces a slightly larger estimate of 0.0057, indicating that the baseline finding is not impacted by rapid resales or very short holding periods. Fourth, restricting the sample to positive SAP changes only increases the coefficient to 0.0070. This suggests that observed energy-efficiency upgrades are strongly associated with price growth, while negative SAP changes may partly reflect deterioration, reassessment differences, or measurement error.

Taken together, these robustness checks indicate that the repeated-sales result is stable across alternative specifications. Depending on the restriction applied, a 10-point increase in SAP is associated with a higher price of approximately 4.6% to 7.3%, with the preferred estimate remaining close to 5.7%.

4.3 Supplementary heterogeneity analysis

To assess whether the capitalisation of energy-efficiency improvements varies across housing contexts, a supplementary repeated-sales specification interacted the change in SAP score with baseline dwelling type. Detached homes were used as the reference category, and six groups were defined: detached, semi-detached, terrace, flat, maisonette and bungalow. The results indicate meaningful heterogeneity across dwelling types. For detached homes, a one-point increase in SAP is associated with a 0.52% increase in sale price. The interaction term for bungalows is positive and statistically significant, implying a stronger SAP effect than for detached homes. By contrast, the interaction terms for flats and terraced homes are negative and statistically significant, indicating weaker capitalisation of SAP improvements in those dwelling types. The coefficients for maisonettes and semi-detached homes are not statistically

different from the detached reference group. Overall, the findings suggest that the pricing of energy-efficiency improvements is not uniform across the housing stock.

Table 5: Heterogeneity in the effect of SAP improvements by dwelling type

Variable	Coefficient
Change in SAP score	0.0052***
Change in SAP × Bungalow	0.0017***
Change in SAP × Flat	-0.0035*
Change in SAP × Maisonette	0.0017
Change in SAP × Semi-Detached	-0.0004
Change in SAP × Terrace	-0.0008*
Years between sales	0.0281***
Observations	28,707
Adj. (R ²)	0.1901

***Note:** The reference group is detached homes. The dependent variable is the change in the log sale price between consecutive matched sales of the same property. Standard errors are clustered at the council level. Sale-year, previous-sale-year and council fixed effects are included. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

A plausible interpretation is that the market may attach greater value to energy-efficiency upgrades where they are more directly attributable to the individual dwelling. Detached homes and bungalows may experience greater heat loss because they have more exposed surfaces, whereas flats and maisonettes are more often located within blocks and may already be relatively energy efficient on average. At the same time, these differences may also reflect variation in the types of buyers attracted to different dwellings. Buyers may place different values on lower running costs, thermal comfort, future retrofit risk, or environmental performance. More broadly, the strength of these effects may also vary with wider economic conditions, including energy prices, policy changes, and housing-market conditions at the time of sale.

4.4 Supplementary all-sales hedonic exercise

A supplementary all-sales hedonic model was also estimated on the broader matched sales sample. Although this approach retained more observations and allowed a richer set of observable housing controls, the SAP coefficient proved highly sensitive to specification choice. In some specifications, it was positive and significant, while in others, it became insignificant or negative once alternative controls for built form, property type, tenure, room counts, and construction age were included. Table 6 summarises these results. The key point

is that the all-sales estimates do not provide a stable cross-sectional measure of the SAP effect, which reinforces the decision to treat the repeated-sales framework as the preferred empirical strategy.

Table 6: Supplementary all-sales hedonic results

Model	SAP coefficient	Standard error	Interpretation
Rich hedonic specification	0.0009***	0.0002	Positive but small
Hedonic without built form	-0.0005**	0.0002	Negative and small
Simple hedonic specification	-0.0001	0.0003	No robust effect

Chapter 5. Discussion, Policy Relevance and Limitations

5.1 Discussion and relation to the literature

The main finding of this dissertation is that improvements in residential energy efficiency are positively associated with within-property house price growth. Across the preferred repeated-sales specifications, the estimated coefficient on the change in SAP score is consistently positive, statistically significant, and economically meaningful. The preferred estimates imply that a 10-point increase in SAP is associated with a roughly 5-6% higher sale prices.

This result is consistent with the view that residential energy efficiency is capitalised into housing-market outcomes. In economic terms, the housing market appears to place a positive value on improved energy performance, as hedonic pricing theory would predict if buyers valued the bundle of benefits associated with more efficient homes. More specifically, in a capitalisation framework, buyers should be willing to pay more for homes with lower expected energy bills, improved thermal comfort, and lower exposure to future retrofit or regulatory costs, so long as these benefits are recognised and priced in the market. The results therefore suggest that such gains are recognised, at least in part, through the market price of the dwelling.

The finding is particularly notable because it emerges in a repeated-sales setting. By comparing the same property over time, the preferred specification accounts for time-invariant characteristics that are difficult to observe directly, such as locational quality, plot features, and other persistent dwelling attributes. This makes the repeated-sales result more persuasive than a simple cross-sectional relationship between energy efficiency and prices. The stability of the estimate across alternative specifications further strengthens this

interpretation. In that sense, the repeated-sales framework provides stronger evidence that the observed premium reflects the pricing of energy-performance improvements rather than fixed differences in underlying housing quality.

A supplementary heterogeneity analysis also suggests that the capitalisation of energy-efficiency improvements varies across dwelling types, with stronger effects for bungalows and weaker effects for flats and terraced homes relative to detached properties. One possible explanation for the heterogeneity in results is that energy-efficiency improvements may be more valuable in dwelling types with higher baseline heat loss and greater potential bill savings. Official statistics show that flats and maisonettes are, on average, more energy efficient than houses, which may reflect lower external wall exposure because they are more likely to be grouped in blocks (ONS, 2021). By contrast, detached properties have more exposed surfaces and tend to consume more energy than purpose-built flats, which may increase both the private value of efficiency improvements and the extent to which buyers notice them. Some industry estimates also suggest that the cost of upgrading homes from EPC D to C rises sharply with property size and type, from around £3,653 for a one-bedroom flat to about £12,540 for a larger detached home, indicating that retrofit costs and gains may vary substantially across the housing stock (Propcert, 2022). These mechanisms are suggestive rather than definitive, but they are consistent with the pattern found in the data.

At the same time, the results should not be interpreted as a fully causal estimate of energy efficiency in isolation. Changes in SAP are likely to coincide with broader housing improvements, such as refurbishment or modernisation, that may also raise sale prices. More broadly, while hedonic pricing and capitalisation theory predict a positive premium for energy efficiency, the size of that premium in practice will depend on whether buyers fully internalise future bill savings, trust available energy-performance signals, and expect to remain in the property long enough to benefit from the upgrade. The repeated-sales design removes time-invariant unobserved quality, but it cannot fully separate the energy-efficiency component from other time-varying improvements. The estimated SAP coefficient is therefore best understood as evidence of capitalisation associated with energy-efficiency improvements, rather than a pure treatment effect.

These findings align broadly with the wider literature showing that residential energy efficiency is often positively associated with sale prices. They are also consistent with studies

highlighting the importance of identification strategy. The instability of the supplementary all-sales hedonic exercise in this dissertation supports the concern that energy efficiency is closely correlated with unobserved dwelling quality, making cross-sectional estimates highly sensitive to how housing characteristics are controlled for. By contrast, the repeated-sales estimates are much more stable, reinforcing the methodological argument for within-property approaches in this setting and suggesting that standard cross-sectional hedonic models may overstate or understate the true premium depending on the extent to which housing quality is observed.

The results also contribute to the literature by focusing on continuous SAP changes rather than relying only on EPC bands. This helps capture the relationship between underlying energy-performance improvements and price growth more directly. Although it does not rule out the possibility that some part of market valuation may also reflect EPC labels, behavioural responses, or threshold effects rather than underlying bill savings alone. More broadly, the positive coefficient found here is consistent with a housing market in which energy efficiency has become more economically relevant as energy costs and policy attention have increased.

5.2 Policy relevance

The policy implications of these findings are important. If energy efficiency is capitalised into house prices, then part of the value of retrofit may be recoverable through the housing market rather than only through lower energy bills. This strengthens the private case for energy-efficiency investment and suggests that improved energy performance may contribute not only to lower running costs, but also to higher housing wealth.

This matters because the costs and benefits of energy efficiency are distributed unevenly across households. Higher-income owner-occupiers may be better able to finance an upfront retrofit or pay a premium for an efficient home, whereas lower-income households and renters may value lower bills highly but face tighter credit constraints. If energy efficiency is capitalised into prices, some of the gain may appear as higher housing wealth for sellers, while part of the benefit is offset by reduced affordability for buyers. This creates a policy trade-off between decarbonisation and affordability. The strength of these incentives also depends on wider macroeconomic conditions. Bank of England interest rates affect mortgage

costs and housing demand, while energy-price shocks and inflation alter both the value of future bill savings and the cost of retrofit materials.

These findings are especially relevant in the current UK policy context. The January 2026 Warm Homes Plan aims to upgrade up to 5 million homes by 2030, alongside other public investments and new rules for landlords (DESNZ, 2026). In the private rented sector, the existing minimum standard remains EPC E, but the government's January 2026 response confirmed a higher PRS MEES for all tenancies by 1 October 2030, supported by a £10,000 per-property investment cap (DESNZ, 2026). Recent announcements in the social rented sector also point to a tighter regulatory environment, with the government confirming a move toward EPC C or equivalent for social rented homes by 2030 (MHCLG and DESNZ, 2026). Taken together, these developments suggest that the market value of energy efficiency may increasingly reflect not only lower running costs, but also future compliance obligations and transition risk.

For policymakers, the results support interventions to improve residential energy performance. If the market rewards more efficient homes, then policies that increase retrofit uptake may generate both environmental benefits and private-value gains. This is relevant for programmes designed to reduce household energy demand, address fuel poverty, and support net-zero targets. The findings also suggest that information policies such as EPC disclosure may have meaningful economic effects if they improve the visibility of energy performance to market participants.

These implications should still be treated with caution. A positive price effect does not mean that all households can finance upgrades or that the market fully values energy efficiency. Financing constraints, behavioural frictions, landlord-tenant split incentives, and unequal access to retrofit opportunities remain important. The findings therefore support the relevance of policy, but do not imply that market forces alone will deliver the socially optimal level of energy efficiency investment. Nor should these results be treated as a full policy evaluation: judging retrofit policy still requires comparing programme costs with private and social benefits, and considering who gains and who bears the costs.

5.3 Limitations

This analysis has several limitations. First, the repeated-sales sample is selective, as it includes only properties that can be successfully matched across EPC and PPD data and that transact at least twice. This may limit representativeness relative to the full housing stock. Second, administrative matching is imperfect, and some mismatches or missed matches may remain despite extensive cleaning and the one-year EPC window. Third, SAP is a modelled measure of energy efficiency and may be noisy or outdated at the point of sale. Fourth, although the repeated-sales design removes time-invariant unobserved dwelling characteristics, it cannot fully address time-varying confounding, particularly where SAP improvements coincide with other renovations.

Future research could consider using the Home Energy Model (HEM) alongside Price Paid Data to address some of these concerns (DESNZ, 2024). The HEM is the UK government's replacement for SAP and is designed to more accurately assess a home's energy performance. It is intended to be a more precise measure than SAP and will include more metrics that researchers can use to test which aspects of energy performance buyers are pricing, rather than treating energy efficiency as a single index.

Overall, however, the evidence is consistent with the view that improvements in residential energy efficiency are capitalised into house prices in England. The key methodological conclusion is that the most credible evidence in this study comes from the repeated-sales framework rather than from cross-sectional hedonic models, which proved too specification-sensitive to support a stable estimate.

Chapter 6. Conclusion

This dissertation set out to examine whether improvements in residential energy efficiency are capitalised into house prices in England. Using matched EPC and Land Registry Price Paid Data, it finds consistent evidence that improvements in SAP scores are positively associated with within-property house price growth. In the preferred repeated-sales specification, a 10-point increase in SAP is associated with a sale-price increase of roughly 5.7%, while robustness checks imply a plausible range of around 4.6% to 7.3%.

These findings support the view that residential energy efficiency is valued in the housing market. They are consistent with hedonic pricing theory, under which a dwelling's price

reflects the value buyers place on its characteristics, and with a capitalisation framework in which lower expected energy bills, improved comfort, and lower future retrofit or regulatory risk are reflected in current sale prices. In this sense, the results suggest that the value of energy efficiency is not purely environmental or technical, but is at least partly recognised through the market value of residential property.

A central methodological conclusion of the dissertation is that empirical design matters. Although the project initially considered an all-sales hedonic model, those estimates proved highly sensitive to specification choice. By contrast, the repeated-sales framework produced much more stable and interpretable results. This suggests that within-property approaches may provide a more credible basis for studying the pricing of energy efficiency when cross-sectional estimates are likely to be confounded by unobserved dwelling quality.

The findings should nevertheless be interpreted with caution. The repeated-sales design removes time-invariant unobserved dwelling characteristics, but it cannot fully separate SAP improvements from other time-varying housing improvements that may occur between sales. The estimates are therefore best understood as evidence of capitalisation associated with energy-efficiency improvements, rather than a fully causal estimate of energy efficiency alone. In addition, the repeated-sales sample is selective, and both administrative matching and EPC-based SAP measures are subject to some measurement error.

Overall, this dissertation contributes to the literature by providing recent evidence from England using continuous SAP scores and a repeated-sales empirical strategy. Its central conclusion is that improvements in residential energy efficiency are positively associated with higher house prices, and that this relationship is economically meaningful. More broadly, the results suggest that energy efficiency matters not only for household energy use and climate policy, but also for the value and resilience of housing assets in the market.

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