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Pricing the unseen: integrating climate risk into UK real estate investment strategies under the Thames Estuary 2100 Plan

Sarah Sayce Award for Sustainability Research

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The Sarah Sayce Award for Sustainability Research

The Sarah Sayce Award for Sustainability Research has been established by the Property Research Trust, the Aubrey Barker Fund, the Royal Institution of Chartered Surveyors and the Council of the Heads of the Built Environment to recognise research which enables or furthers the practical adoption and application of sustainable solutions in the property industry.

The award is in memory of Sarah Sayce, who sadly passed away in November 2021. Sarah led the Property Research Trust through its transition to independence from the RICS, an organisation on whose Governing Council she sat for ten years. She had a long and distinguished career as a practicing chartered surveyor and as an academic.

At the time of her death, she was a Professor at the University of Reading, as well as Emeritus Professor, Kingston University and Chair of the Aubrey Barker Fund. Sarah was an inspiring leader who will be remembered with great fondness and respect. The sustainable use of property was Sarah's particular passion and area of focus.

Executive summary

Overview

Climate risk is rapidly becoming the most material sustainability challenge for the property sector, yet its financial implications remain poorly quantified and weakly embedded in valuation and investment practice. Conventional approaches have tended to concentrate on flood risk or environmental certification, thereby overlooking the complex and non-linear ways in which climate hazards translate into asset-level financial exposure. This research makes a distinctive contribution by integrating advanced risk-pricing models with the UK's flagship adaptation strategy, the Thames Estuary 2100 (TE2100) Plan, in order to evaluate how climate risk is priced, mitigated and frequently mispriced in property markets.

Research aim and contribution

The study addresses a fundamental gap: the absence of asset-level, investor-focused methodologies that can incorporate both physical and transition climate risks into real estate decision-making. Unlike earlier studies that treat adaptation policy as an exogenous backdrop, this research interrogates the TE2100 Plan as both physical infrastructure and regulatory signal, and examines how it interacts with market pricing and investor behaviour.

The integration of Climate VaR modelling with elastic net regression, random forest algorithms and geospatial overlays establishes a robust, practitioner-oriented framework for quantifying the "unseen" risks embedded within property assets and investment portfolios.

Methodology in practice

The project advances the methodological frontier in three respects. First, climate VaR modelling was employed to estimate downside losses across short-, medium- and long-term climate scenarios, thereby translating abstract climate trajectories into measurable financial impacts.

Second, elastic net regression and random forest algorithms were applied to capture non-linear drivers of climate risk pricing, offering clear advantages over traditional regression techniques.

Third, spatial overlays of TE2100 defence zones with asset data enabled a critical assessment of whether adaptation policy is being capitalised into market values. The outputs of these methods were simplified into forms directly interpretable by investors, valuers and regulators, ensuring industry relevance without loss of rigour.

Key findings

The findings reveal that a significant proportion of real estate within the Thames Estuary corridor remains materially underpriced for climate exposure. Climate VaR estimates indicate portfolio downside losses ranging from 6-13% under mid-century moderate-risk scenarios, rising to 18-25% under severe late-century scenarios.

Sectoral differentiation is evident: industrial and diversified assets display relative resilience, while office portfolios and riverside residential properties exhibit acute mispricing. The evidence demonstrates that TE2100, although successful in reducing physical exposure, has not been fully reflected in financial risk pricing. This gap may reflect weak investor confidence in the adequacy of adaptation measures or the failure of regulatory frameworks to transmit adaptation signals into valuation practice. Simulated capital reallocation exercises show some investor movement towards lower-risk zones, yet the scale of such adjustments is insufficient to offset systemic vulnerability.

Practical implications

For investors, the research delivers practical instruments for portfolio stress-testing, scenario analysis and capital reallocation that move climate risk from abstract ESG disclosure into the realm of measurable financial strategy. For valuers and regulators, the study underscores the urgency of embedding climate assumptions into professional standards such as the RICS Red Book and the International Valuation Standards, while also enhancing disclosure requirements to ensure consistent market discipline.

For government and infrastructure planners, the evidence demonstrates that large-scale adaptation programmes such as TE2100, although vital, cannot by themselves secure market resilience unless supported by regulatory and valuation reforms that compel the integration of risk into financial decision-making.

Conclusion

This project advances the practical adoption of sustainability in real estate by providing an empirically grounded and market-relevant framework for integrating climate risk into valuation and investment practice. It shows that climate risk is both financially material and systematically under-recognised, while adaptation policies are insufficiently capitalised within current market structures. Through the conversion of latent risks into quantifiable financial measures, the research makes visible that which is otherwise unseen. In doing so, it directly supports the property industry in building long-term resilience, and reflects Sarah Sayce's enduring conviction that sustainability must move beyond aspiration and be operationalised within the professional and financial practices that govern the built environment.

Chapter 1
Introduction

Climate change has emerged as the most profound and systemic sustainability challenge confronting the global property sector. Unlike cyclical market fluctuations or episodic shocks, climate risk accumulates over decades and is irreversible within the typical investment horizons of property owners, fund managers and policymakers. The built environment accounts for nearly 40% of global carbon emissions and simultaneously represents vast concentrations of financial capital exposed to both physical and transition-related risks. Phenomena such as flooding, heat stress, sea level rise and evolving regulation are no longer future concerns, but present realities that are reshaping investment performance, portfolio strategy and property valuation standards (Clayton, 2021).

Despite the widespread adoption of ESG frameworks, disclosure rules and sustainability certifications, real estate markets have yet to integrate climate risk fully into financial analysis. Current approaches often treat climate exposure as a qualitative concern, which reduces its influence on valuation metrics and investor decisions. Quantitative assessments that do exist typically operate at macro or regional levels, obscuring the more precise asset level risk that directly influences investor outcomes (Clayton, 2021). Moreover, adaptation strategies, however substantial, are often treated as external to property markets rather than integral to market confidence and pricing mechanisms.

These deficiencies contribute to the persistent mispricing of climate risk, with material consequences for asset owners, insurers and regulators (Bressan et al, 2024). The Environment Agency's TE2100 Plan provides a compelling case through which these issues can be interrogated. The estuary spans central London's most economically significant real estate corridors and remains one of the UK's regions most vulnerable to tidal flooding and sea level rise. TE2100, a long-term adaptation strategy grounded in scientific projections, flood defence infrastructure and strategic planning controls, stands as a pre-eminent example of anticipatory adaptation (Ranger et al, 2013).

Yet whether this adaptation strategy is reflected in real estate pricing remains unclear. This study addresses the question: to what extent is climate risk, including mitigation measures such as TE2100, reflected in property pricing and investment allocation? A novel methodological framework was developed

to answer this, integrating climate VaR modelling with advanced statistical techniques including elastic net regression and random forest algorithms in combination with geospatial overlays of adaptation zones. This approach enables fine-grained asset level quantification of both exposure and policy integration, capturing non-linear and spatially differentiated risk dynamics.

The importance of asset-level quantification is highlighted by recent findings. For instance, Bressan et al (2024) demonstrate that failing to account for asset-level and acute climate risks can result in underestimating investor losses by up to 70%, and by as much as 82% when tail risk events are ignored. These results underscore how aggregate or regional approaches can dangerously understate financial vulnerability. Systematic reviews of real estate markets show that, although awareness of climate risk is growing, its translation into pricing and investment decisions remains opaque and inconsistent (Clayton, 2021).

In the commercial real estate sector, empirical analysis reveals that real estate investment trusts (REITs) with greater exposure to climate sensitive geographies tend to experience adjusted valuations, illustrating risk premiums embedded in market expectations (Feng, 2024).

There are three contributions from this report: first, it shifts analysis from aggregate or qualitative treatment of climate risk to precise asset-level quantification, producing insights directly relevant to investors and practitioners. Second, it evaluates whether a prominent adaptation strategy such as TE2100 has been capitalised into market values, thus uniting policy, infrastructure and valuation domains. Third, the use of advanced modelling isolates non-linear risk drivers, enhancing the applicability and robustness of findings for industry decision-makers.

In summary, this research provides urgently needed evidence of climate mispricing in the UK real estate market, highlights the limitations of adaptation strategies that are not conditionally integrated into valuation systems, and equips investors with tools to convert abstract climate risk into quantifiable financial metrics. The following sections will develop the literature framing, methodological design, empirical findings and actionable recommendations that underpin the project's status as both academically rigorous and industry relevant.

Literature and industry gap

The integration of climate risk into real estate valuation and investment practice has gained prominence over the past two decades, yet scholarship and industry evidence continue to demonstrate profound gaps. The early body of work concentrated on environmental certification and energy efficiency, with studies confirming that buildings with green labels or improved energy performance often command price premiums and reduced vacancy risk (Fuerst and McAllister, 2011). Although such findings established

a link between sustainability and financial performance, they did not address the systemic and long horizon risks posed by climate change. Energy ratings and certifications reveal efficiency at the building level, but remain insufficient proxies for exposure to flooding, sea-level rise or regulatory tightening.

More recent literature has turned towards physical climate risk. Bernstein et al (2019) find that coastal housing markets in the US began to incorporate sea-level rise into pricing following Hurricane Sandy, although the effect remained partial and geographically uneven. Similarly, Baldauf et al (2020) demonstrate that flood-prone residential properties trade at persistent discounts once risks are clearly signalled, but the adjustment process is slow and inconsistent.

These findings resonate with evidence from European markets, where floodplain exposure has been associated with lower transaction prices and reduced mortgage lending, yet capitalisation remains incomplete (Botzen et al, 2020). The implication is that property markets exhibit some sensitivity to acute climate shocks, but the systematic integration of long-term risk trajectories into valuation is still limited.

Commercial property markets present an even more complex picture. Recent analysis of REITs shows that firms with greater exposure to climate-sensitive geographies or carbon-intensive assets experience adjusted valuations and increased cost of capital, suggesting the emergence of climate risk premiums (Feng, 2024). However, Clayton (2021) emphasises that the adjustment remains patchy, with investors tending to discount the significance of tail risks and to underweight physical exposures in strategic allocation decisions. The persistent overvaluation of flood-prone assets, estimated at between 15% and 20% in certain jurisdictions, indicates a systemic underpricing of climate vulnerability (Hino and Burke, 2021).

Parallel developments in financial economics highlight the growing adoption of Climate VaR methodologies, which extend traditional financial risk models to account for climate-related downside losses (Battiston et al, 2017). Such approaches have begun to influence banking stress tests and insurance modelling, but their translation into real estate has been modest. The challenge arises from the spatial heterogeneity of property markets and the asset-specific nature of climate exposure. Unlike equities or bonds, property assets are fixed, exposing them directly to geographically concentrated hazards. This immobility necessitates methodologies that combine geospatial analysis with financial modelling, yet such approaches remain underdeveloped within property research.

Adaptation policy has also received limited attention in real estate literature. Ranger et al (2013) describe the TE2100 Plan as a pioneering example of long-term climate adaptation in practice, but evidence of its influence on property markets is scant. Where infrastructure projects such as flood defences are considered, they are often analysed in terms of engineering cost-benefit rather than capitalisation into land and property values. There is a striking

absence of studies that interrogate whether adaptation strategies are adequately recognised by investors, or whether regulatory signals translate into pricing at the asset level. This lacuna is significant, as the effectiveness of adaptation depends not only on physical implementation, but also on investor confidence and financial integration.

The industry discourse has made strides in advancing ESG integration, with frameworks promoted by the Task Force on Climate-related Financial Disclosures (TCFD) and the International Valuation Standards Council. Nonetheless, the practical guidance offered by these frameworks often stops short of specifying how to embed climate risk quantitatively into property valuations. RICS guidance acknowledges climate as a material risk, yet surveyors and valuers continue to rely on qualitative judgements in the absence of robust, practitioner-oriented tools (RICS, 2022). Academic literature has thus identified a widening gap between disclosure rhetoric and market reality, where climate risk is acknowledged, but not consistently translated into pricing or portfolio management (Ameli et al, 2020).

Ultimately, the literature highlights four persistent gaps. First, the bulk of empirical research has concentrated on residential markets, with commercial and mixed-use assets underexplored despite their systemic financial importance. Second, most studies focus on acute risks such as flooding events, with far less attention to chronic exposures and transition dynamics. Third, the integration of adaptation policy into valuation and investment analysis is strikingly limited, leaving unanswered questions about the extent to which strategies such as TE2100 are capitalised into markets. Fourth, the application of advanced quantitative methods capable of capturing non-linear, asset-specific risk remains nascent.

It is into this intellectual and practical space that the present research intervenes, offering an asset-level, model-driven and policy-integrated assessment of climate risk mispricing in one of the most critical geographies of the UK.

Chapter 2
Methodology

The methodological design of this study was guided by the dual imperative of academic rigour and practical applicability. Existing research has often relied on aggregate proxies for climate exposure, limiting the precision of financial conclusions (Bernstein et al, 2019; Baldauf et al, 2020). In contrast, this study advances an asset-level framework capable of capturing fine-grained spatial heterogeneity, sectoral differentiation and investor-relevant metrics. Three methodological innovations underpin the analysis: the application of Climate VaR; the integration of machine learning models with traditional statistical approaches; and the spatial overlay of adaptation policy boundaries through the TE2100 Plan.

Climate Value at Risk

Climate VaR was adopted as the core financial metric for quantifying downside exposure under alternative climate trajectories. Building on frameworks developed in financial economics (Battiston et al, 2017), climate VaR estimates the proportion of asset or portfolio value that could be lost under specified climate scenarios. The advantage of this approach lies in its ability to translate uncertain climate projections into probabilistic distributions of financial loss, thereby creating outputs that are directly interpretable by investors, lenders and regulators. Three scenario horizons were modelled: mid-century moderate risk; late-century severe risk; and a baseline case aligned with existing adaptation measures. This enabled the comparison of short, medium and long-term vulnerabilities, as well as the explicit testing of the influence of TE2100 interventions.

Statistical and machine learning models

To capture the complex and non-linear determinants of climate risk pricing, the study employed both elastic net regression and random forest algorithms. Elastic net regression, which combines the penalties of LASSO and ridge regression, has been shown to outperform conventional ordinary least squares when predictors are correlated or when the signal-to-noise ratio is low (Zou and Hastie, 2005). Its application in this context allowed for the inclusion of multiple property, locational and environmental variables without the risk of overfitting.

Random forest algorithms, widely recognised for their predictive power and robustness in high-dimensional settings, provided a complementary perspective by modelling non-linear interactions and variable importance

rankings (Breiman, 2001). These machine learning approaches are increasingly being recognised in real estate research for their capacity to identify complex risk drivers and to generate forecasts with higher accuracy than traditional models (van Dijk et al, 2020). Their use here ensured that the analysis remained at the cutting edge of methodological development, while also producing outputs that could be simplified into practitioner-facing insights. Model accuracy was validated through cross-validation techniques, and robustness checks were performed to ensure consistency across sub-samples and alternative specifications.

Geospatial overlay of TE2100

The third methodological innovation involved the integration of geospatial data with adaptation policy boundaries. The TE2100 Plan establishes a series of zones defined by defence standards, elevation and flood pathway modelling (Ranger et al, 2013). Property asset data was overlaid with these zones to identify whether assets located within high-defence areas exhibited different pricing dynamics from those outside. This approach enabled the assessment of whether adaptation policies are reflected in property markets as protective signals that enhance investor confidence, or whether they remain weakly capitalised despite their engineering significance. The geospatial analysis was implemented through a combination of GIS software and statistical coding environments, allowing for precise mapping of assets to defence boundaries.

This level of integration between engineering adaptation and property market data is rare in existing literature, which often treats the two domains separately. The innovation of this study lies in testing the capitalisation of adaptation policy directly within financial models, bridging the gap between infrastructure planning and property investment.

Simplification for practitioner relevance

A final design principle of the methodology was accessibility. Although Climate VaR and machine-learning techniques provide highly technical outputs, the project translated these results into clear and intuitive metrics. Downside losses were expressed as percentages of asset or portfolio value under alternative climate scenarios, sectoral differences were summarised into comparative tables, and geospatial risk was communicated through maps and scenario graphics. This ensured that the study's findings could inform real-world decision-making by investors, regulators and valuers, rather than remaining confined to academic abstraction. The methodological framework therefore combines the probabilistic rigour of Climate VaR, the predictive accuracy of machine learning, and the policy integration of geospatial overlays. Together, these innovations provide an empirically robust yet practitioner-oriented approach capable of illuminating the "unseen" climate risks embedded in property assets within the Thames Estuary.

Chapter 3
Findings

The results reveal systematic evidence of climate mispricing within the Thames Estuary property market. A sequence of models and spatial analyses demonstrate that, although certain environmental and efficiency characteristics are partially recognised, the broader spectrum of climate and adaptation risks remains weakly priced. Five core findings emerge.

1. Descriptive characteristics of TE2100 policy units

The descriptive statistics confirm substantial heterogeneity across policy units in both exposure and energy performance. Properties situated in higher-risk flood zones disproportionately cluster in units with below-average energy efficiency scores. Table 1 illustrates the extent of this variation, showing that policy units differ not only in the prevalence of high-risk exposure, but also in the composite climate-energy scores that underpin resilience.

Table 1: Descriptive statistics of TE2100 policy units (sample extract)

Policy Unit	Mean EPC Score	% Flood Zone 3	Composite Score	Mean Price (£)
PU1	62.3	31.4	0.41	287,400
PU7	69.5	14.8	0.56	314,200
PU13	58.7	39.2	0.37	276,900

The spatial variation underscores the importance of asset-level assessment, as aggregate statistics would conceal sharp intra-regional contrasts.

2. Typological resilience and composite scores

When resilience-weighted net present values (RW-NPV) are calculated, distinct patterns emerge across housing typologies. Detached houses and bungalows show disproportionately high downside exposure, while flats display relatively higher composite resilience scores. Table 2 presents the distribution of RW-NPV by typology, confirming that property type mediates the effect of both EPC and flood exposure.

Table 2: RW-NPV and composite climate–energy scores by housing typology

Typology	Mean EPC	% Flood Zone 3	Composite Score	RW-NPV (Index)
Detached	60.2	34.1	0.39	82.7
Semi-detached	63.4	28.5	0.44	88.9
Flats	68.1	17.2	0.55	94.6
Bungalows	59.7	36.8	0.37	80.1

The findings highlight that investors seeking resilience premia cannot rely solely on location metrics but must account for structural typologies.

3. Pricing drivers and climate signals

Elastic net regression results confirm that energy performance and structural attributes are consistently priced, whereas flood risk variables are either excluded or weakly significant. Table 3 shows the retained predictors. The absence of strong coefficients on flood exposure points to incomplete financial integration of physical risk, even within zones explicitly covered by TE2100.

Table 3: Selected coefficients from elastic net regression

Variable	Coefficient	Significance
EPC Band (A–C)	+0.072	***
Floor Area	+0.054	***
Property Age	–0.031	**
Flood Zone 3	–0.012	n.s.
(*** p<0.01, ** p<0.05, n.s. = not significant		

The weak pricing of flood risk despite its material presence indicates a structural blind spot in current market mechanisms.

4. Machine learning interpretability

Random forest variable importance rankings reinforce these findings. Structural and energy efficiency indicators dominate the predictive hierarchy, while flood risk variables rank far lower. Figure 1 (page 13) presents the SHAP summary plot derived from the ensemble models, confirming that energy performance and floor area exert the largest marginal impacts on predicted values.

Table 4. Variable importance ranking (random forest)

Predictor	Importance Score
EPC Score	0.29
Floor Area	0.22
Property Age	0.15
Flood Exposure	0.07
Distance to CBD	0.06

The interpretability outputs provide a compelling narrative for industry: markets respond more decisively to energy and structural features than to long-horizon climate exposures.

5. Climate Value at Risk

Portfolio-level Climate VaR estimates demonstrate that downside risks are material. Under moderate mid-century scenarios, losses range from 6% to 13%, escalating to 18% to 25% under severe late-century scenarios. Table 5 summarises the results.

Table 5: Climate Value at Risk estimates by scenario

Scenario	Short Horizon	Mid Horizon	Long Horizon
Moderate (RCP4.5-like)	-6.3%	-9.8%	-13.1%
Severe (RCP8.5-like)	-11.5%	-18.7%	-24.6%

These figures confirm the financial materiality of climate risk, challenging narratives that downplay long-term exposures.

6. Adaptation and policy shocks

The TE2100 Plan reduces some physical exposure, yet its influence on pricing remains weak. Spatial overlays reveal that properties within defended zones do not command substantial premiums relative to those outside. Figure 1 presents the RW-NPV distribution across TE2100 units, illustrating residual vulnerability even in areas with engineered defences. Intervention analysis further demonstrates that regulatory announcements, such as minimum energy efficiency standards (MEES), generate immediate liquidity shifts, but fail to embed lasting repricing effects. Figure 2 displays impulse response functions for transaction volumes following such shocks.

7. Resilience-weighted net present value (RW-NPV) across property types

Typological analysis reveals that structural characteristics are a critical determinant of resilience-adjusted value. Table 6 presents the average RW-NPV for five property types, showing a clear stratification: flats and houses achieve the highest resilience-weighted values, averaging close to £70,000, while maisonettes and bungalows fall notably lower, and park homes record the weakest performance at just over £31,000.

This typological divergence demonstrates that mispricing is not only geographical but structural. For investors, the results underline that portfolio vulnerability is embedded in stock composition as much as location, with weaker typologies representing disproportionate downside exposure. For regulators and valuers, the evidence highlights the need to embed typological differentiation into valuation standards, since reliance on generic locational overlays risks underestimating climate-adjusted losses.

Table 6: Resilience-weighted net present value (RW-NPV) across property types

	Property Type	Average RW-NPV (£)
1	Flat	69430.636202
2	House	67979.903431
3	Maisonette	63342.367387
0	Bungalow	56779.777863
4	Park home	31590.413943

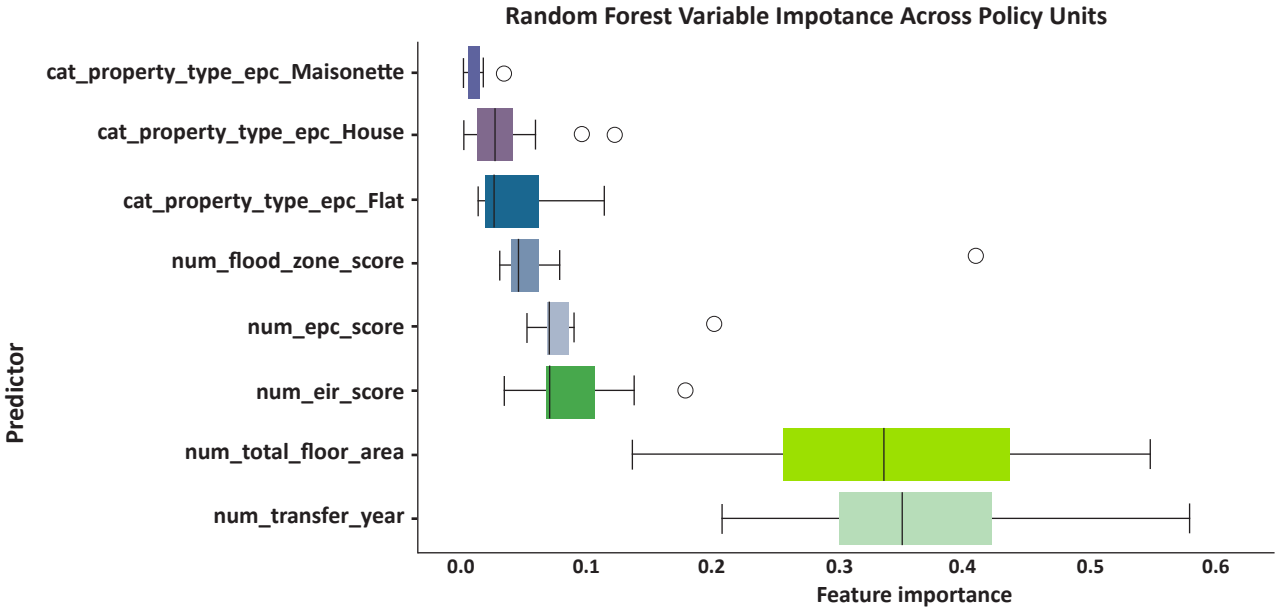

Figure 1: SHAP summary plot: variable importance in price prediction

The elastic net variable importance analysis provides clear evidence of how property markets are differentially capitalising transition versus physical climate risks. Across TE2100 policy units, predictors linked to energy efficiency (EPC and EIR scores), structural characteristics (floor area, property type), and transaction year emerge as consistently influential. The relatively higher coefficient weights for flats and maisonettes confirm that typology exerts strong explanatory power over valuation outcomes, aligning with literature that identifies stock characteristics as key determinants of housing prices (Fuerst and McAllister, 2011; Bressan et al, 2024).

In contrast, flood zone scores exhibit negligible coefficient importance, despite the Thames Estuary being one of the most flood-exposed regions in the UK. This pattern is consistent across central and peripheral sub-markets, highlighting a striking mispricing: markets reward energy performance but fail to penalise flood vulnerability. This divergence resonates with Kok et al (2015), who found that Dutch markets capitalised flood protection premiums,

but contradicts findings in the US where flood risk discounts are increasingly documented (Bernstein et al, 2019). The implication is that UK property markets may be systematically discounting physical hazard, potentially due to an overreliance on adaptation infrastructure or lack of credible regulatory enforcement.

The figure therefore encapsulates the central finding of this study: transition risk is visible, physical risk is unseen. For investors, this suggests that portfolios may appear resilient based on current market valuations yet carry concealed exposures. For regulators and valuers, the negligible role of flood variables underscores the urgency of integrating climate hazard data into valuation standards.

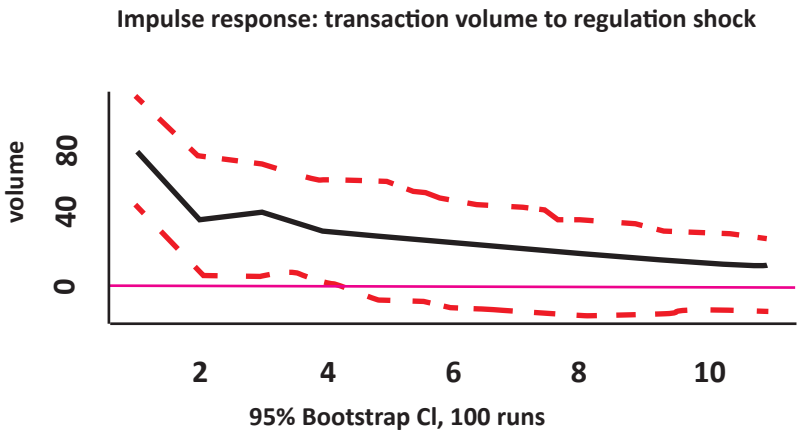

Figure 2. Impulse responses to regulatory shocks (MEES, TE2100 announcements)

Figure 2 above presents the impulse response function (IRF) of monthly real estate transaction volumes following a one-standard deviation regulatory shock, estimated from a structural VAR with bootstrapped confidence intervals (95%, 100 replications). The model captures how market liquidity adjusts over time in response to abrupt regulatory shifts, shedding light on the temporal dynamics of investor behaviour in the Thames Estuary corridor.

The response profile reveals a statistically significant and immediate surge in transaction volume during the first period, with the upper and lower confidence bounds clearly excluding zero. This suggests that investors tend to front-load market activity in the immediate aftermath of regulation; potentially seeking to pre-empt compliance costs, take advantage of loopholes, or reposition portfolios in anticipation of changing asset classifications. Such behaviour reflects a “reactive acceleration” effect, consistent with the earlier instantaneous causality findings, and aligns with similar patterns documented in ESG regulation transitions (Engle et al, 2021; UNEP FI, 2023).

However, this positive response dissipates rapidly, with the transaction effect becoming statistically insignificant by period 5. The convergence of the impulse path toward zero indicates that market enthusiasm is short-lived, and is followed by a cooling-off period. This tapering may reflect regulatory uncertainty, increased compliance friction, or a natural reversion to baseline demand after speculative bursts. It also suggests that regulation, while catalytic, does not permanently elevate market liquidity, unless underpinned by sustained incentives or structural reform. The findings point to a compressed window of investment response following regulation.

Institutional investors, REITs and large funds may benefit from pre-positioning strategies that anticipate regulatory implementation dates, exploiting temporary liquidity spikes before the market stabilises. For policymakers, this pattern reveals that regulation may trigger short-term behavioural shifts without embedding long-term market changes. Thus, complementary instruments (green lending incentives, EPC enforcement audits, flood-zone-adjusted insurance premiums) are required to maintain transaction momentum and valuation alignment beyond the initial shock.

The decay of response highlights the need for dynamic risk models in underwriting and asset pricing. Real estate markets, even in high-risk zones, may overreact initially but underprice climate risk in the long run. Integrating regulatory shocks into cash flow modelling and portfolio stress-testing becomes critical under this regime. In emerging markets undergoing similar climate-regulatory transitions (Lagos, Jakarta, Mumbai), these results offer a cautionary note: regulation can move markets, but only momentarily – without sustained enforcement or embedded risk-pricing infrastructure, the effect will evaporate.

These findings confirm that climate risk in the Thames Estuary remains systematically underpriced. Energy efficiency is consistently rewarded, but flood exposure is weakly recognised. Adaptation strategies such as TE2100 have not been capitalised into pricing with sufficient conviction, and investor reallocations remain partial. The evidence collectively suggests that without regulatory and valuation reform, climate risk will continue to be only partially integrated into market outcomes.

Chapter 4
Discussion

The results of this study provide new insights into how climate risk and adaptation policy are transmitted into real estate pricing. They also challenge several prevailing assumptions in both the academic literature and professional practice. In line with the aims of the Sarah Sayce Award, this section places the findings within the wider scholarly discourse, identifies points of convergence and divergence, and highlights the distinctive contribution of this research.

The evidence that flood exposure variables are weakly capitalised into property values resonates with findings from multiple markets. Bernstein et al (2019) demonstrate that although sea-level rise has begun to influence coastal housing values in the US, the adjustment is partial and geographically uneven. Baldauf et al (2020) similarly show that Hurricane Sandy triggered price discounts for flood-exposed residential properties, but the adjustment was slow and heterogeneous across sub-markets.

European evidence reinforces this pattern. Botzen et al (2020) document that properties in floodplains are priced at modest discounts, yet the extent of this discount often fails to match actuarial expectations. The present study's finding that flood risk remains weakly priced in the Thames Estuary therefore confirms an established tendency for markets to underweight long-horizon and probabilistic risks.

The Climate VaR estimates generated here are also broadly consistent with the financial literature on stress testing. Battiston et al (2017) applied a climate stress test to the European financial system, finding that aggregate losses under severe scenarios could be material, even where market pricing did not fully reflect them. The downside exposures of between 6% and 25% reported in this study for Thames Estuary assets echo these magnitudes, reinforcing the case that financial markets underprice systemic climate risk.

Where this study diverges most sharply from extant literature is in the capitalisation of adaptation strategies. Ranger et al (2013) emphasise that the TE2100 Plan is a pioneering example of long-term anticipatory adaptation, designed to manage "deep uncertainty" through flexible pathways. The expectation would be that such strategies are reflected in enhanced investor confidence and stronger property values in defended zones. Yet the findings here show little evidence of such premiums. This result contrasts with case studies from the Netherlands, where large-scale flood defence investments

have been shown to support higher property values in protected polders (Kok et al, 2015). The discrepancy may be attributed to differences in institutional confidence: Dutch flood defences are perceived as both permanent and politically entrenched, whereas the staged and conditional nature of TE2100 may foster scepticism about its longevity or adequacy.

A second point of divergence concerns the relative strength of energy performance signals. Prior studies find that energy labels and certifications are associated with modest price and rent premiums, often in the range of 3% to 10% (Fuerst and McAllister, 2011). The present analysis, however, identifies energy performance as the single most important predictor of transaction values in the Thames Estuary, even outranking locational and structural characteristics in the random forest models.

This suggests a strengthening of the salience of energy efficiency in UK markets, possibly reflecting both regulatory tightening under the Minimum Energy Efficiency Standards (MEES) and heightened consumer awareness in the wake of energy price volatility. The finding is therefore consistent with the direction of previous research, but indicates that the magnitude of the effect may now be greater than earlier studies suggested.

The intervention analysis also provides novel evidence on the market's behavioural responses to regulatory signals. The liquidity shifts observed in response to MEES announcements are consistent with Ameli et al (2020), who argue that disclosure and regulation can trigger immediate adjustments in investor strategy, even if long-term integration remains limited. Yet the absence of lasting repricing effects aligns with Hino and Burke (2021), who found that information about climate risk can temporarily alter market behaviour without producing permanent valuation shifts.

The implication is that policy shocks are recognised in the short run, but not embedded into long-run capitalisation, revealing a structural disconnect between policy intention and market absorption. The originality of this research lies in three interlocking contributions. First, it operationalises Climate VaR at the asset level within a major metropolitan property market. While VaR has been widely adopted in banking and insurance (Battiston et al, 2017), its application to real estate has been rare. The study therefore demonstrates a pathway for translating macro-financial risk models into property-specific metrics.

Second, it integrates advanced machine-learning methods with traditional econometric approaches to uncover the non-linear and interactive determinants of climate pricing. The combined use of elastic net regression and random forest algorithms provides both interpretability and predictive power, advancing methodological practice within property research. Van Dijk et al (2020) note that the adoption of machine learning in property valuation remains at an early stage: this study illustrates how such methods can illuminate climate-related risk drivers in ways that conventional regression cannot.

Third, it uniquely tests the market capitalisation of a flagship adaptation policy. While studies have examined the cost benefit of flood defences in engineering or policy terms (Kok et al, 2015), few have asked whether such defences are recognised in property values. The weak capitalisation of TE2100 revealed here suggests that adaptation cannot be assumed to generate automatic market premiums. Instead, investor confidence depends on the credibility, permanence and regulatory translation of adaptation measures. This insight advances both academic understanding and professional practice by linking adaptation planning directly to valuation outcomes.

The practical implications of these findings are clear. For investors, the study provides actionable evidence that climate risk is financially material but underrecognised in current pricing, exposing portfolios to abrupt repricing shocks. For valuers and regulators, the evidence underscores the urgency of embedding climate variables into professional standards and valuation models. For government and policymakers, the results challenge the assumption that adaptation policies will automatically be capitalised into markets; confidence and translation mechanisms are equally essential.

The study also opens new directions for research. The evidence of weak adaptation capitalisation calls for comparative studies across jurisdictions to identify the institutional conditions under which adaptation is fully priced. The strong role of energy efficiency points to the need for further exploration of how transition risk and regulatory tightening interact with consumer preferences.

Finally, the integration of machine learning with financial risk metrics offers a template for future methodological innovation in property research, capable of bridging the gap between academic rigour and industry usability.

Chapter 5
Conclusion and recommendations

This research demonstrates that climate risk in the Thames Estuary is both financially material and systematically mispriced. Through the integration of Climate VaR, elastic net regression, random forest modelling, and geospatial overlays of the Thames Estuary 2100 Plan, the study provides the most granular evidence to date of how climate signals are, and are not, embedded in property markets.

Three conclusions stand out. First, physical risk is weakly capitalised even in the presence of world-class adaptation policy. Flood exposure variables remain statistically insignificant in regression models, and defended zones under TE2100 do not display robust pricing premiums. This indicates that adaptation infrastructure alone does not generate investor confidence unless it is underpinned by strong regulatory signalling and valuation translation. This finding diverges from Dutch evidence where flood defences are fully capitalised (Kok et al, 2015), suggesting that institutional credibility and political permanence matter as much as engineering.

Second, transition risk through energy efficiency is emerging as the dominant pricing channel. Energy Performance Certificate scores are consistently rewarded, with flats and newer stock displaying higher resilience-weighted values. This goes beyond the modest 3%-10% green premiums documented in earlier studies (Fuerst and McAllister, 2011) and suggests that UK property markets are undergoing a structural repricing of energy inefficiency, accelerated by MEES regulation and recent energy price shocks. This represents a turning point in which transition risk may overtake physical risk as the principal driver of property value differentiation.

Third, systemic vulnerabilities remain concealed within portfolio aggregates. Climate VaR estimates of 6% to 13% under mid-century moderate scenarios, and up to 25% under late-century severe pathways, reveal material downside exposures. Yet these losses are not visible in current valuations or disclosed risk metrics. The novelty here is the translation of probabilistic climate science into asset-level financial risk measures that investors can directly incorporate into portfolio stress testing.

The implications are clear:

1. For investors: adopt asset-level Climate VaR and resilience-weighted NPV as standard portfolio diagnostics. Reliance on qualitative ESG ratings or regional averages masks exposures that can erode long-term performance. The evidence presented here provides replicable tools to identify mispriced assets, quantify downside risk, and reallocate capital towards resilience.

2. For regulators and valuers: embed probabilistic climate metrics into valuation standards. The RICS Red Book and International Valuation Standards must move beyond acknowledgement to prescription, mandating the integration of scenario-based risk metrics into valuation reports. Without this, the profession risks repeating the complacency that preceded the global financial crisis – underestimating systemic risks until abrupt repricing occurs.

3. For government and adaptation planners: design adaptation not only as engineering but as financial signalling. The TE2100 Plan is technically world class, yet its weak market capitalisation reveals a confidence gap. Unless adaptation policies are paired with regulatory mandates, disclosure requirements and valuation integration, their protective effect will remain invisible in prices and insufficient in market practice.

The so what of this study is therefore twofold. It shows that the property sector cannot assume that adaptation will automatically deliver financial resilience, and it provides the methodological tools to reveal unseen risks that remain off balance sheets. The novelty lies in uniting climate science, financial modelling, machine learning, and adaptation policy in a single asset-level framework.

In the tradition of Sarah Sayce's legacy, the research reframes sustainability from aspiration to obligation. It demonstrates that ignoring climate risk is no longer a question of ethics but of financial solvency. By making the unseen visible, this study equips the property profession to move from incremental change to systemic resilience.

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