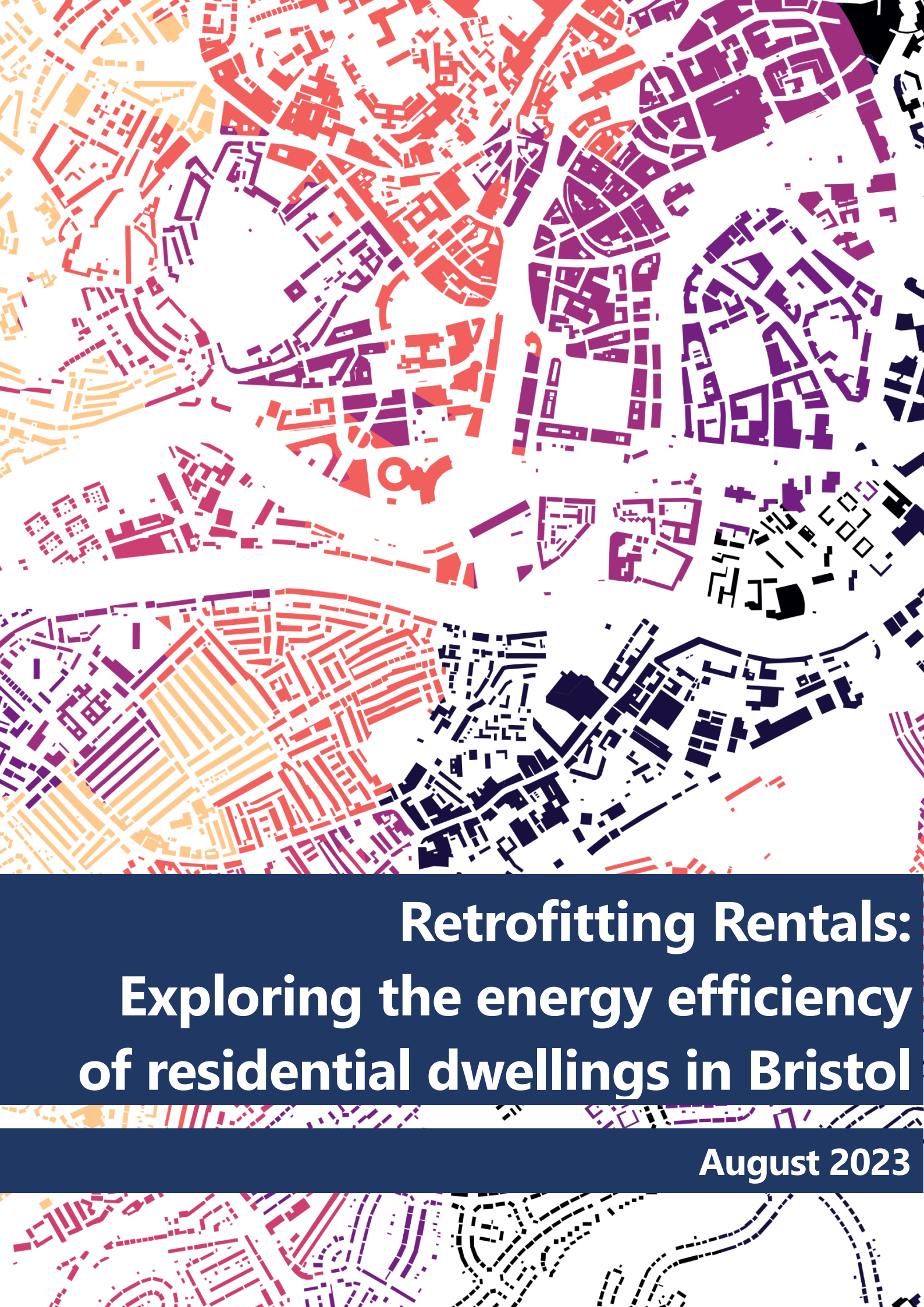

Retrofitting Rentals: Exploring the energy efficiency of residential dwellings in Bristol

August 2023

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1.0 Introduction and Executive Summary

Bristol stands as the fastest-growing UK core city. Its population grew 10% between 2011 and 2021, from 428,000 to 472,500 (UK Census, 2011 and 2021). It is a city where a large and growing proportion of residents rent their homes: 50,683 privately (26.8%) and 35,878 socially (18.7%) (UK Census, 2021). This means that more than a quarter of households in the city privately rent their homes, surpassing the national average by 6-9%.[1] Housing sits at the centre of many collective and intersecting environmental and social challenges, and working to improve the energy efficiency of privately rented dwellings can play a pivotal role in generating solutions for energy security, energy poverty, climate change, and the increasing cost of living.

This report endeavours to highlight the spatial inequalities of dwellings' energy efficiency across the Bristol Local Authority District through the application of statistical and spatial analysis. First, a number of datasets and how they are used is explained alongside a brief exploration of each dataset in relation to Bristol. Analysis is then explored in more detail by specifically focusing on energy efficiency, before moving onto analysis of geovisualisations and modelling. Analysis predominantly relies on Energy Performance Certificate (EPC) data. As such, analysis is limited to dwellings that have an EPC, and so within the owner-occupied tenure, there is a disproportionate overrepresentation of new builds due to EPCs being introduced in 2007.

There are several maps included in this report. A companion web map has been constructed so users can interact with these maps, alongside a few other useful maps.

The main findings of this report are as follows:

- The median EPC rating for all dwellings in Bristol is 67, matching the English average of 67. For private and social rentals, Bristol outperforms the English average, but lags in owner-occupied dwellings.
- The median efficiency rating for all dwellings in Bristol is D, apart from social rentals which have a median efficiency rating of C.
- 56% of all of Bristol's dwellings have an energy efficiency rating of D and below. 3% are F and below.
- Dwellings in the most deprived decile are associated with a median efficiency score 9 points lower than the least deprived decile.
- Flats are the built form where private rentals fall behind other tenures the most in terms of energy efficiency.

[1] 6% according to 2021 census data, 9% using Bristol City Council's own figures.

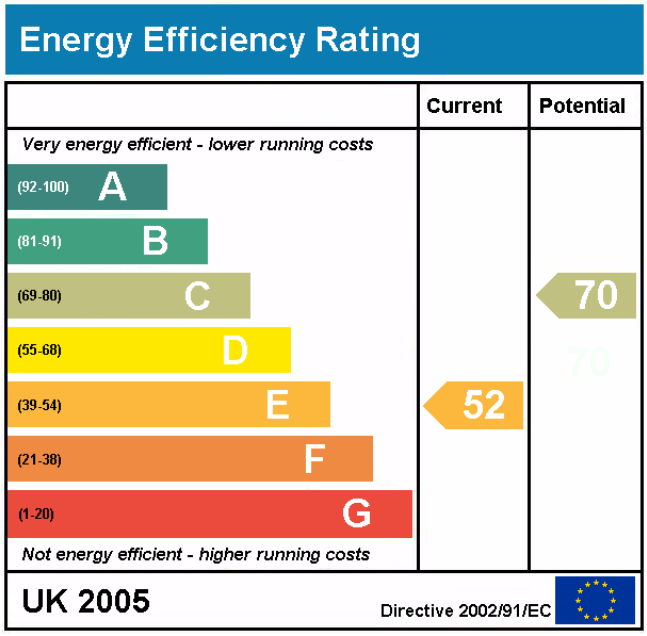
2.0 Data

This research combines several independent data sources to conduct analysis:

- Energy Performance Certificate (EPC) data (Open Data Communities, 2023) at Unique Property Reference Number (UPRN) level.
- A GeoPackage (a spatial data file used for mapping).
- The Land Registry's Price Paid Data, adjusted to Price per Square Meter (Chi et al, 2022).
- The 2019 Indices of Multiple Deprivation (IMD) (Ministry of Housing, Communities & Local Government, 2019).
- Various administrative boundary shapefiles and a UPRN shapefile (Office of National Statistics, 2023; Ordnance Survey, 2023).

2.1 Energy Performance Certificates (EPCs)

Every property in the UK is required to undergo a Standard Assessment Procedure (SAP) assigning it an Energy Performance Certificate (EPC) (see Figure 1 for an example certificate). This gives each dwelling an energy efficiency score from 1-120, with a higher value indicating a more energy efficient property. An EPC also captures several characteristics about each dwelling that is useful to researchers, such as tenure, floorspace, dwelling type (house, flat, etc.), and the fuel type used for heating. Each EPC is given the associated UPRN allowing for the geolocation of all properties. This report agglomerates UPRNs to various levels of administrative geography, such as Census Output Areas (OAs) (Figure 2, left) or Lower-Level Super Output Areas (LSOAs) (Figure 2, right). In the instance that multiple EPCs exist for the same address, previous EPCs are discarded, and the most recent EPC is used. EPCs became a mandatory regulatory mechanism relatively recently (first being used in 2007), and many owner-occupied dwellings that are not 'new builds' are therefore missing from the dataset. This means that owner-occupied dwellings are underrepresented in this dataset. This also means that within owner-occupied dwellings, new builds are disproportionately overrepresented. These two observations are something readers should remain cognisant of whilst reading and interpreting results.



Population	OA	LSOA
Median	330	1710
Mean	336	1763
Max	2159	3463
Min	102	1130
Range	2057	2333

Table 1 - Population Statistics comparison for OA's and LSOAs. Data: Census, 2021

Figure 1 (above) - An Example EPC

Figure 2 – Map showing Bristol Local Authority District's 2021 Census Output Area Boundaries (left) and Lower Super Output Area Boundaries (Right) Data: ONS Open Geography, 2023

2.2 Price Paid Data

The inclusion of house prices allows for important and novel comparisons for area-level house values and energy efficiency. Given the increasing importance of asset-wealth for household financial security, consideration of the value of housing is an important consideration. The financialisation of housing is pertinent for many cities across the UK, but particularly acute for Bristol in particular, where shortfalls in housing

supply and high demand inflate property and land values to very high amounts, increasing the incentive for financial speculation and commodifying housing.

2.3 Deprivation

The 2019 IMDs serve as a metric for gauging multidimensional poverty for LSOAs. This is made up of several indicators including deprivation affecting children; deprivation affecting older people; income deprivation; employment deprivation; education, skills and training deprivation; health deprivation; and crime deprivation. Deprivation is useful to include as persistent levels can result in long-term neglect of housing stock (Buyuklieva and Dennett, 2023). The presence of persistent deprivation within certain areas can result in landlords being hesitant to invest funds into enhancing energy efficiency. This reluctance may stem from a perception that the priority for tenants in the most deprived areas is to provide the absolute cheapest rental rates (Lang et al., 2021).

2.4 Building Attributes

Each EPC is issued for a specific property, taking into account a variety (over 90) attributes resulting in a score of energy efficiency from 0-120. This research focuses on efficiency scores, tenure, building age, and building type. The ways there are defined and grouped is explored below.

2.4.1 Efficiency

The efficiency rating assigned to each dwelling after its SAP is scored from 0-120. The median efficiency score in Bristol is 67, the mean score is 65.5, with a standard deviation of 13 (Figure 3).

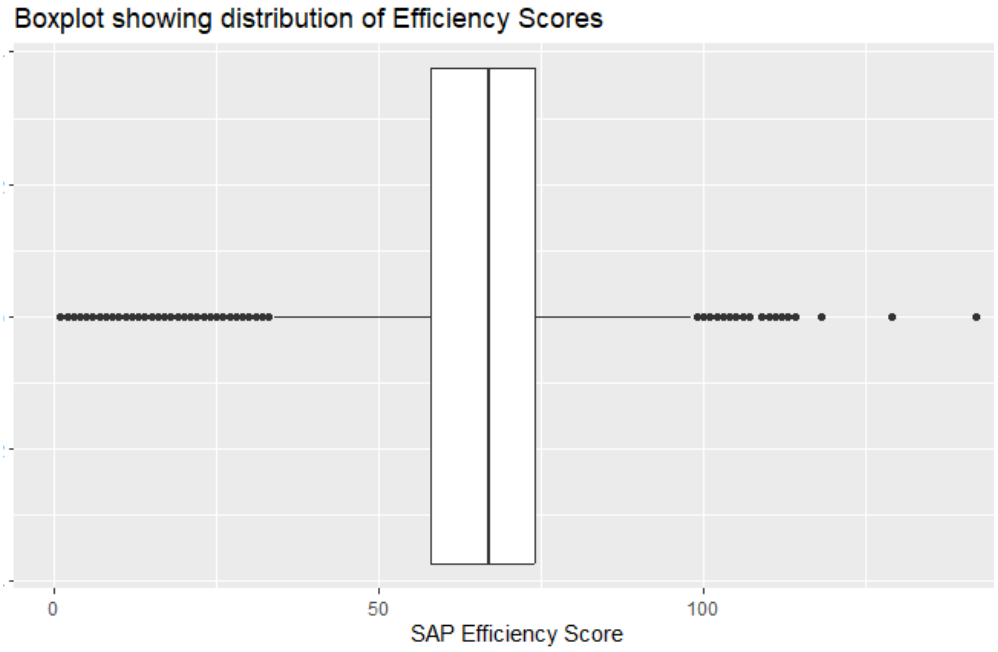


Figure 3 – Boxplot showing the distribution of dwellings' efficiency scores in Bristol Local Authority District. Data: Open Data Communities (2023)

2.4.2 Tenure

The three tenures that make up most of the housing sector are:

- Owner-occupied: people who own the property they live in outright or with a mortgage.
- Privately rented: people who rent their dwelling from a private landlord.
- Socially rented: people who rent their dwelling from a local authority or housing association.

Figure 4 indicates the saliency of addressing the efficiency of private rentals in Bristol, with a significantly larger proportion of the city's residents privately renting their dwellings than the national figure. Bristol has a lower proportion of owner-occupied dwellings than the English average (-7.5%), with higher rates of both social rentals (+1.6%) and private rentals (+5.9%) as of 2021.

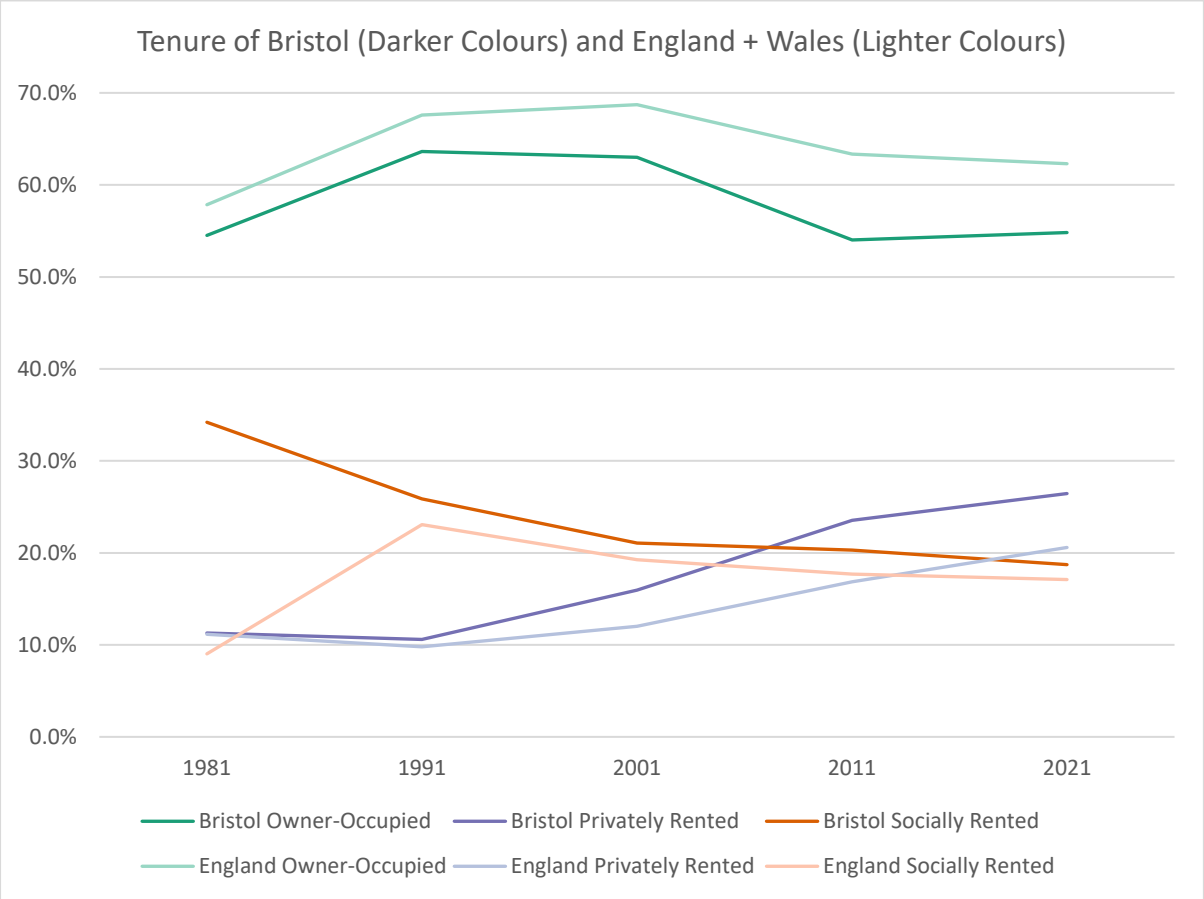


Figure 4 - The proportion of dwellings in each tenure for Bristol (darker colours) and England (lighter colours) since 1981. Source: Census, 1981, 1991, 2001, 2011, 2021

Table 2 also indicates how relatively high Bristol ranks in terms of private rentals as a proportion of Local Authority Districts' total dwellings. Bristol ranks 46th out of 318 Local Authority Districts for the proportion of dwellings that are privately rented.

2021 Census		Owner-Occupied		Socially Rented		Privately Rented		Private
City	Total Dwellings	Count	Proportion	Count	Proportion	Count	Proportion	Rental Rank
Brighton and Hove	121,401	63,412	52.2%	18,051	14.9%	39,938	32.9%	13
Manchester	214,730	81,604	38.0%	63,276	29.5%	69,850	32.5%	15
Nottingham	124,744	56,926	45.6%	31,797	25.5%	36,021	28.9%	33
Bristol	**191,636**	**105,075**	**54.8%**	**35,878**	**18.7%**	**50,683**	**26.4%**	46
Liverpool	207,490	98,419	47.4%	54,757	26.4%	54,314	26.2%	48
Cardiff	147,331	85,865	58.3%	25,278	17.2%	36,188	24.6%	56
Newcastle upon Tyne	122,796	61,058	49.7%	33,474	27.3%	28,264	23.0%	66
Birmingham	423,455	226,657	53.5%	99,498	23.5%	97,300	23.0%	67
Leeds	341,465	196,531	57.6%	69,741	20.4%	75,193	22.0%	75
England	**23,436,087**	**14,605,020**	**62.3%**	**4,005,663**	**17.1%**	**4,825,404**	**20.6%**	NA
Sheffield	231,947	135,948	58.6%	52,334	22.6%	43,665	18.8%	129

Table 2 - Proportion of Tenures across a selection of English Local Authority District Cities. "Private Rental Rank" column refers to the where the Local Authority District ranks in terms of proportion of privately rented dwellings across all Local Authority Districts captured in the 2021 census. Data: Census, 2021

2.4.3 Building Age

Property ages are coarsened from raw EPC categories (of which there are nearly 30) by grouping into categories of a roughly equal duration. Figure 5 A graph showing counts of buildings in Bristol by age.

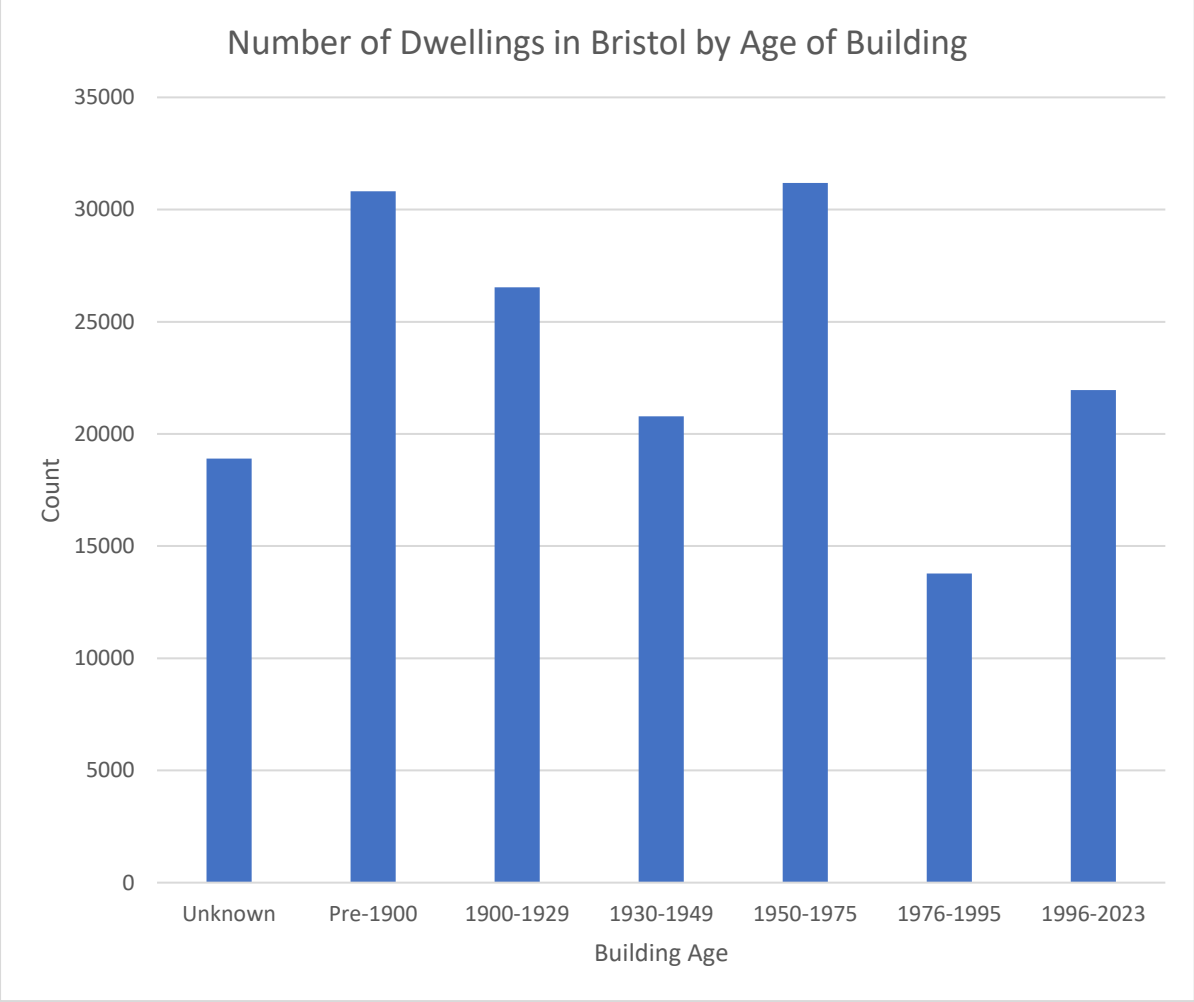


Figure 5 – Bar graph showing the counts of dwellings by age in Bristol. Data: Open Data Communities (2023)

2.4.4 Building type

The EPC assessment encompasses various building characteristics, including the configuration of the dwelling such as mid- or end-terrace, semi-detached, or detached. Additionally, the dwelling types are categorised as houses, flats, bungalows, maisonettes, or park homes. In this study, bungalows, maisonettes, and park homes are consolidated under the 'other' category, due to their relatively low occurrence. Figure 6 presents a summary of this variable. As mentioned above, owner-occupied dwellings are underrepresented due to limitations of the EPC dataset.

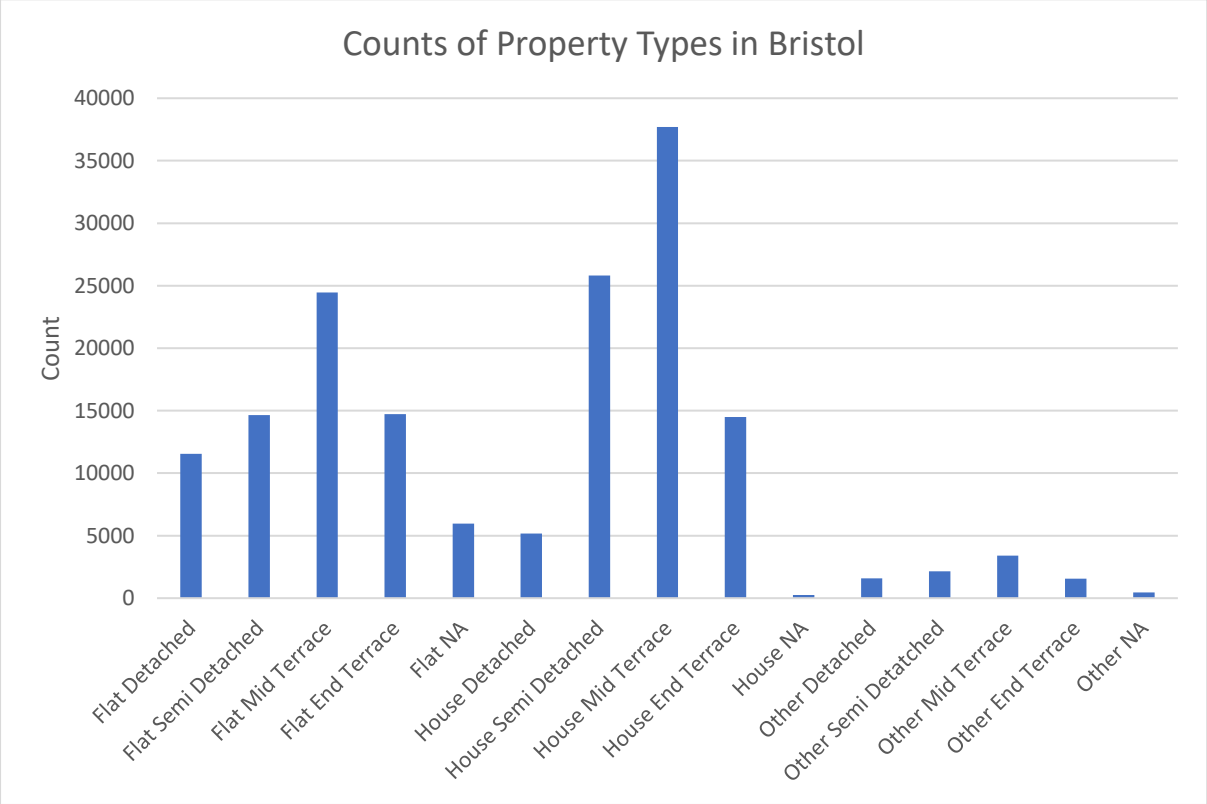


Figure 6 – Bar graph showing the counts of different dwelling types in the Bristol Local Authority District. Data: Open Data Communities (2023)

3.0 Analysis

3.1 Tenure

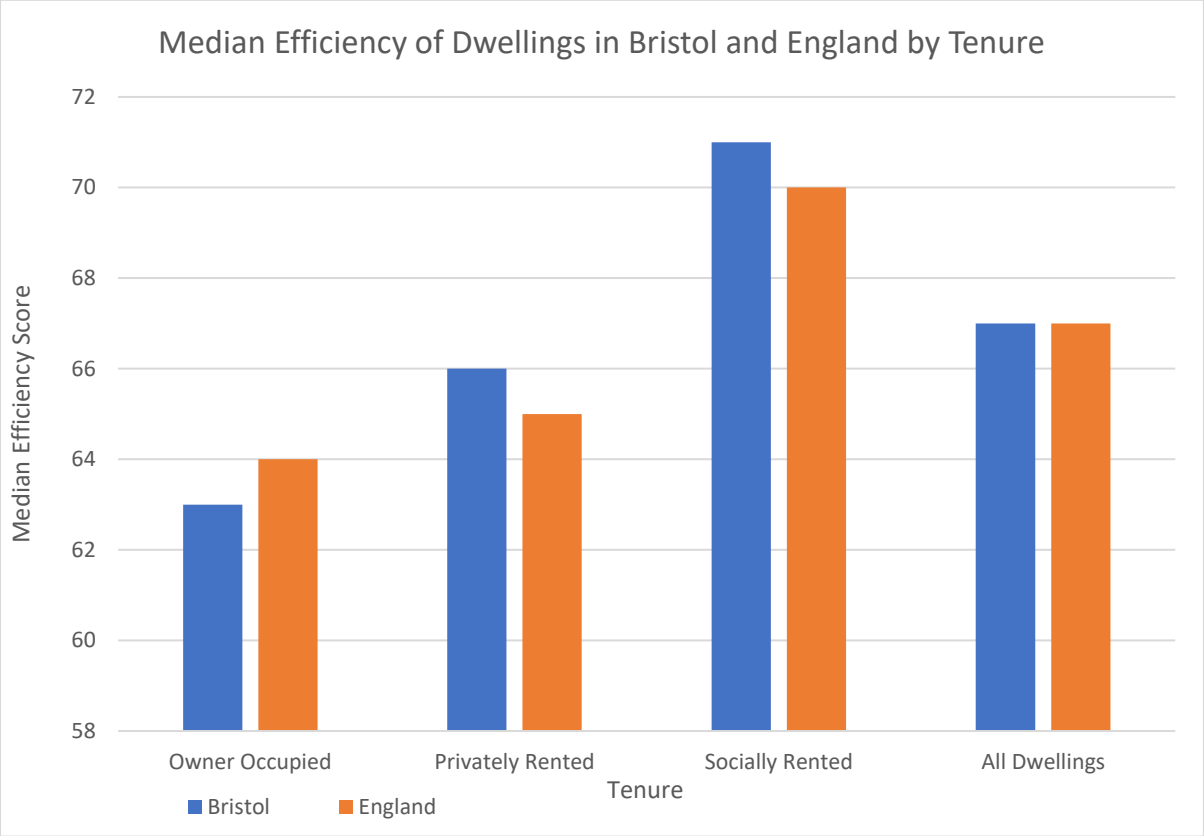


Figure 7 - Median efficiency scores for dwellings by tenure in Bristol and England. Data: Office for National Statistics, 2022, and Open Data Communities (2023).

Figure 7 indicates that both socially and privately rented dwellings in Bristol are, on average, slightly more energy efficient than the English average, with a lower median efficiency score only for owner-occupied dwellings. This also indicates that privately rented homes are generally less efficient than socially rented homes, but more efficient that owner-occupied ones. This aligns with the established understanding that social housing tends operate as a protective factor for low-income households against varying dimensions of poverty, including energy poverty.

3.2 Form

Delving deeper into the specifics of Bristol's dwellings and introducing property form, Figure 8 reveals that the largest tenure/property type are owner-occupied houses, but flats are the most common socially rented and privately rented property type. This graph also indicates that the efficiency scores of privately rented and owner-occupied dwellings are more comparable than socially rented dwellings. Of note is the median efficiency scores for flats: this is the only tenure/form combination where private rentals are less efficient than those that are owner-occupied. However, whilst this indication is likely valid, given that EPC data underestimates the efficiency of owner-

occupied dwellings (due to underrepresentation in the dataset), the true extent to which owner-occupied dwellings compare to privately rented ones is unknown.

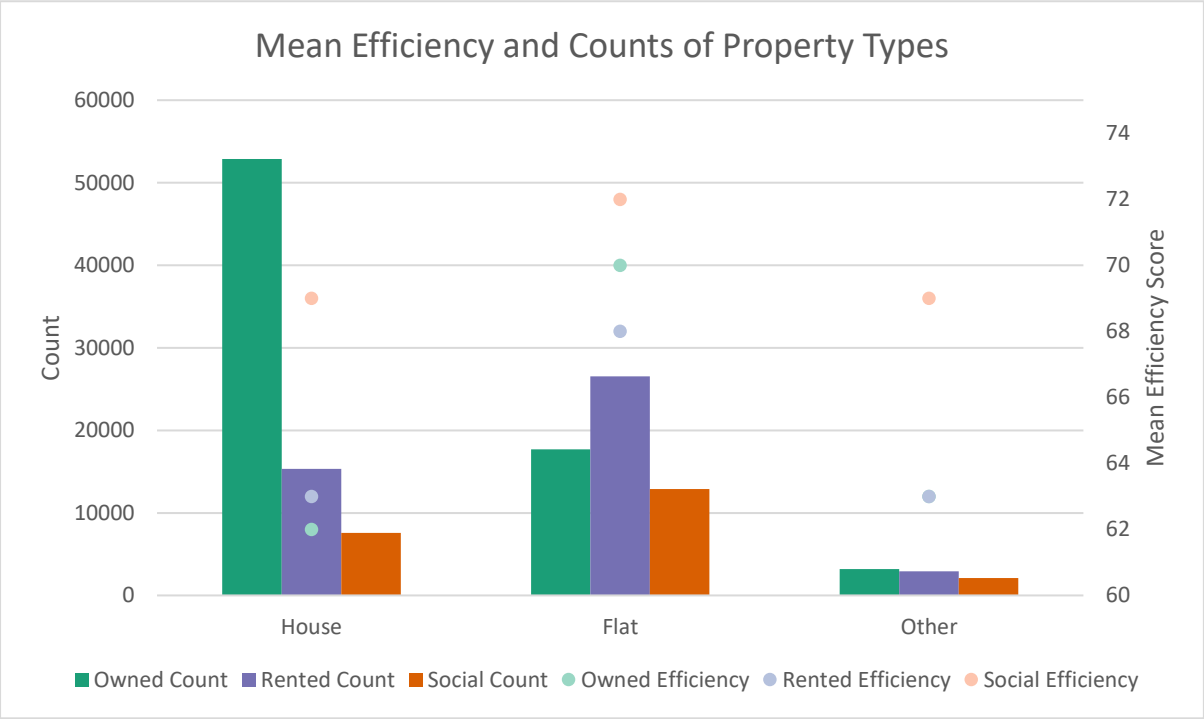


Figure 8 – Bar graph and scatterplot showing counts of property types by tenure and median efficiency scores in Bristol Local Authority District. Owned-Other efficiency is also 69. Data: Open Data Communities (2023)

3.3 Age

Figure 9 is a graphical representation of a simple linear regression between building age and energy efficiency, confirming preexisting narratives that older buildings are less energy efficient or more difficult and costly to insulate (Department for Levelling Up, Housing & Communities, 2022). This also indicates a relatively sizeable improvement in efficiency from the 1950's. Figure 10 and Figure 11 builds on these findings, where we can observe that the building ages with the largest share of private rentals are the very oldest and very newest. For mid-20th century dwellings, owner-occupancy dominates.

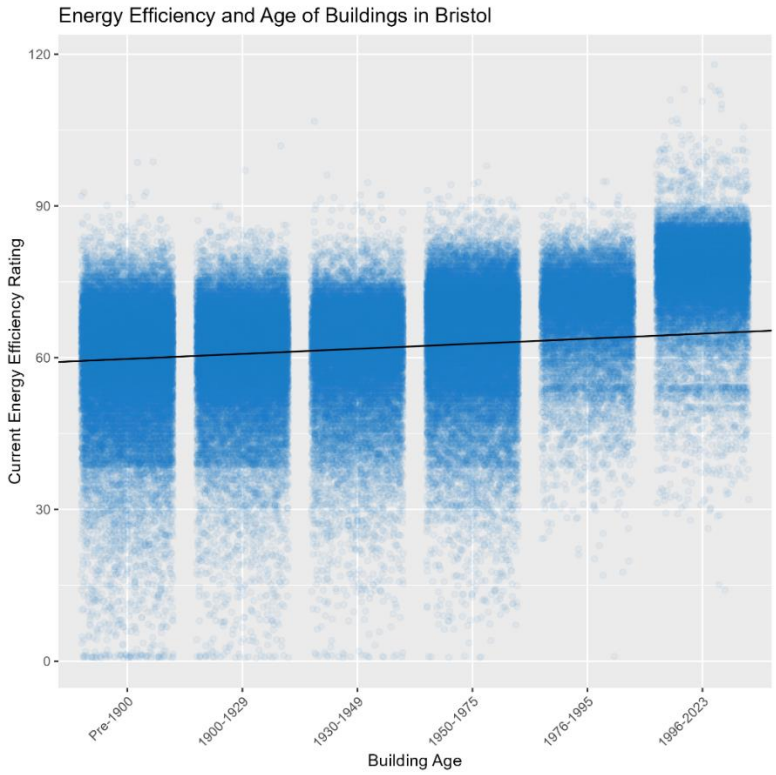


Figure 9 – Scatterplot and linear regression line of building ages and efficiency scores in Bristol Local Authority District. Data: Open Data Communities (2023)

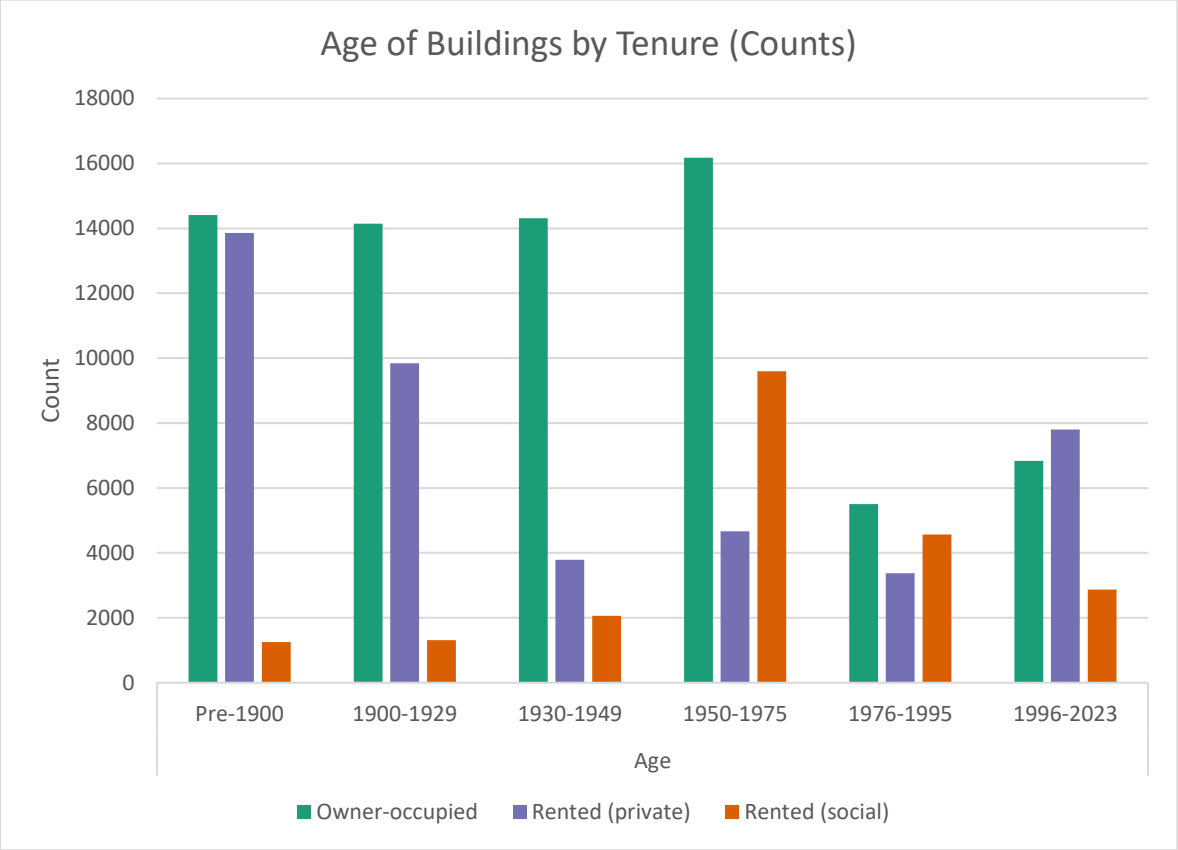


Figure 10 – Bar graph showing counts of buildings by age and tenure in Bristol Local Authority District. Data: Open Data Communities (2023)

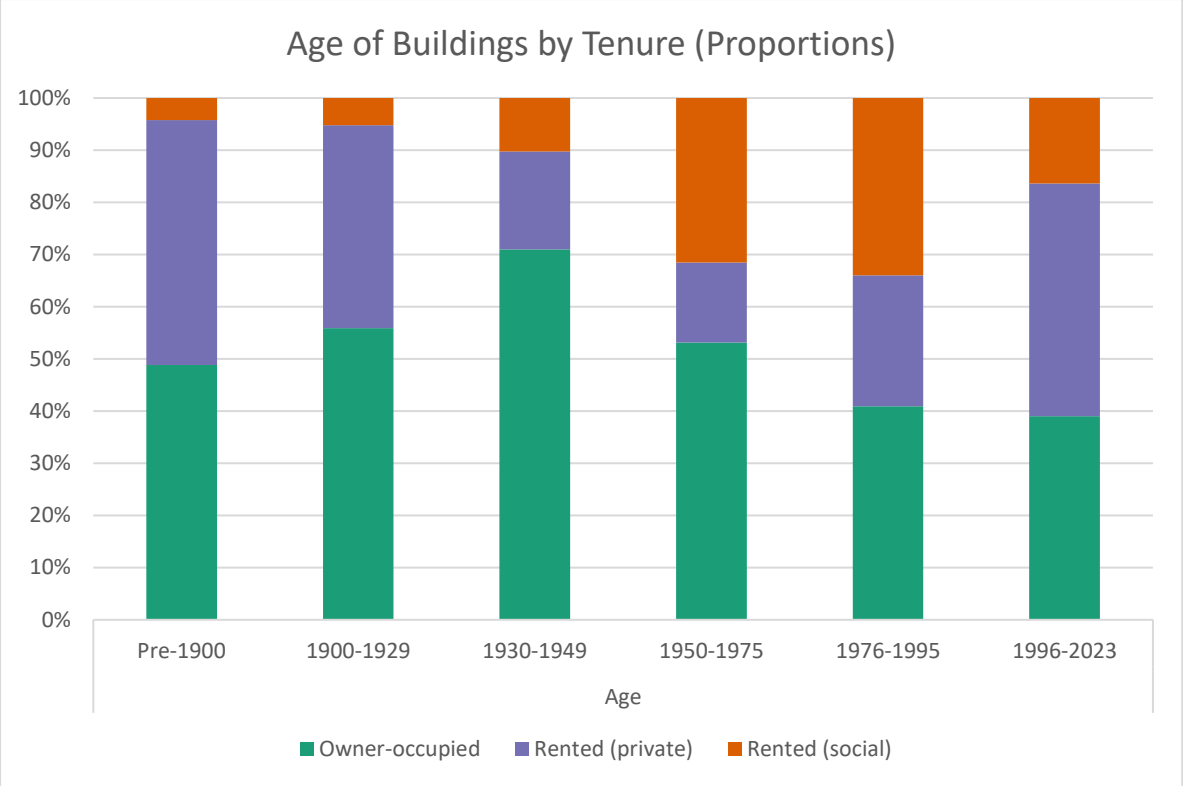


Figure 11 – Bar graph showing buildings by age and proportional tenure in Bristol Local Authority District. Data: Open Data Communities (2023)

3.4 Deprivation

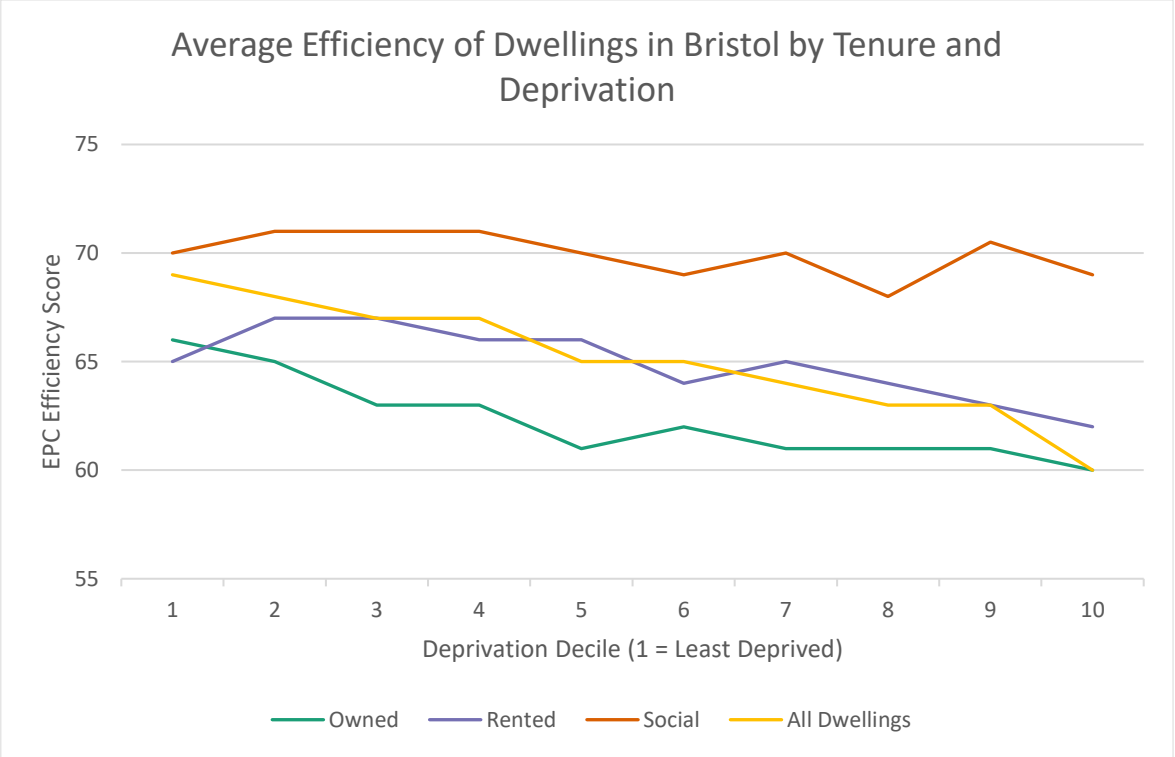


Figure 12 – Line graph showing median EPC scores by property type and deprivation decile (1 = least deprived) in Bristol Local Authority District. Data: Open Data Communities, 2023 and Ministry of Housing, Communities & Local Government, 2019.

Figure 12 indicates that greater levels of deprivation are associated with decreased levels of energy efficiency for all dwellings in Bristol. Breaking this down by tenure, we observe that privately rented dwellings in the most deprived decile are 3 points lower in median efficiency than those in the least deprived decile, compared to 1 point lower for socially rented and 6 points lower for owner-occupied. Considering all tenure types, this expands to 9 points overall, likely due to the greater variability between categories. These figures are relatively small in magnitude (akin to smaller-scale improvements such as using energy efficient lighting or installing double glazing) but indicate there is a hierarchy to energy efficiency and deprivation. Social rentals are associated with relatively consistent levels of energy efficiency across all levels of deprivation, potentially speaking to the efficacy of stronger regulation. Owner-occupied and private rentals are associated with marked decreases in efficiency as deprivation increases, however, compounding the negative impacts of energy poverty for those already worse off.

3.5 Building Type

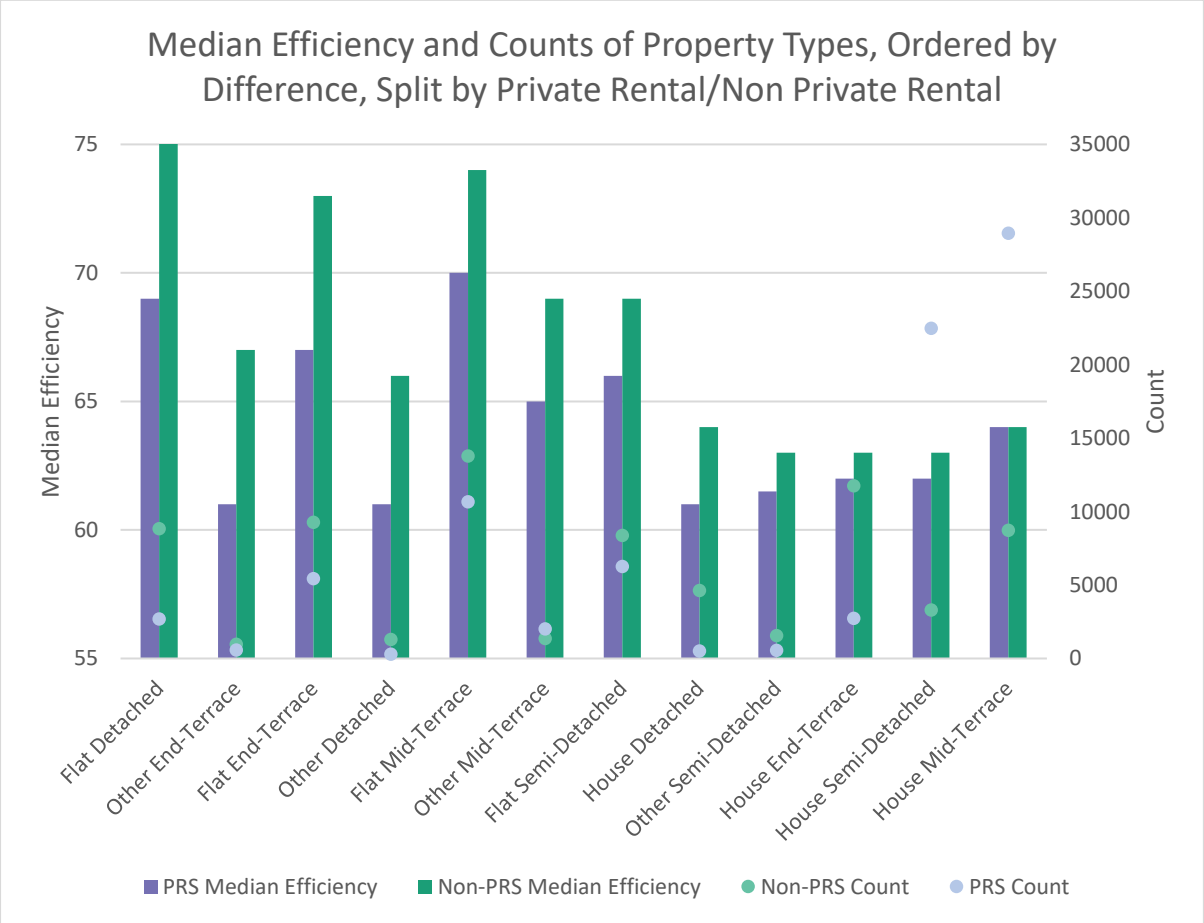


Figure 13 – Bar graph and scatterplot showing counts of different building types (lines) and median efficiency scores (bars) split by tenure for Bristol Local Authority District. Categories are ordered from left to right by difference in efficiency, sot the leftmost category is the one in which private rentals trail the most behind non-private rentals in terms of efficiency. Data: Open Data Communities, 2023

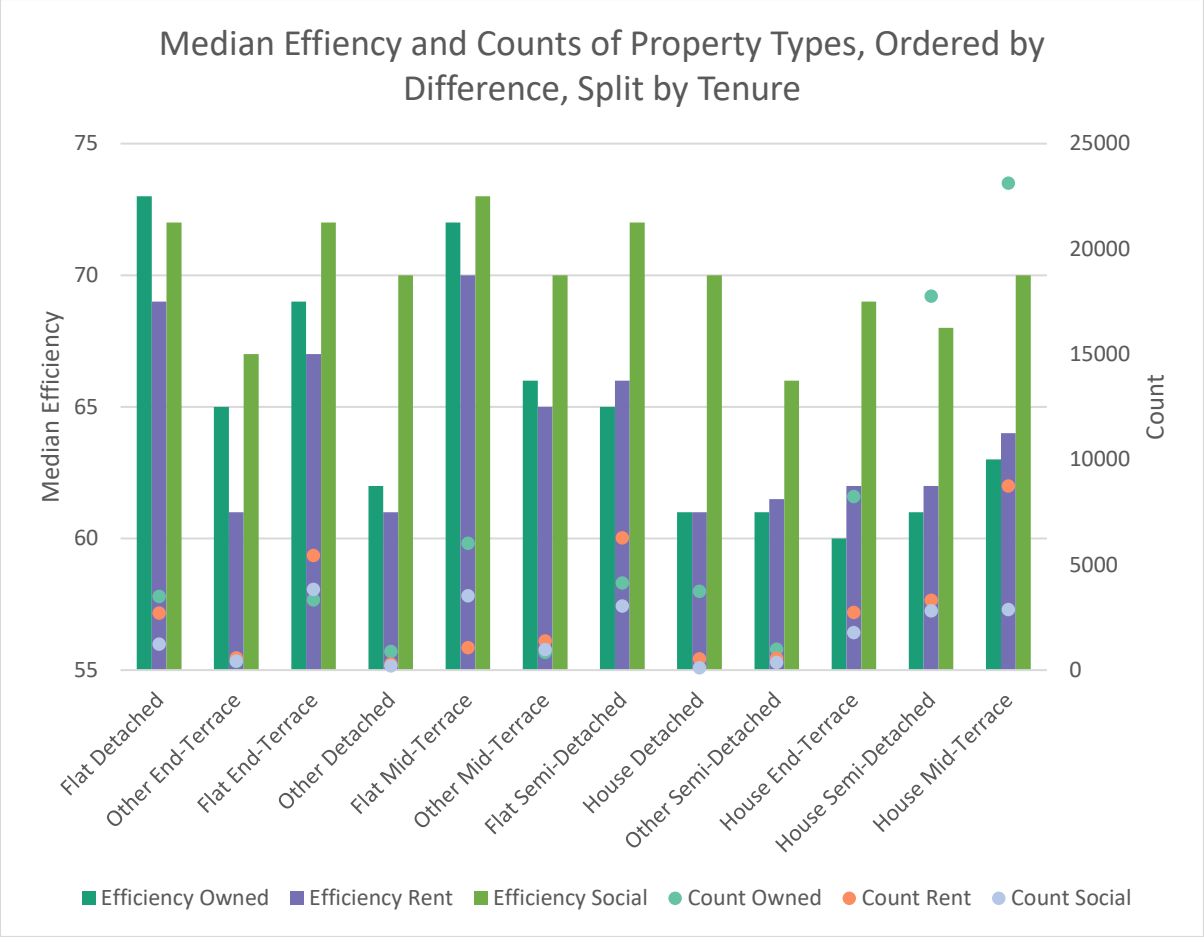


Figure 14 – Bar graph and scatterplot showing counts of different building types (lines) and median efficiency scores (bars) split by tenure (to greater levels of granularity than Figure 13) for Bristol Local Authority District. Categories are ordered the same as Figure 13. Data: Open Data Communities, 2023.

Incorporating building type, tenure, and efficiency into analysis yields a number of pertinent observations. Figure 13 and Figure 14 order these categories by greatest to smallest difference in efficiency by tenure, left to right. First looking at efficiency, we see that the largest disparity in efficiency between private rentals and non-private rentals is in detached flats. Figure 13 and Figure 14 confirm the findings of Figure 8 above, showing that flats are generally the form for which private rentals falls behind other tenures the most in terms of efficiency. At the right end of the graphs, we see that houses are the form most similar in terms of efficiency across tenures. Considering that terraced and semi-detached houses are one of the most common built forms in Bristol, however, Figure 15 spatially unpacks the distribution of privately rented houses to explore if this a difference in efficiency is more apparent in certain areas. However, Figure 15 indicates there is no clear clustering to energy inefficient privately rented houses.

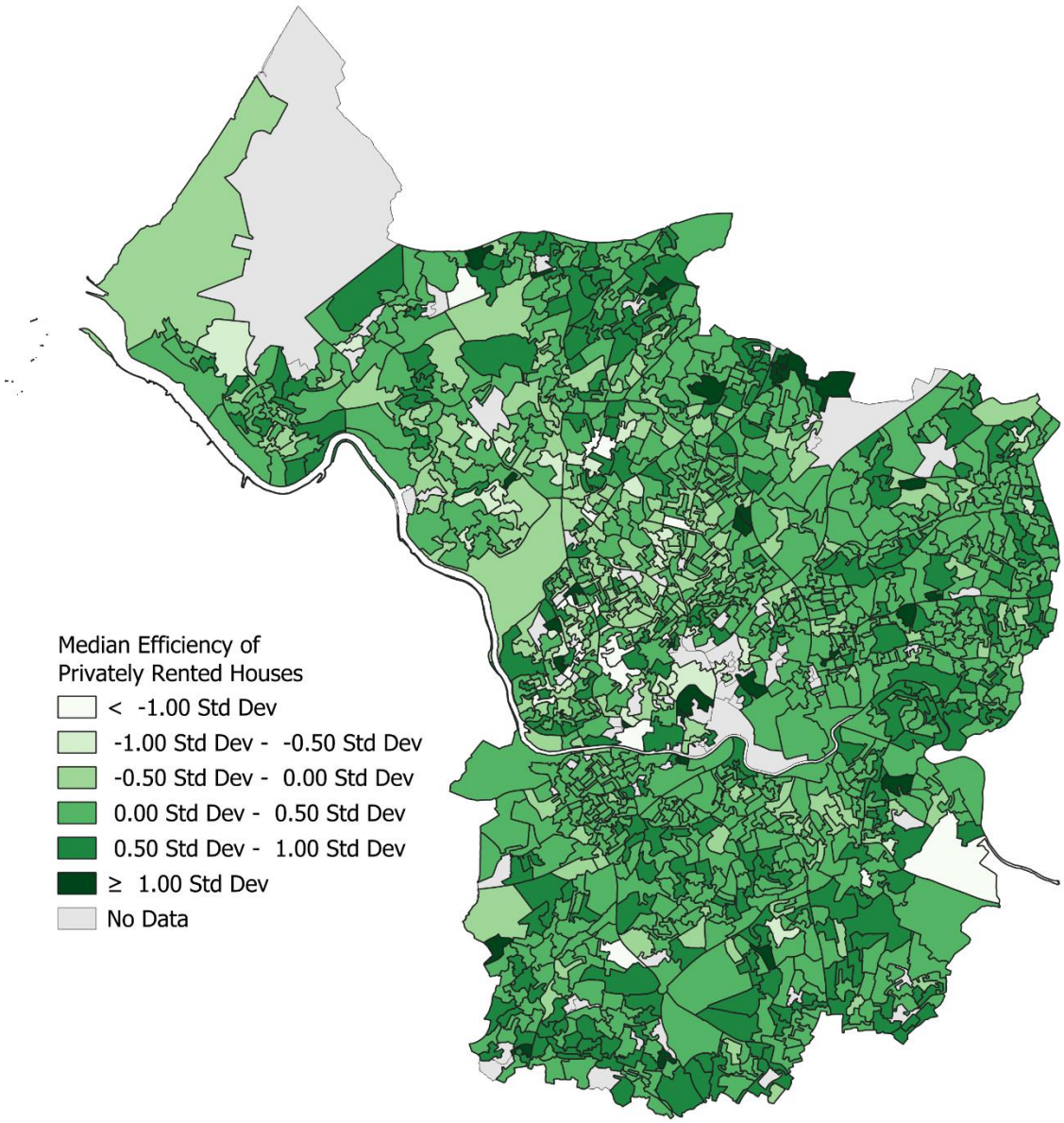


Figure 15 - Map of Bristol Local Authority District by Output Area. Coloured by standard deviations of median efficiency scores for privately rented houses by OA in Bristol. Data: Open Data Communities, 2023

Spatial analysis is further expanded upon in section 3.6. Figure 16 shows these differences by property type and deprivation, showing the rates of decline in efficiency as deprivation increases. For owned and rented flats, there is a substantial step down as dwellings drop into the most deprived half (as opposed to a linear decline as seen with owned houses).

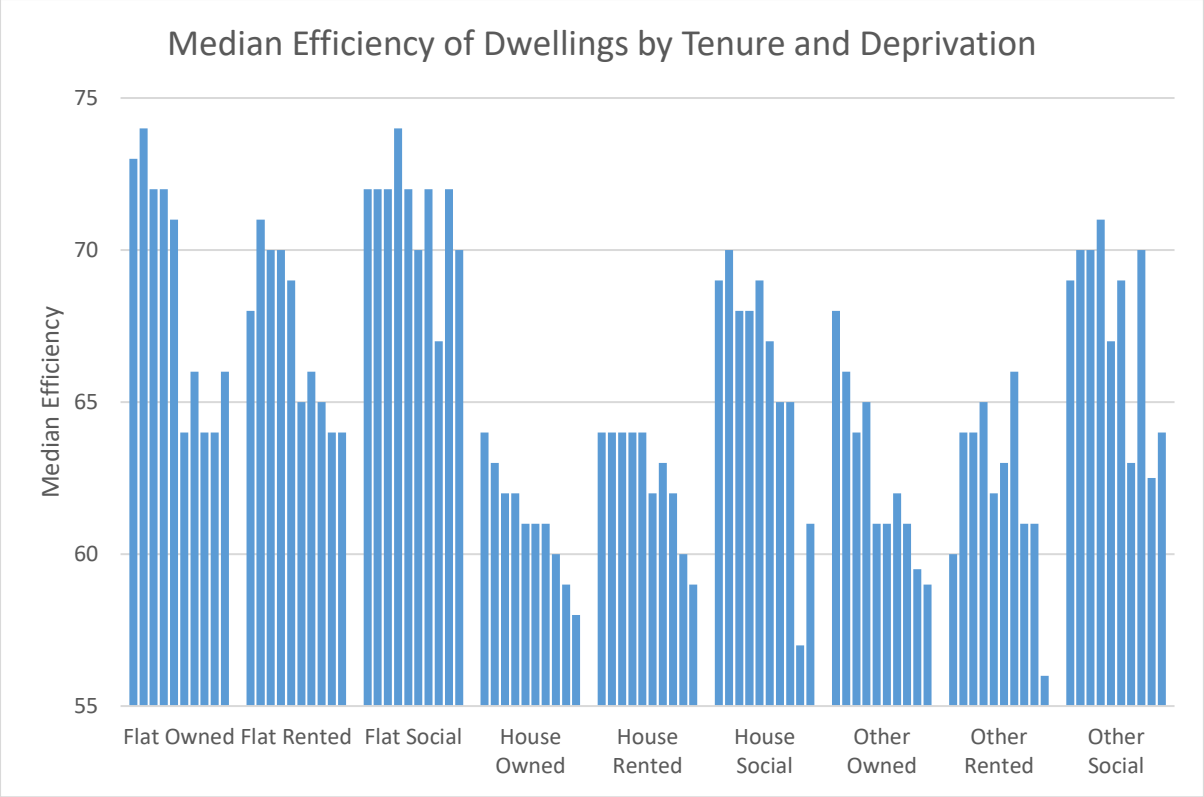


Figure 16 (above) – Bar graph showing median efficiency scores for dwellings by tenure and deprivation for Bristol Local Authority District.. Deprivation deciles are displayed from left to right as 1-10 (1 = least deprived decile) within each group. Data: Open Data Communities, 2023

3.6 Mapping efficiency

All maps included in this report (as well as additional maps exploring other relevant variables) are available to explore interactively here.

Figure 17 shows a map of the Bristol Local Authority District by OA. Here we can observe that when considering all dwellings, the most efficient areas are typically around the city centre, with worse performance in various areas further out, and with a large cluster located in the northwest. Comparing this with Figure 18 and Figure 19, we can observe that these inefficiencies correlate larger buildings and to an extent, older buildings.

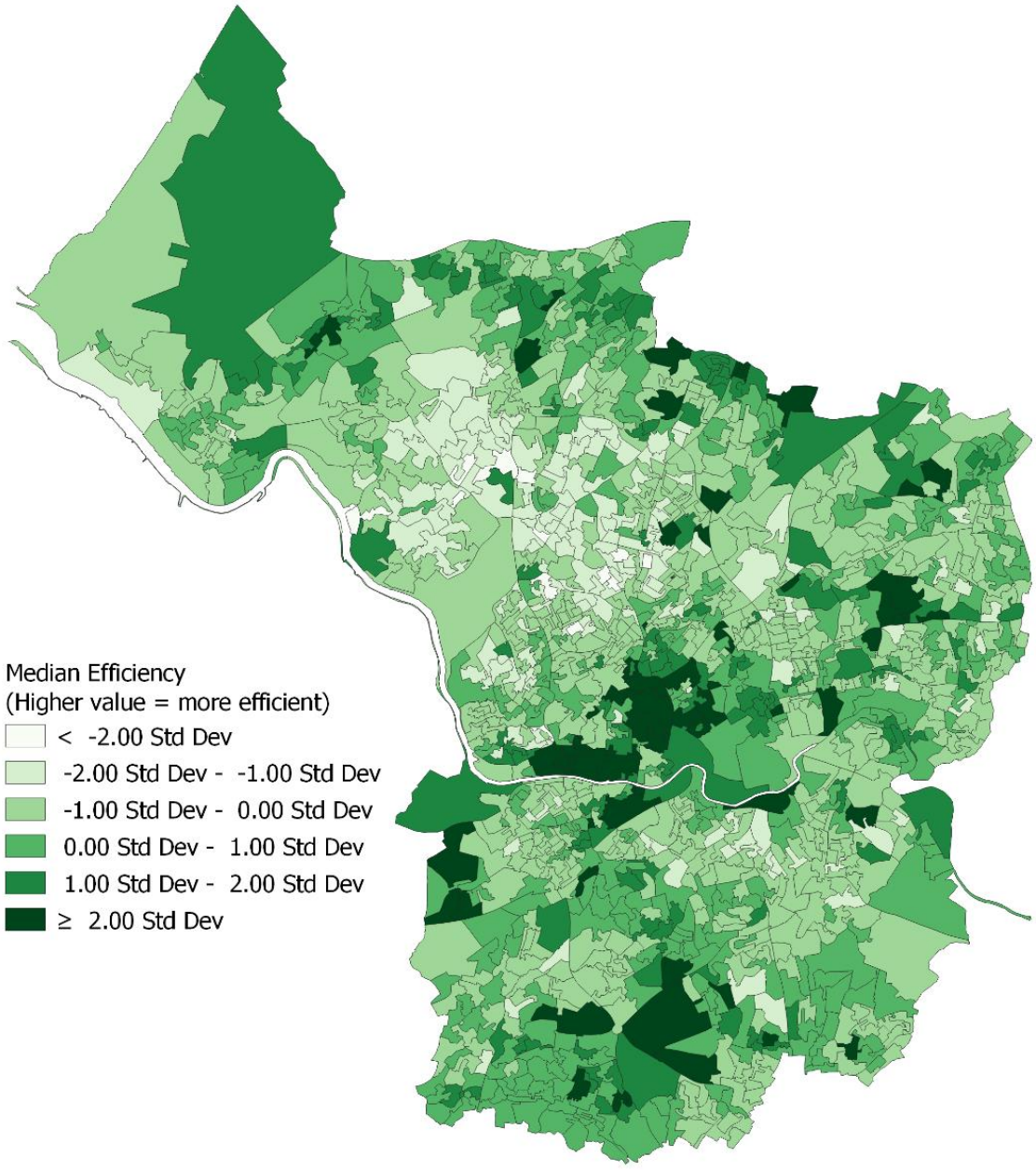


Figure 17 - Map of Bristol Local Authority District by Output Area. Coloured by standard deviations of median efficiency scores for dwellings by OA in Bristol. Data: Open Data Communities, 2023

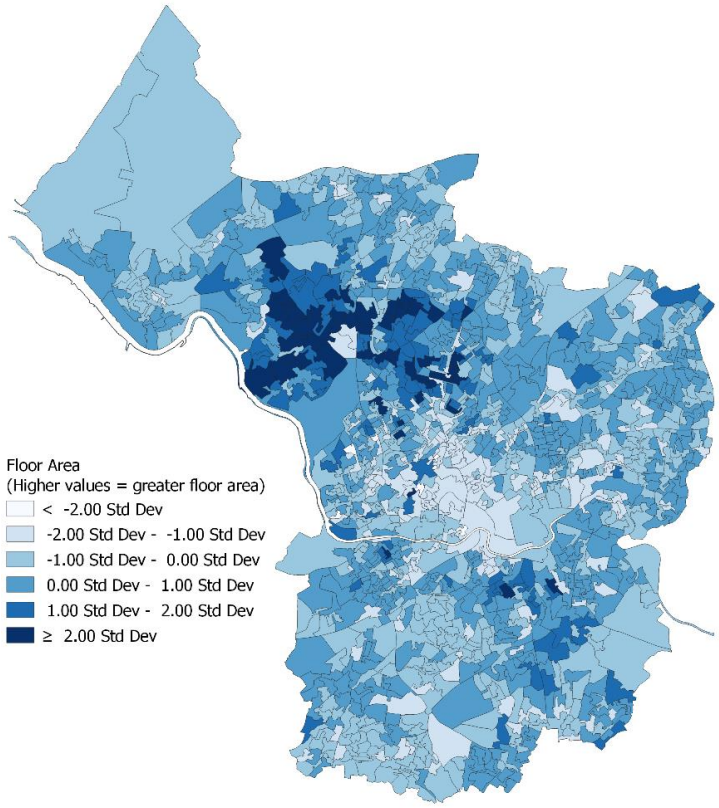


Figure 18 (above) – Map of Bristol Local Authority District by Output Area. Coloured by median total floor area of dwellings. 1 standard deviation is approximately 20sqm, and the mean value is 80sqm. Data: Open Data Communities, 2023.

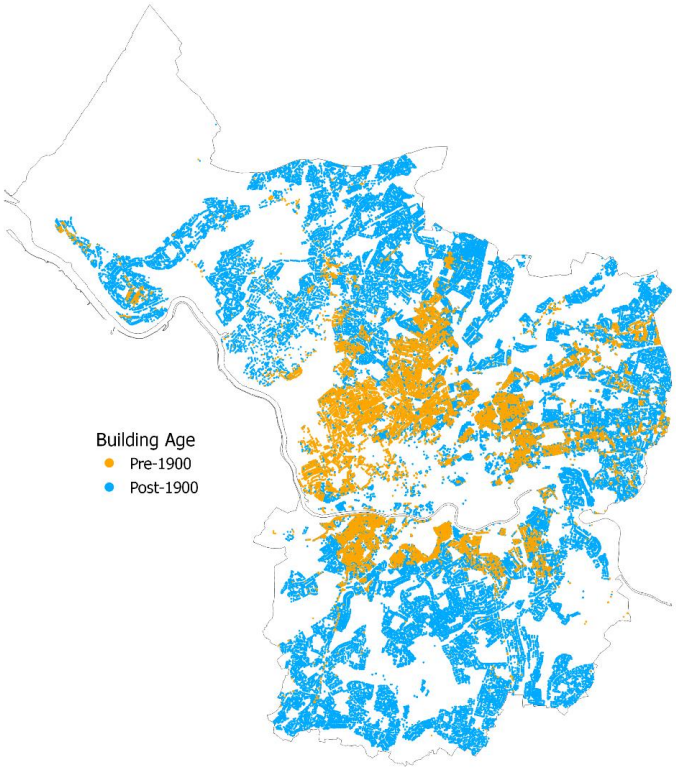


Figure 19 – Map of Bristol Local Authority District, showing all dwellings as points, split by listed age as pre-1900 and post-1900. Data: Open Data Communities, 2023

3.6.1 Mapping areas of greatest need

Figures 20-25 visualise the proportion of different types of dwelling in each OA that fall below a certain energy efficiency threshold. To aid interpretation, two colour palettes are implemented to distinguish between OAs that have less than 5 dwellings, or 5 or more, in total. Additionally, different proportion thresholds are used for visualising properties D and below, and properties F and below.

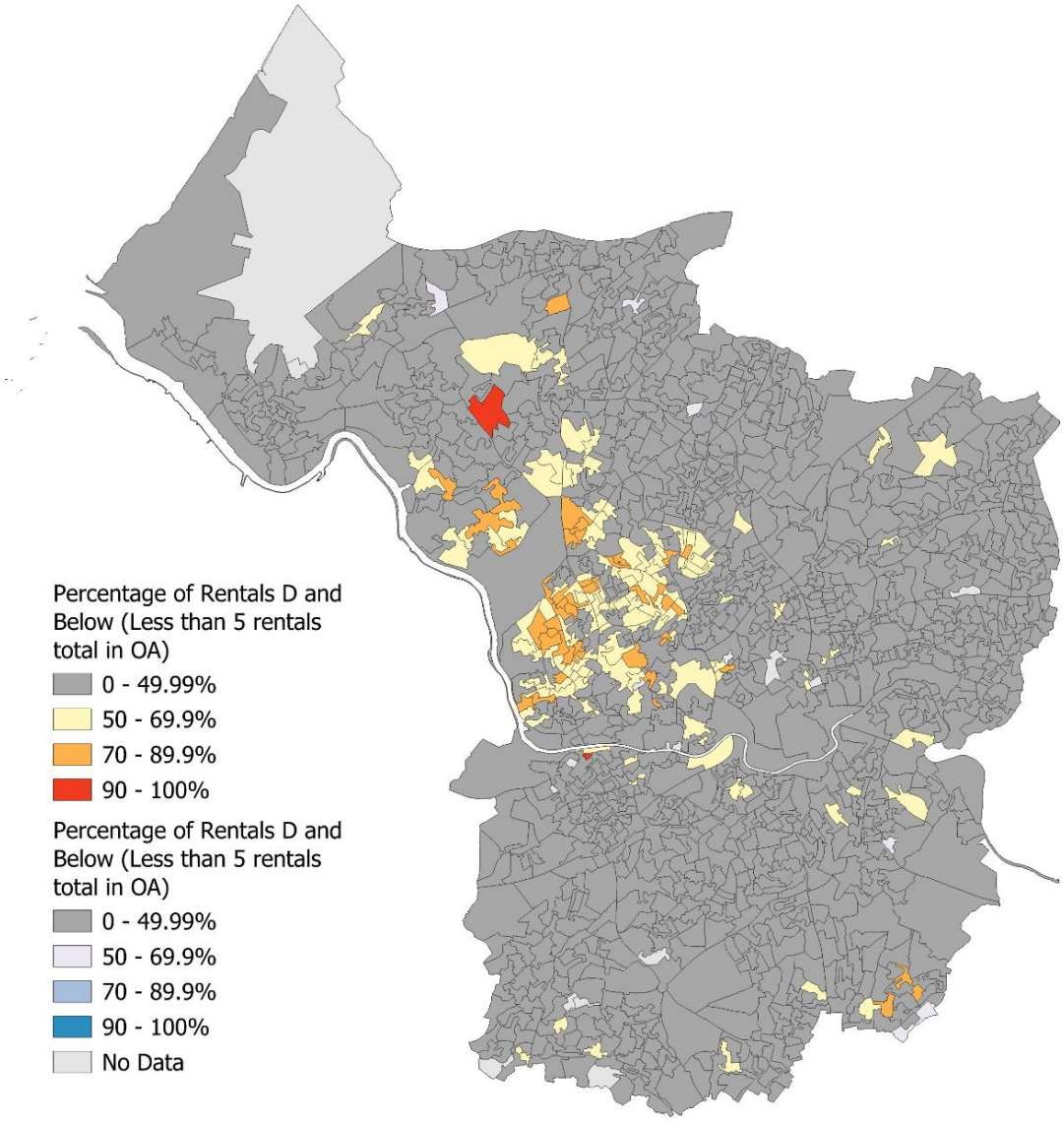


Figure 20 - Map of Bristol Local Authority District by Output Area. Coloured by percentage of private rentals in each OA that have an EPC efficiency rating of D and below. Data: Open Data Communities, 2023

Figure 20 shows the percentage of each OAs privately rented dwellings that are rated D and below for efficiency – an important consideration given the government's Net Zero Strategy recommends homes to reach higher minimum standards of efficiency band C by 2035. Figure 20 indicates the cluster of high proportion, energy inefficiency properties located immediately northwest of the city centre (Clifton, Redland, Cotham).

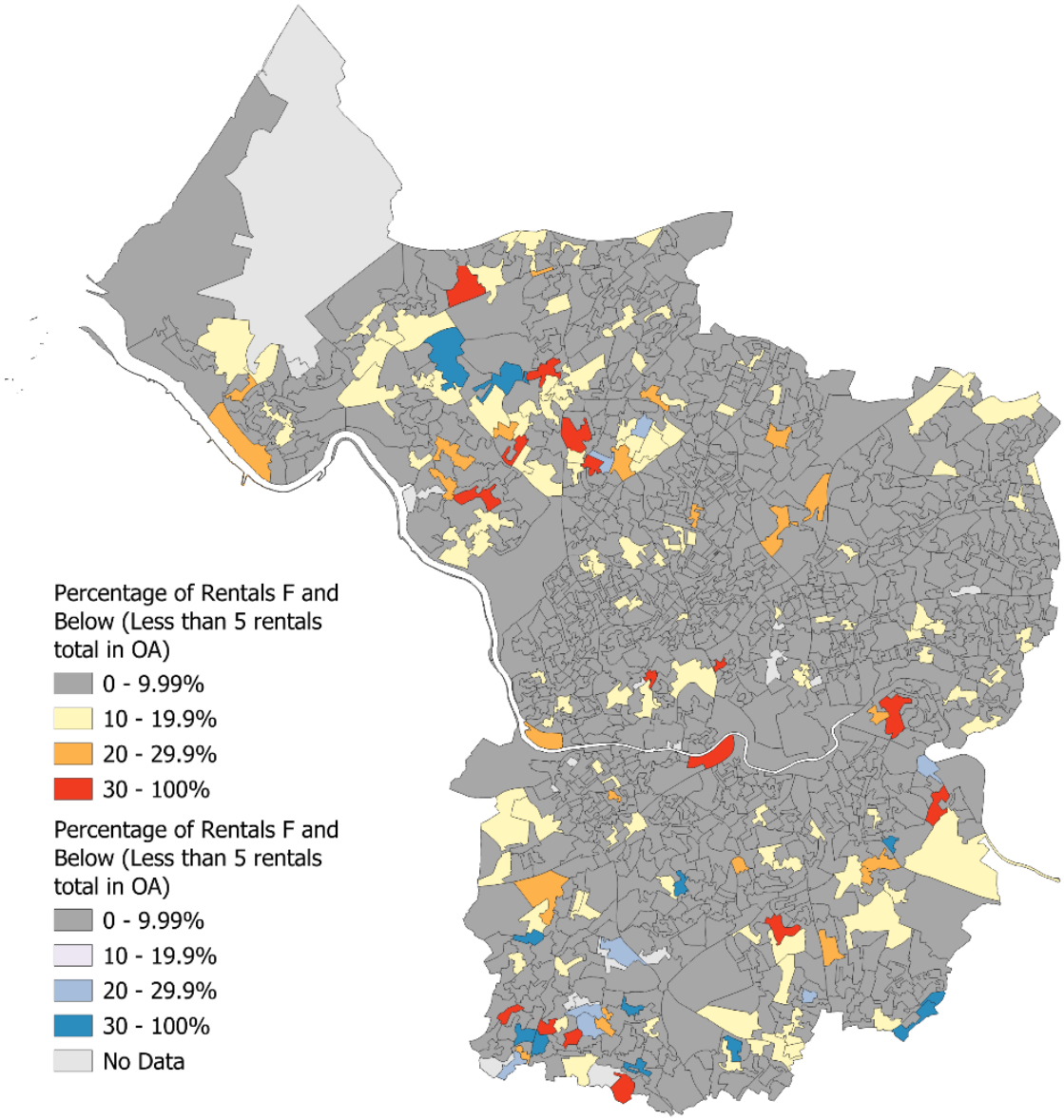


Figure 21 - Map of Bristol Local Authority District by Output Area. Coloured by percentage of private rentals in each OA that have an EPC efficiency rating of F and below. Data: Open Data Communities, 2023

Figure 21 visualises a stricter criterion, examining private rentals that are rated F and below. These extremely inefficient properties are more spatially disparate, but there is still some vague clustering in the very northwest and southwest of the map. There is also an incontiguous distribution of inefficient OAs across the entire city.

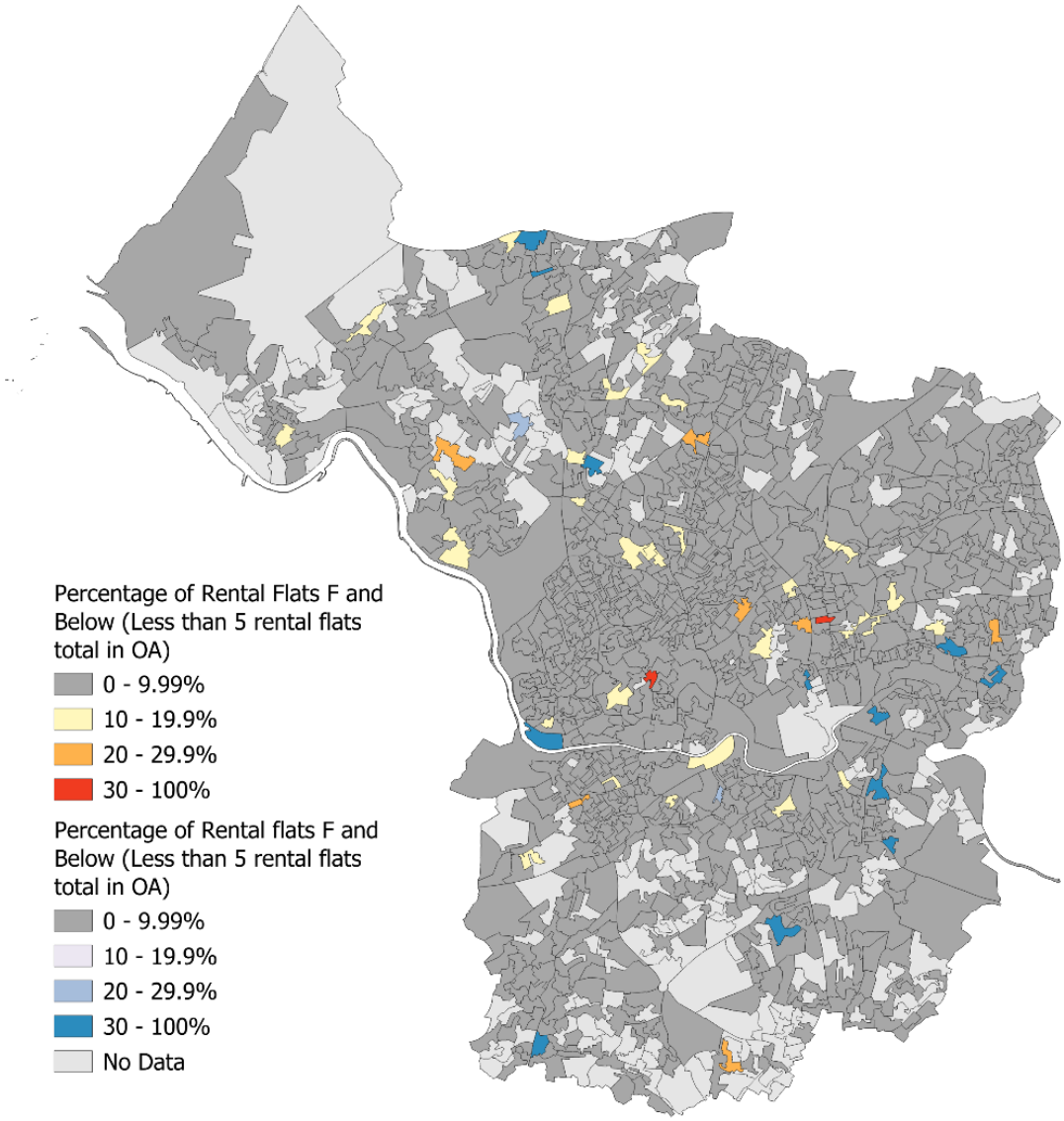


Figure 22 - Map of Bristol Local Authority District by Output Area. Coloured by percentage of privately rented flats in each OA that have an EPC efficiency rating of F and below. Data: Open Data Communities, 2023

Figure 22 refines this criterion even further, exploring privately rented flats rated F and below. These are similarly spatially disparate and incontiguous, but the red and orange areas are certainly worth greater exploration, as they represent the OAs with the highest percentage of energy inefficiency flats.

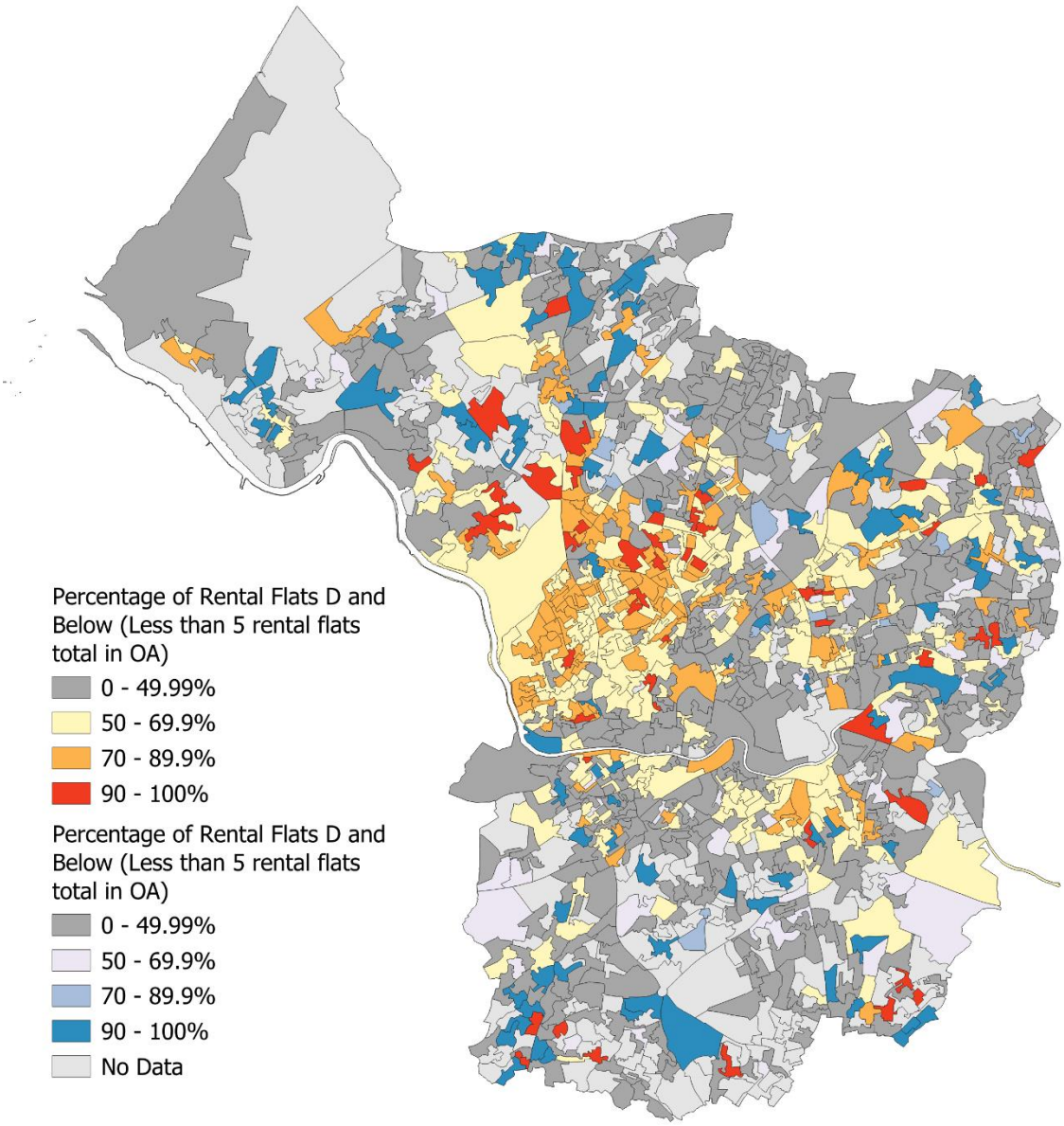


Figure 23 - Map of Bristol Local Authority District by Output Area. Coloured by percentage of privately rented flats in each OA that have an EPC efficiency rating of D and below. Data: Open Data Communities, 2023

Figure 23 looks at privately rented flats only, but loosens the efficiency criteria, visualising privately rented flats rated D or below. This elucidates some more obvious clustering, with notable inefficient proportions northwest of the city centre, and also immediately southeast, around Totterdown. The red areas are also worth greater exploration, as these are the OAs where over 90% of privately rented flats are rated D or below.

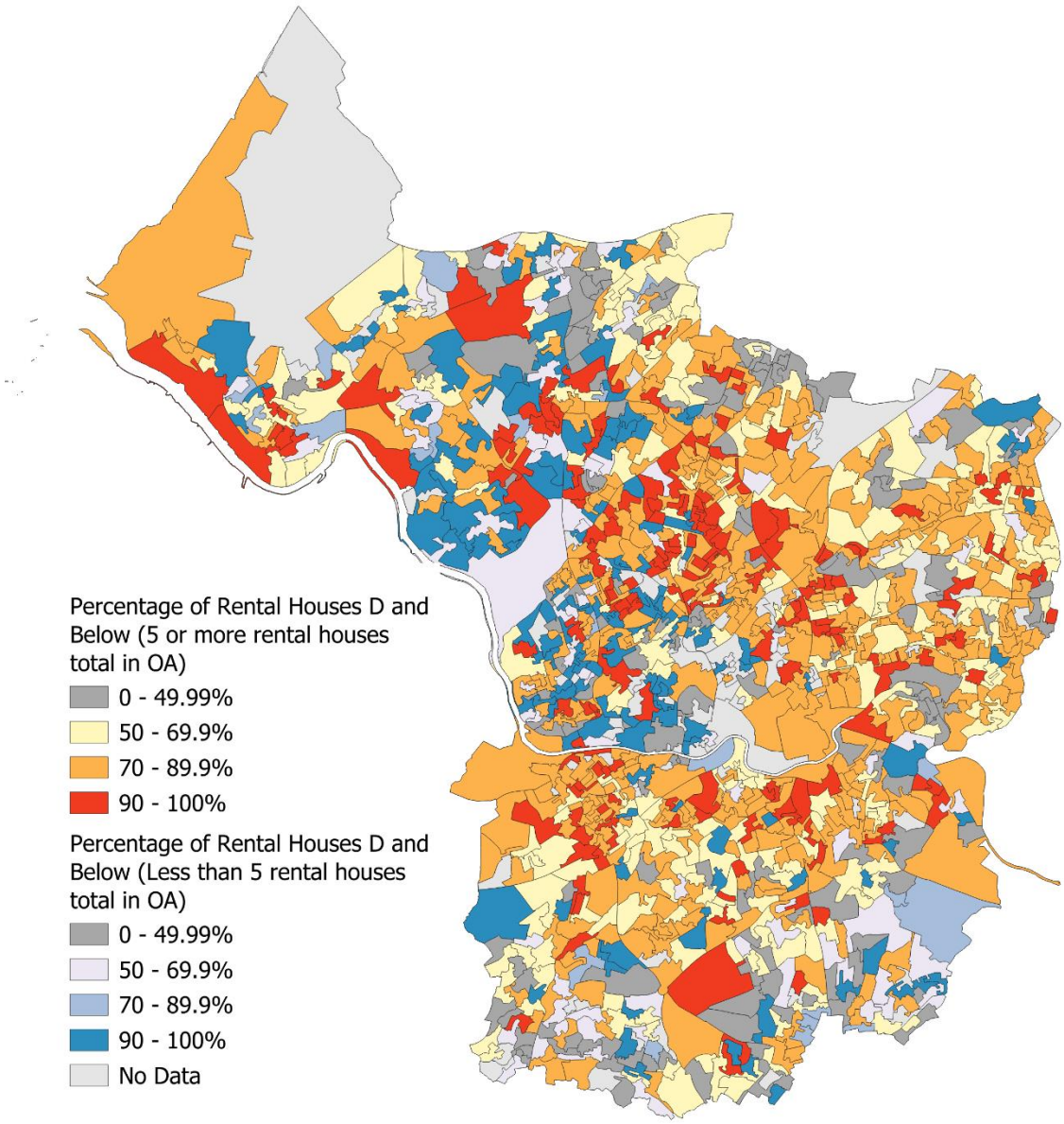


Figure 24 - Map of Bristol Local Authority District by Output Area. Coloured by percentage of privately rented houses in each OA that have an EPC efficiency rating of D and below. Data: Open Data Communities, 2023

Figure 24 turns this to houses and is a stark indicator of the very high levels of inefficient housing across the entire city, with very large numbers of OAs (59%) having over 70% of their privately rented houses D and below.

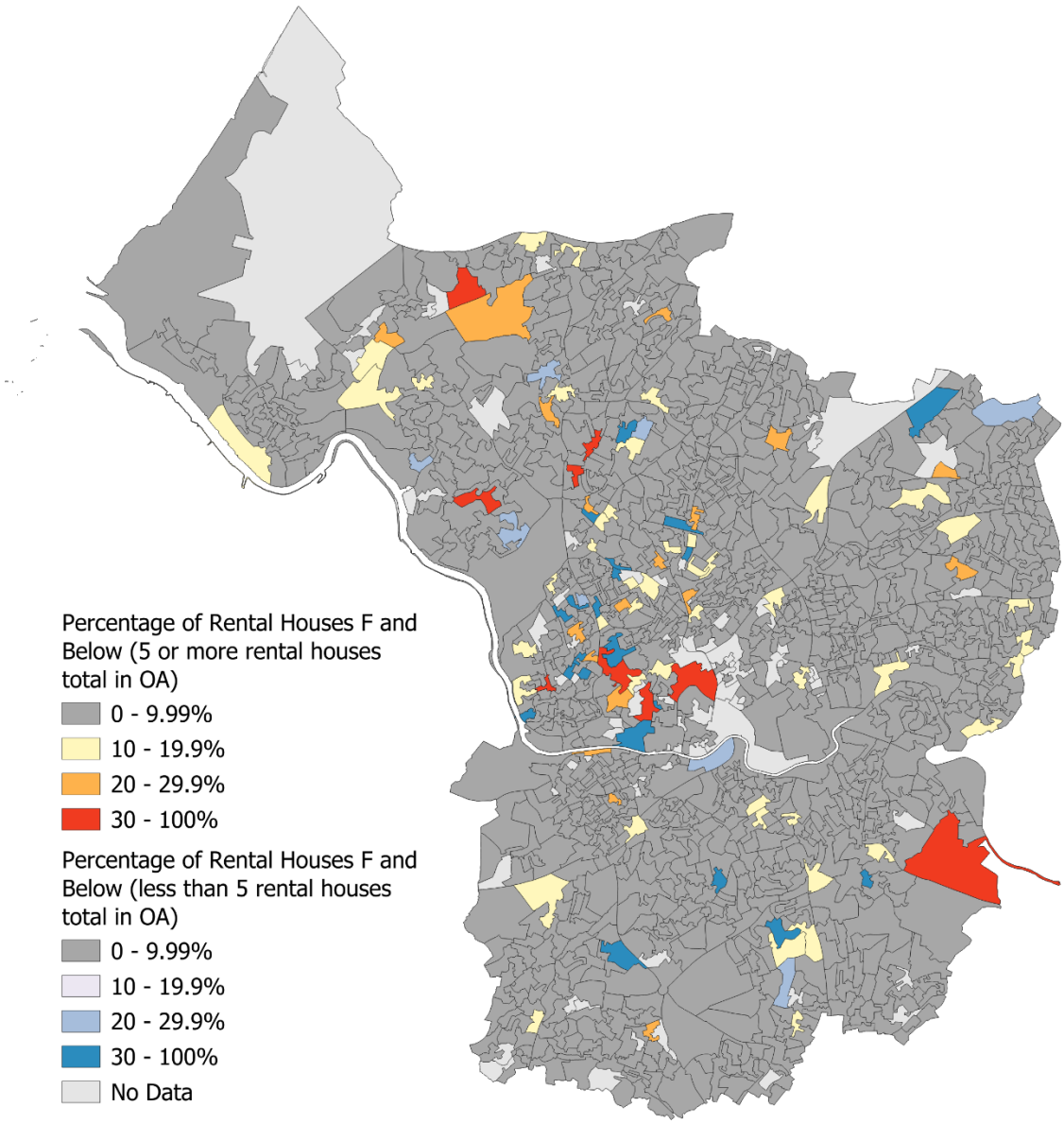


Figure 25 - Map of Bristol Local Authority District by Output Area. Coloured by percentage of privately rented houses in each OA that have an EPC efficiency rating of F and below. Data: Open Data Communities, 2023

Figure 25 refines the privately rented house visualisation to F and below and shows a cluster in the centre of the city, alongside various spatially disparate OAs across the city with high levels of very inefficient privately rented houses.

3.7 Explaining and Modelling EPC Scores

Multilevel regression is a statistical technique that explores the relationships between variables whilst controlling for clustering – in this instance, geographical clustering. The results of models can inform us of the nature and strengths of the relationships between variables, enabling us to rank the size of their association with energy efficiency. This is useful for this research as it makes clear what factors have the strongest relationships on the energy efficiency of dwellings. The equation used is:

(efficiency ~ property type + tenure + age + floorspace + deprivation + (1|OA))

Predictors	Efficiency	p
(Intercept)	87.57	<0.001
Building type (reference category = Houses)		
Flat	2.91	<0.001
Tenure (reference category = Owner-Occupied)		
Privately Rented	1.07	<0.001
Socially Rented	7.94	<0.001
Building age (reference category = 1996-2023)		
Pre-1900	-14.39	<0.001
1900-1929	-13.59	<0.001
1930-1949	-12.55	<0.001
1950-1975	-10.18	<0.001
1976-1995	-5.85	<0.001
Unknown Age	1.21	<0.001
Floor Area	-1.15	<0.001
Deprivation	-0.37	<0.001
Random Effects		
σ2	103.52	
τ00 OA11CD	5.11	
ICC	0.05	
N OA11CD	1237	
Observations	124593	
Marginal R2 / Conditional R2	0.242/0.278	

Table 3 – Table of results of multilevel model, statistically significant results reported only.

Table 4 reports the results of this regression, allowing for meaningful comparison between variables and revealing which variables have a greater influence on energy efficiency. We can see that the age of buildings has the largest influence on efficiency, with newer properties exhibiting much better performance, potentially attributable to improved building techniques and technologies with regards to efficiency. After age, the tenure of dwellings has the largest influence, where social rentals are substantially more energy efficient, potentially reflecting how this tenure is more tightly regulated. Next largest is if the dwelling is a flat, which are generally more efficiency than houses, likely due to fewer external walls from which to lose heat. Next is floor area, with larger homes being less energy inefficient. Next are private rentals, which are slightly more efficient than owner-occupied dwellings. Finally, deprivation has a significant influence, but the smallest in magnitude of all variables tested, whereby greater levels of deprivation are associated with less efficient dwellings. These results largely reflect the results of a similar analysis undertaken at a national level (Buyuklieva and Dennet, 2023), reinforcing their credibility.

Moving to the observed random (group-level) effects, the relatively small Intraclass Correlation Coefficient (ICC) indicates that dwellings in each OA exhibit greater dissimilarity in their characteristics than similarity. The marginal R2 reveals that the variables included explain a fair amount of variation in the results, and the conditional R2 reveals that most of the unexplained variation is between dwellings rather than between groups. These results underscore a caveat in area-level assumptions: due to pronounced variations in properties situated in close proximity, any area-level analysis necessitates must be broken down to more granular levels accounting for specific property-level information.

4.0 Conclusion

The objective of this report was to provide innovative and spatially sensitive insights into the inequalities of rental properties in Bristol, with a primary focus on energy efficiency. Through a series of various data manipulations, statistical analyses, spatial assessments, and generating data visualisations, this report makes clear the difficult challenges that Bristol confronts when targeting the improvement of energy efficiency in residential dwellings. This challenge is particularly pronounced due to over half of the city's current residences falling below the 2035 Band C target.

The discrepancies in energy efficiency are evident across different tenures and building forms. Notably, the only building type where private rentals lag behind owner-occupied residences is flats - an architectural category that is relatively abundant in Bristol. Considering the expenses linked to bolstering energy efficiency, the pursuit of the Band C target will entail various social, economic, and political ramifications. This will place additional strain on what is already a vastly undersupplied rental market (Bristol One City, 2023).

Furthermore, energy performance is most clearly associated with property age, which may reflect both buildings' structures but also the way in which they are used. There may be constraints on improvements due to historic conservation, and homes with higher running costs might not actually cost more to run, for example if they are not used at full capacity (Buyuklieva and Dennet, 2023).

Establishing a compelling economic rationale is crucial to foster and increased willingness to retrofit. Improving energy efficiency in the lowest-cost rentals will prove particularly difficult given landlords' perceptions that tenants are most interested in the absolute lowest rental rates, and apathy given that landlords do not benefit from the financial savings of tenants' reduced energy bills (Lang et al, 2021; Ambrose, 2015). Making a strong economic case is essential to increase willingness to retrofit, and appealing to property managers is also essential for any retrofitting success, as should the overall goal of reducing the organisational burden for landlords or tenants wishing to retrofit (ibid).

4.1 Future Work

Whilst this report offers a localised overview to relatively fine levels of administrative geography, the analysis is based only on public data analysed in a fairly limited context. Any policy recommendations stemming from the findings of this report should therefore be made alongside consideration for local knowledge, practical expertise, and insights of 'on the ground' retrofitting. Moreover, there is potential value in incorporating more comprehensive and precise, but potentially restricted, data that Local Authorities may have access to. We ultimately recommend that deeper local analyses are conducted to inform optimal policy decisions.

This study primarily delves into the existing energy efficiency status of properties in Bristol, with less emphasis on assessing the feasibility and potential extent of efficiency enhancements. A more comprehensive analysis of this nature could offer valuable insights and direction for policymakers as they contemplate strategic areas, contexts, and circumstances where any retrofitting initiatives might most effectively be rolled out.

This work has also focused extensively on the current state of properties' energy efficiencies in Bristol, with little consideration for the viability and scope for efficiency improvements. An analysis of this kind would potentially offer very useful clues and guidance to policymakers when considering the locations and contexts of where any retrofitting initiatives might most effectively be rolled out.

While this report briefly addressed the incorporation of house prices into the analysis (section 2.2), the initial findings were inconclusive (potentially due to the complex interplay between supply, demand, building values, land values, interest rates, mortgage availability, changing financial regulations, changing planning regulations, all at varying geographies) and a more thorough investigation might yield further valuable insights. Although findings of analysis of this variable were not fully integrated into the report, a version of a house price map is accessible for exploration through the companion online mapping tool.

Finally, as mentioned throughout this report, there is a notable caveat that EPC data is not a complete representation of the city's dwellings, with owner-occupied properties underrepresented. Conducting analysis using more comprehensive data sources would inevitably lead to results that are more valid and accurate.

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6.0 Appendix: Codebook for interactive web map

Layer Name	Geography Type	Data Category	Description
Buildings Built After 1900	Point Data	Building Age	Point data showing all buildings constructed after 1900 according to EPC dataset
Buildings Built Before 1900	Point Data	Building Age	Point data showing all buildings constructed before 1900 according to EPC dataset
Deprivation Decile	LSOA	Deprivation	2019 IMD decile for each OA (1 = least deprived)
Median House Price	Output Area (OA)	Building Price	Median price of all dwellings in each OA as of 2022
Median Floor Area	Output Area (OA)	Building Area	Standard deviations from mean of median floorspace values by OA
Median Efficiency	Output Area (OA)	Efficiency	Median efficiency of all dwellings by OA according to EPC data.
Median Efficiency Owned	Output Area (OA)	Efficiency	Median efficiency of all owner-occupied dwellings by OA according to EPC data.
Median Efficiency Rented	Output Area (OA)	Efficiency	Median efficiency of all privately rented dwellings by OA according to EPC data.
Median Efficiency Social	Output Area (OA)	Efficiency	Median efficiency of all socially rented dwellings by OA according to EPC data.
Median Efficiency Flats	Output Area (OA)	Efficiency	Median efficiency of all flats by OA according to EPC data.
Median Efficiency Houses	Output Area (OA)	Efficiency	Median efficiency of all Houses by OA according to EPC data.
Median Efficiency Owned Flats	Output Area (OA)	Efficiency	Median efficiency of all owner-occupied flats by OA according to EPC data.
Median Efficiency Rented Flats	Output Area (OA)	Efficiency	Median efficiency of all privately rented flats by OA according to EPC data.
Median Efficiency Owned Houses	Output Area (OA)	Efficiency	Median efficiency of all owner-occupied houses by OA according to EPC data.
Median Efficiency Rented Houses	Output Area (OA)	Efficiency	Median efficiency of all privately rented houses by OA according to EPC data.
Percent Private Rentals D and Below (less than 5 private rentals in OA)	Output Area (OA)	Efficiency	Percentage of privately rented dwellings that are rated D and below by OA according to EPC data. Only showing OAs less than 5 private rentals (to be used in conjunction with category immediately below)
Percent Private Rentals D and Below (5 or more private rentals in OA)	Output Area (OA)	Efficiency	Percentage of privately rented dwellings that are rated D and below by OA according to EPC data. Only showing OAs with 5 or more private rentals (to be used in conjunction with category immediately above)
Percent Private Rentals F and Below (less than 5 private rentals in OA)	Output Area (OA)	Efficiency	Percentage of privately rented dwellings that are rated F and below by OA according to EPC data. Only showing OAs less than 5 private rentals (to be used in conjunction with category immediately below)

Layer Name	Geography Type	Data Category	Description
Percent Rented Flats F and Below (less than 5 rented flats in OA)	Output Area (OA)	Efficiency	Percentage of privately rented flats that are rated F and below by OA according to EPC data. Only showing OAs less than 5 privately rented flats (to be used in conjunction with category immediately below)
Percent Rented Flats F and Below (5 or more rented flats in OA)	Output Area (OA)	Efficiency	Percentage of privately rented flats that are rated F and below by OA according to EPC data. Only showing OAs with 5 or more privately rented flats (to be used in conjunction with category immediately above)
Percent Rented Houses F and Below (less than 5 rented houses in OA)	Output Area (OA)	Efficiency	Percentage of privately rented houses that are rated F and below by OA according to EPC data. Only showing OAs less than 5 privately rented houses (to be used in conjunction with category immediately below)
Percent Rented Houses F and Below (5 or more rented houses in OA)	Output Area (OA)	Efficiency	Percentage of privately rented houses that are rated F and below by OA according to EPC data. Only showing OAs with 5 or more privately rented houses (to be used in conjunction with category immediately above)