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Reducing carbon from heritage buildings: the importance of residents' views, values and behaviours

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ABSTRACT

Significant energy and carbon originate in the existing built environment and retrofit is therefore a key carbon reduction strategy. However heritage buildings -comprising around 20% of UK buildings- are challenging to retrofit appropriately due to their historical values and traditional construction. Retrofit carbon savings are dependent on current energy use which is strongly influenced by residents' behaviours, and retrofit decisions for domestic heritage are generally the responsibility of homeowners. Therefore both residents' views and behaviours are important for effective retrofit strategies. However behaviours are rarely considered in standard energy models and residents' views are often overlooked in heritage retrofit policy. This paper analyses a survey of the views, values and behaviours of 147 residents of pre-1940 buildings. The majority are found to strongly value their homes' heritage and mainly view exterior building alterations negatively. However residents' heritage values and acceptable retrofits, frequently differ from those of experts and policy makers. Residents report actively engaging in several positive energy behaviours and many have already undertaken common carbon saving measures. These findings imply that, for effective carbon reduction from heritage buildings, policy and legislation needs to extend beyond current definitions of 'heritage' and acknowledge residents' complex values, motivations and energy behaviours.

KEYWORDS

Carbon reduction; heritage buildings; retrofit; policies; user behaviour; thermal comfort

Introduction

This paper investigates the heritage values, carbon reduction views and energy behaviours of residents of heritage buildings, and explores the implications for retrofitting decisions and approaches.

Significant energy use and carbon emissions originate in the built environment and must be urgently reduced to help mitigate climate change.¹ The rate of building stock replacement in Europe is only around 1% per year,² so retrofitting to improve the performance of existing buildings is a key strategy. Buildings with heritage value help shape the character of urban and rural landscapes and have a range of historic, aesthetic and communal values.³ However these buildings are particularly challenging to retrofit

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sensitively because of their individual values and traditional, often regionally specific, construction techniques.⁴

There are no clear definitions of heritage buildings so estimating their exact numbers is challenging. Based on planning designations, about 1–2% of UK homes are estimated to be individually listed.⁵ There are over 10,000 heritage conservation areas in the UK, but no data about how many individual buildings they contain.⁶ In addition to these nationally recognised listings some buildings may be locally designated.⁷ Heritage value can also be estimated based on building age and construction techniques. Of the 28.5 million homes in the UK, 20.6% (5,872,000) were built before 1919 which is a common cut-off date for heritage buildings.⁸ Another common date is 1944 and 35.6% of UK homes were built before this date, giving the UK some of the oldest building stock in Europe.⁹ There is, therefore, significant uncertainty about the percentage of buildings with heritage value in the UK but this is tentatively estimated to be around 20%, many of which are not officially designated.¹⁰

Decisions on whether to retrofit heritage buildings are largely at the discretion of, and arranged by, the homeowner. However, the views of residents and the values that they invest in their buildings are often neglected by policy interpretations and expert-led opinions of heritage values.¹¹ Therefore retrofit measures considered appropriate by policy makers may not be acceptable to heritage residents¹², who are unlikely to enact changes that negatively affect features they value.¹³

Furthermore, the effectiveness of retrofit options for carbon reduction is dependent on the buildings' current energy performance. This is decided to a considerable extent by residents' energy behaviours.¹⁴ However such behaviours are poorly understood, particularly in heritage buildings¹⁵ and are rarely considered in standard energy and carbon models.¹⁶ In addition, heritage buildings are often characterised in the literature as cold and uncomfortable to live in¹⁷ which may lead to assumptions about their performance. However, in the UK there has been little research into residents' perceptions of their indoor environmental comfort¹⁸ to substantiate these assumptions. These perceptions may have an important role in understanding energy behaviours, identifying appropriate retrofit solutions, and reducing the gap between predicted energy and carbon savings, and actual savings.

This paper examines these issues by asking the following research questions:

1. How do the views, values and behaviours of heritage building residents differ from official assumptions?
2. What influence do these views, values and behaviours have on the acceptability of different retrofit options to residents?
3. What implications does this have for common retrofitting approaches to buildings with heritage values?

Following a review of the literature, methodology and context are described. The survey results are then presented, before their implications are discussed and a number of conclusions made.

Background and literature review

There is currently a lack of evidence about residents' perceptions of the heritage values of their buildings¹⁹ which is partially blamed on limited consultation and expert-led solutions.²⁰ A recent review of the literature also identified a lack of consideration of the heritage values of specific buildings, with studies often relying on generalisations.²¹ There is a tendency to give only limited space for considerations of heritage²² or to take planning restrictions as the sole arbiter of value.²³ Protection of heritage is often imposed in a top down manner and therefore may not reflect the values of local communities.²⁴ Resident's views of heritage are context specific and must be understood individually.²⁵

One study, of a UNESCO World Heritage city (Visby, Sweden), found that residents broadly agreed with the city's official heritage characterisation document, which identifies the importance of retaining original windows, doors and roofs. However, when asked about their own homes as opposed to photos of archetype buildings, residents most valued 'the building in context' instead of specific elements.²⁶

This common lack of understanding and recognition of residents' values is problematic because these affect the acceptability of different changes to the building.²⁷ A small study in Cambridge, UK demonstrated that residents' heritage values affected their decisions to retrofit and the types of alteration they were willing to make.²⁸ Residents' values are particularly important for heritage buildings that have lesser, or no, official heritage designation, because these residents will have greater agency in decisions.²⁹

The energy behaviours of residents are an important factor in the energy performance of all buildings, and this is considered to be particularly so for heritage buildings.³⁰ In one UK heritage study, energy behaviours were found to affect the energy savings of retrofit measures by 62–86% given the same technical conditions.³¹ Behaviours also caused significant variation in a Danish study of a heritage apartment block.³² Residents' behaviours in heritage buildings can often differ from those in more modern buildings.³³ Understanding residents' behaviour is therefore critical in attempts to reduce carbon from heritage buildings.³⁴

Despite their importance however, behaviours are often considered to be outside the scope of energy retrofit projects, which tend to focus on material changes.³⁵ However, compared to behavioural changes, material changes are likely to involve physical alterations to the building fabric, have much higher impact on heritage values, and be significantly more expensive.³⁶

Meanwhile, retrofit decisions and their estimated energy and carbon savings are often based on models of the energy use of the building.³⁷ If these models start with a higher figure for current energy use than in reality, the savings from the subsequent retrofit will be lower than modelled. This is termed the 'pre-bound effect'.³⁸ Indeed Sunikka-Blank and Galvin's (2012) study of the German building stock showed an inverse correlation between actual and modelled energy, with older and supposedly more inefficient houses consuming up to 40% less energy than modelled. A large proportion of this difference was attributed to the energy behaviours of the residents, although for heritage buildings a poor understanding of the U-values

and thermal mass of traditional materials are also considered key factors in modelling discrepancies.³⁹

The overestimation of energy use by standard models, particularly for heritage buildings, has been identified by other studies in several countries.⁴⁰ The subsequent overestimations of the energy saving potential of retrofits has implications both for their cost effectiveness and for the size of energy and carbon savings.⁴¹ The overestimation of the benefits of retrofit could also lead to unnecessary negative impacts on heritage values.⁴² The need to take the embodied carbon -the energy and carbon required for manufacture, transportation, installation and maintenance- of retrofitting solutions into account has also been identified.⁴³ If operational energy savings are not as high as expected, the embodied costs could outweigh them and have been shown to increase life-cycle emissions in some cases.⁴⁴

One reason for the gap between modelled and actual energy use in heritage buildings may be due to assumptions about thermal performance. These buildings are often presented, and modelled, as cold, damp and thermally inefficient⁴⁵, but there is limited evidence of residents' perceptions of comfort in heritage buildings in the UK to either prove or disprove this view.⁴⁶ One survey of UK residents did show that fewer residents of pre-1945 homes were satisfied with their thermal comfort in winter (72%) than those of post-2000 homes (95%).⁴⁷ However, in summer the opposite was true, with 89% of pre-1945 residents satisfied, compared with only 76% in post-2000 homes. This perhaps reflects the growing identification of summer overheating in modern buildings in the UK.⁴⁸

Studies from other countries suggest that heritage buildings perform better than expected, and are perceived as more comfortable by their residents.⁴⁹ A study in a humid subtropical region (following the Köppen classification) of China compared the indoor environmental perceptions of residents of 'Tulou' rammed earth heritage buildings with those of modern rural buildings.⁵⁰ This found that the heritage building residents had higher perceptions of comfort than the modern building residents. Field measurements confirmed that the heritage buildings also had better actual performance across a range of indicators, as well as 28% lower energy usage. Similarly, a comparative study of naturally ventilated heritage buildings and modern, air conditioned buildings in Libya, also identified higher satisfaction with thermal comfort in the heritage buildings.⁵¹ These perceptions of comfort are likely to affect both residents' energy behaviours, and the retrofit options that they might consider.⁵²

Therefore, evidence suggests that residents' heritage values are often overlooked, but are likely to affect the acceptability of retrofits. Meanwhile, residents' energy behaviours are poorly understood but have significant implications for the building performance models which are often used to justify particular retrofit decisions and the subsequent carbon savings. Finally, the limited research into residents' perceptions of comfort suggests that these differ from assumed comfort levels applied in contemporary models. For successful retrofit strategies, the values that residents hold for their heritage buildings, their energy behaviours, and their perceptions of comfort, are all key.

Study context

In order to examine these questions, the county of Cumbria in the UK was chosen as a suitable study area. This area includes the Lake District National Park, which has increased development restrictions in addition to the UK national and local planning legislation and policy frameworks. It was also recently inscribed as a Cultural Landscape World Heritage Site by UNESCO.⁵³

Cumbria is the most North-westerly county in England and is a mostly rural, upland and coastal area containing all of England’s highest mountains and both its longest and deepest lakes.⁵⁴ It is also one of the wettest places in England.^{55,56} Cumbria is one of the most geologically diverse areas of the UK with a complex geological history, most recently shaped by glaciation: with valleys radiating out from the central Lake District mountains (see Figure 1 for map).⁵⁷ More than half of the population of approximately 500,000 is rural, and agriculture, forestry and tourism related services make up the main industries.⁵⁸

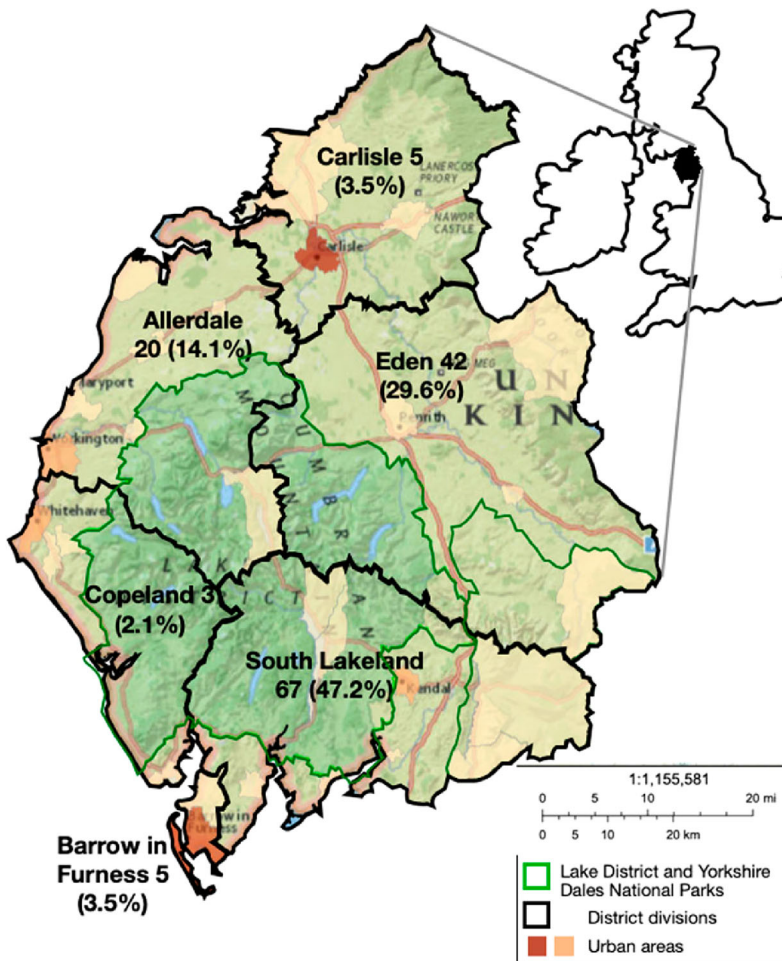


Figure 1. Map of Cumbria and response distribution by district.⁵⁹

The architecture in eastern and central Cumbria is mainly farmsteads and villages, mostly dating from the seventeenth century, while in the ports of the west coast, the southern Furness Peninsular, and the northern city of Carlisle there is more industrial heritage.⁶⁰ There was a significant boom in construction during the late 18th and early 19th centuries due to the rise in tourism, inspired by the romantic movement.⁶¹ Today the visitor economy is still a major factor in Cumbria, and in the National Park over 24% of houses are holiday lets or second homes.⁶²

Method

As part of a larger research project an exploratory survey was created to investigate the views, values and behaviours of residents of pre-1940 buildings. The survey was developed using the concerns identified in the literature review, as well as initial interviews with a small number of Cumbrian sustainability and conservation professionals which were used to identify local topics of interest. The draft survey was piloted with a number of heritage building owners, and then edited in response to their feedback, before launching in Autumn 2019. The final survey focused on six areas: building details; heritage values; energy behaviours and systems; indoor environmental quality; attitudes to and knowledge of reducing carbon emissions from heritage buildings; and acceptable retrofit measures.

For the last of these, respondents were presented with a list of retrofit measures taken from the literature on heritage buildings. Many of these were improvements to the thermal envelope as shown in [Table 1](#).⁶³

Other options for reducing carbon emissions do not relate to the thermal envelope and include renewable energy technologies and some common solutions promoted in energy efficiency policies ([Table 2](#)).⁶⁴

The survey was mainly composed of closed questions, but there were also a small number of open questions for respondents to add additional details if they wished. The only questions that were compulsory were the two regarding consent; all other questions were optional although most respondents answered every question. To encourage participation the survey was completely anonymous and only limited details about participants' location and building details were requested, i.e. the district in which participants lived and the size of conurbation they inhabited.

The survey was shared through the email lists of local sustainability and conservation organisations and through the delivery of 750 leaflets to older houses across Cumbria. The survey ran from the 31st of October 2019 to the 10th of January 2020. A total of

Table 1. Potential thermal envelope retrofits included in survey, with source.

Thermal envelope retrofits	Reference studies
Loft or floor insulation	Iyer-Raniga and Wong (see note 60)
Internal Wall Insulation	Harrestrup and Svendsen (see note 60)
External Wall insulation	Bristol City Council; Richard Griffiths and Steve Goodhew (see note 60)
Window replacement with wood, metal or UPVC frames	Giovanni Litti, Amaryllis Audenaert, and Monica Lavagna; Gillian Menzies (see note 60)
Secondary Glazing	Curtis (see note 60)
Interior or exterior shutters	Chris Wood, Bill Bordass, and Paul Baker (see note 60)
Draught proofing	Wood, Bordass, and Baker (see note 60)

Table 2. Potential retrofits not relating to the thermal envelope.

Retrofits not related to the thermal envelope	Reference studies
Solar Photovoltaic panels	Cristina S. Polo López and Francesco Frontini (see note 61)
Solar thermal panels	Cabeza, de Gracia, and Pisello (see note 61)
Air, ground and water source heat pumps	Cabeza, de Gracia, and Pisello (see note 61)
Hydropower turbine	T. R. Pokharel, H. B. Rijal, and M. Shukuya (see note 61)
Wind turbine	Chris Morgan (see note 61)
Energy efficient lighting	Maurizio Cellura et al. (see note 61)
Energy efficient appliances	Morgan (see note 61)
Thick wall hangings	Sarah Khan (see note 61)
Boiler replacement	Ian G. Hamilton et al.; Lavinia Chiara Tagliabue, Mario Maistrello, and Moreno Fattor (see note 61)

484 people looked at the first page of the survey and 184 people carried on beyond the first page. 37 people did not complete the whole survey or submit their results. One additional respondent did not confirm their consent, so their response was excluded. This provided a total of 147 responses.

Descriptive statistics were assessed in SPSS and a number of cross tabulations and inferential statistics (using independent sample t-tests and Mann–Whitney U tests) were undertaken for some of the key results to help inform the descriptive analysis. The survey sample however was relatively small and not statistically representative, so it was felt to be inappropriate to develop in-depth statistical analysis.⁶⁵ Five respondents asked for their comments not to be published and this wish has been honoured.

Results

Demographics

The survey drew responses from every district of Cumbria ([Figure 1](#)) and their locations were representative in terms of Cumbria's rural/urban division.⁶⁶ There was a bias towards detached houses, but responses included a spread of other housing types as well ([Figure 2](#)). The vast majority of respondents were owner occupiers (96.6%) with only 5 respondents renting (3.4%).

Respondents were asked to state the age of the main/largest part of their building to the nearest decade. Based on this response the construction dates ranged from 1400–1940 ([Figure 3](#)). Around half the buildings were reported as dating between 1801–1900, corresponding to a major increase in building in Cumbria at that time. To put this in context, around 10.1million (35%) of the UK's 28.5million homes were built before 1945 (with very little house building between 1938 and 1945 as a result of the Second World War), making this a significant percentage of the total UK building stock.⁶⁷ Respondents' buildings ranged from Grade I Listed (the highest level of protection in the UK) through to unprotected buildings with no special protection or designation ([Figure 4](#)).

The number of respondents using oil fuelled central heating (22%) is significantly higher than the Cumbria (9%)⁶⁸ or UK average (5%)⁶⁹ which is probably due to a lack of access to the gas grid in many rural areas of Cumbria.⁷⁰ In addition more than twice as many respondents (11%) had no central heating compared with Cumbria as a whole (4%).⁷¹

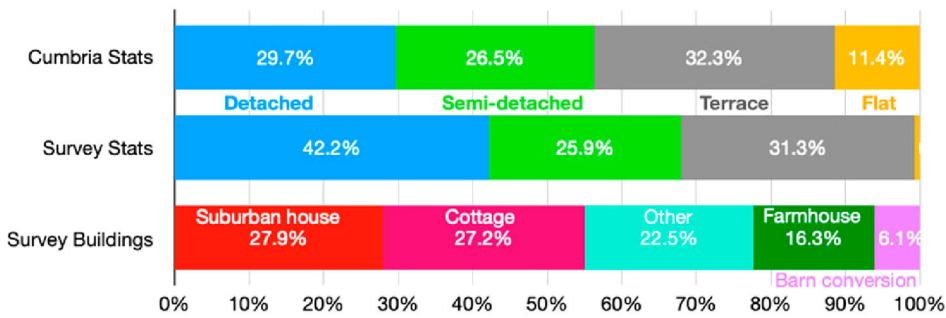


Figure 2. Housing form types, comparing Cumbria wide and survey data, and breakdown of building types from survey.⁷²

Heritage values

The majority of respondents (80.7%) agreed that their buildings had heritage value when presented with the following definition:

Heritage value can include things like: historic value; uniqueness; aesthetic values; values for the local community (i.e. a local landmark); forming part of a distinctive landscape; etc, although this is not exhaustive.

The percentage of residents who perceived their building to hold heritage value varied somewhat by the levels of official heritage designation (Figure 5). While not as high a percentage as residents of listed buildings, nevertheless a clear majority of respondents in unprotected buildings felt that their buildings also had heritage value. Almost as many residents in unprotected buildings ascribe heritage value to them as in conservation areas, suggesting that official designations may not be a significant factor in how people value their buildings. The 28 respondents who did not feel that their buildings had heritage value lived in a range of building types, ages, and designations, (see appendix 1), suggesting that values may be related to residents’ perceptions, and not only a product of specific building features or designations.

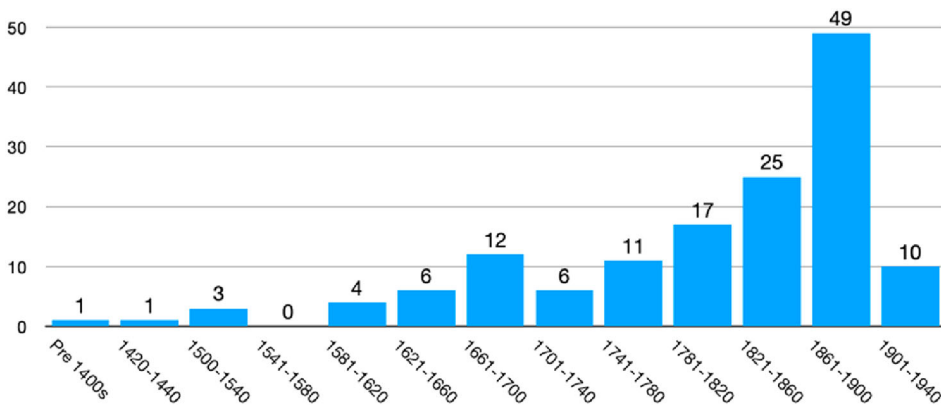


Figure 3. Bar chart of building ages compressed into forty-year age bands.

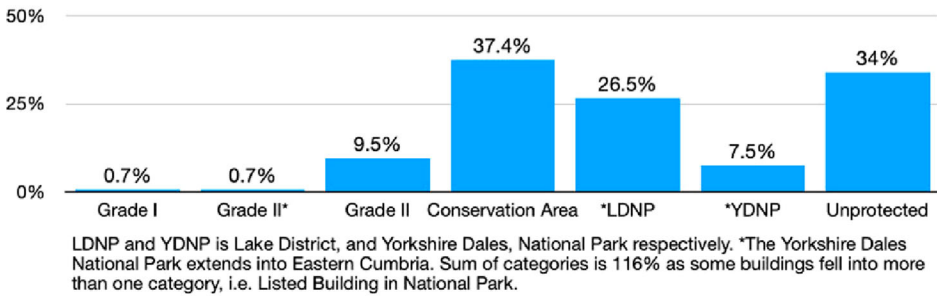


Figure 4. Percentage of buildings with heritage designation.

The specific heritage aspects that respondents most valued relate to traditional construction and ephemeral properties, such as ‘character in the landscape’, rather than the more traditional heritage values identified in policy, such as original features or historic events (Figure 6). Some of the free text comments elucidated these sentiments, for example:

Character, a combination of things you don’t get in modern boxes -good proportion to the rooms, traditional details and materials, a history however modest.

I fell in love with it the first time I walked up the stairs, stumbling on each step -each step is a slightly different height and depth to the next ... those are the quirks that give a house character.

Comments also revealed that the importance of different properties was very specific to the individual, such as: quality of the skirting boards; situation on edge of valley; and sense of age.

The importance of local and context-specific building materials was particularly noted in the comments (‘Local Borrowdale Volcanic stone’, ‘Westmorland Green Slate’, ‘Local Eskdale Granite’, ‘locally quarried sandstone’), which may be related to buildings in different areas of Cumbria being very distinctive because of the locally diverse geology.

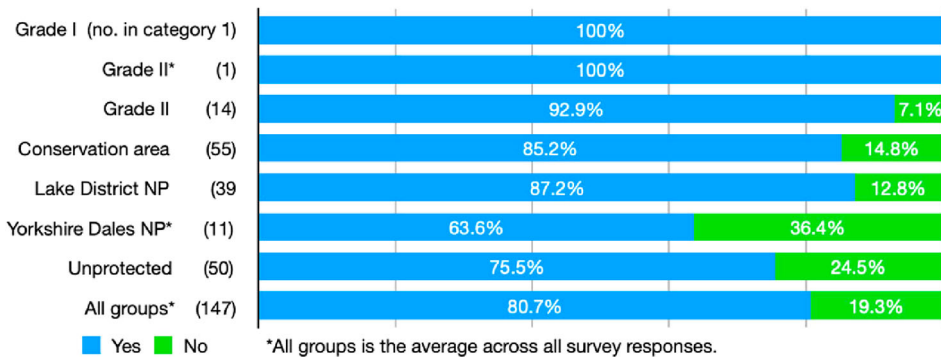


Figure 5. Comparison of heritage values in buildings with different designations.

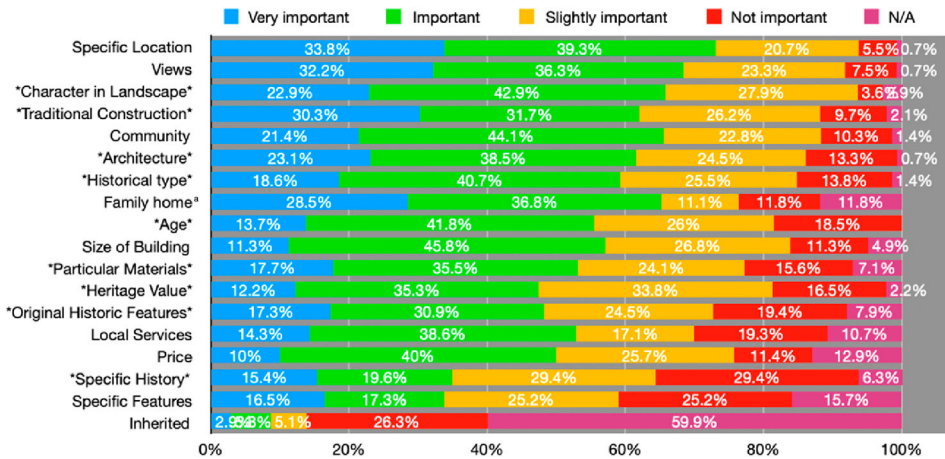


Figure 6. Valued aspects of resident’s buildings, arranged in order of mean value (most important to least important) – *xxx* indicates specifically heritage aspects. ¹Based on initial interviews and piloting many people value their buildings as ‘family homes’, i.e. ‘it’s a great home to bring up a family’ compared with people who may value their home because it is inherited.

Energy and heating behaviours

A list of common ‘energy saving behaviours’ were presented to respondents, asking them to identify those that they currently enacted and those they might be willing to do in the future (Figure 7).

The majority of residents reported that they were already engaged in a range of positive energy behaviours or were willing to do so. No heating in bedrooms elicited a mixed response, with 35.6% of residents already doing this but 36.3% saying it was not something they would do. Smart home technology was shown to have a low take up and a number of respondents identified issues with broadband speeds as precluding this option in rural areas. Residents also demonstrated high levels of concern about energy use and carbon emissions.

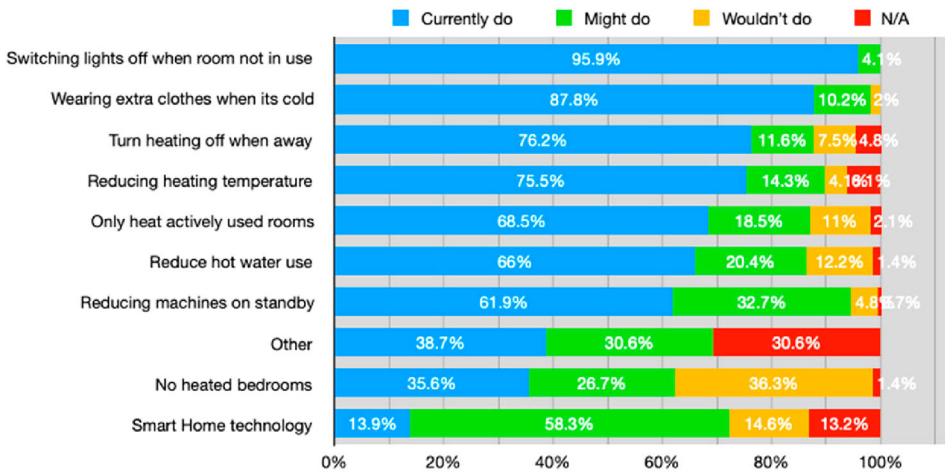


Figure 7. Stacked bar chart of common energy behaviours.

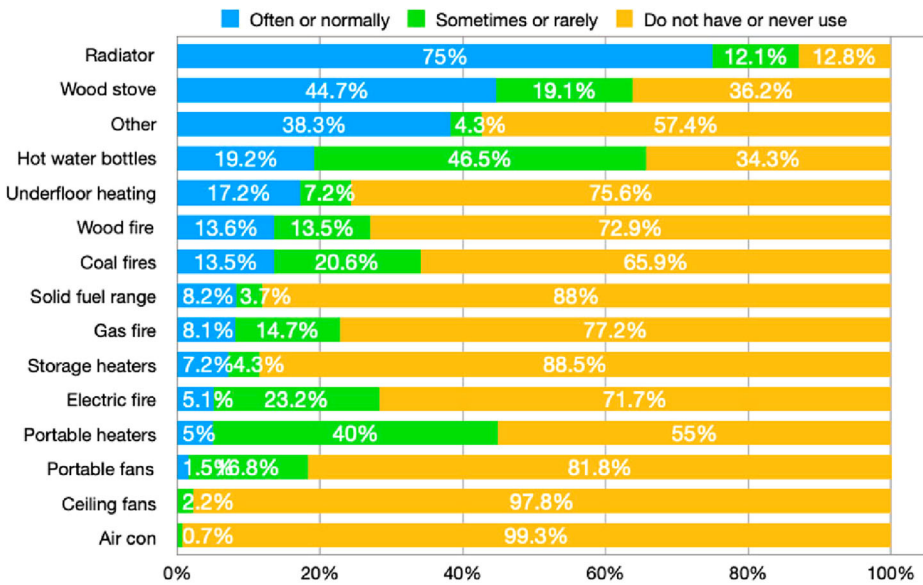


Figure 8. Stacked bar of heating type frequency.

We only heat the house when the children are in and not in bed! After they're in bed, the heating goes off. Adults are smarter at wearing jumpers!

Residents' decisions and actions are therefore complex, particularly compared with often simplified models and advice. A possible link between behaviour and heritage values could be suggested, for example in the following quote:

I don't want insulation to hide my lath & plaster & medieval timber ceilings (I don't heat upstairs anyway, so no benefit)

Respondents were also asked about their use of different heating and cooling sources as shown in compressed form in [Figure 8](#). Many residents use personal 'heating systems', such as hot water bottles, portable heaters, and electric blankets, to maintain their comfort.

The average reported temperature that respondents set their thermostats to was 19°C ([Figure 9](#)), 2°C lower than that assumed by standard methodologies such as the Standard Assessment Procedure (SAP) used to create energy performance certificates (EPCs) in the UK.⁷³ Comments implied that residents know that their houses are cooler, with suggestions that they accept this because of the historic nature of the building.

I only heat my living room. It's cosy in cold weather when the stove is on.

... If main room is heated by stove, rest of house can be cooler. We've acclimatised to a cool house – visitors often find it cold!

Perceptions of indoor environmental quality

Residents' perceptions of indoor comfort across a range of indicators were also examined. Overall levels of satisfaction with comfort were high, with the vast majority of respondents (93.9%) either satisfied or very satisfied with comfort in their buildings.

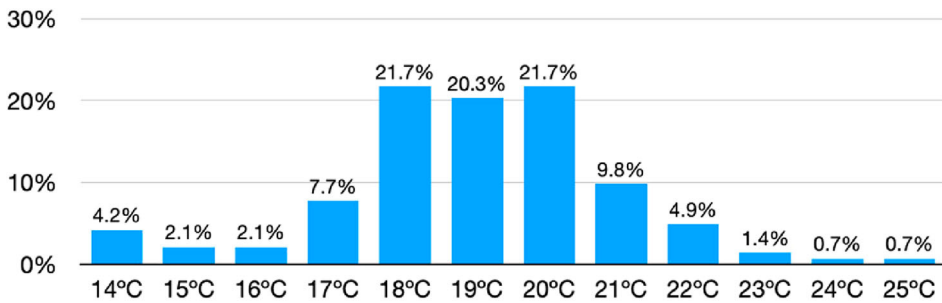


Figure 9. Percentage of respondents with each reported thermostat setting.

Perceptions of thermal satisfaction (Figure 10) were acceptable for most residents (both warm and cool categories are generally considered within the acceptable range),⁷⁴ although their thermal preferences (Figure 11) indicated that 45% would prefer warmer winter conditions. The buildings were however perceived to perform very well in summer, reflecting research from other countries suggesting that heritage buildings are often more thermally comfortable in hot weather than more modern buildings.⁷⁵

The majority of residents also viewed other parameters of environmental quality in a positive light (Figures 12–17). Although most residents felt their buildings were draughty in winter (Figure 12) the majority wanted conditions to stay as they were (Figure 13). Almost all respondents were satisfied with air quality and this was remarkably uniform across both seasons (95.3% winter and 95.2% summer). There was some concern with dampness (Figure 14), and a significant percentage of respondents felt that their buildings were rather dim, (low illuminance levels), especially in winter (Figure 15). This was the only parameter where more respondents desired a change than were content with current conditions (Figure 16). Some residents indicated that they were more accepting of this inconvenience due to the heritage nature of the buildings.

My house has relatively small windows and is rather dark, but I tolerate this because it is part of the architecture to be expected in a traditional Cumbrian farmhouse.

Finally over half of respondents considered their buildings to be quiet for both external and internal noise levels (Figure 17) and the majority desired no change in noise levels (77.5% external and 90.3% internal). Some comments, however, identified that concerns with road/traffic noise was a key factor in their desire to introduce either secondary or double glazing. Residents in towns appeared to have the most dissatisfaction with

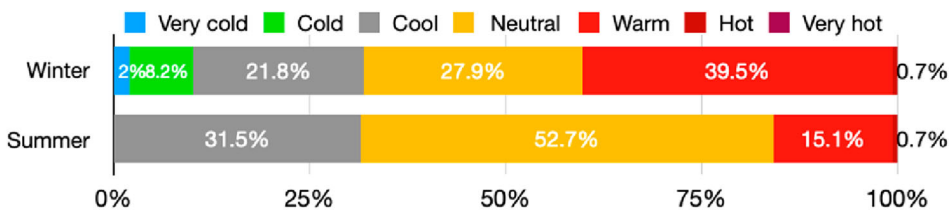


Figure 10. Thermal sensation of residents.

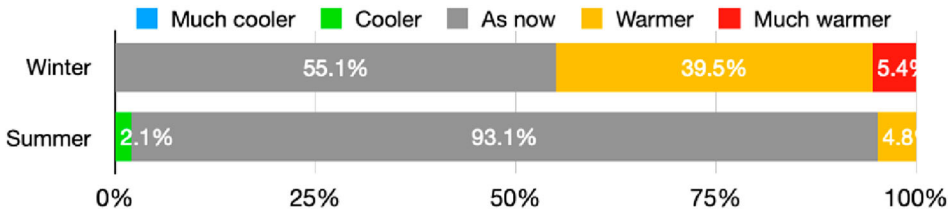


Figure 11. Thermal preference of residents.

noise levels but, surprisingly, this was followed by those in rural areas, while residents of villages perceived the lowest levels of external noise and were the most content with current circumstances

Energy and carbon reduction

It was generally felt to be much harder to reduce energy and carbon emissions from heritage buildings than from more modern buildings. When residents were asked about the

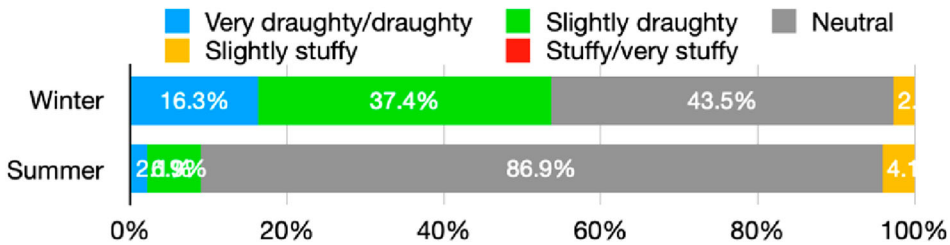


Figure 12. Sensation of ventilation winter/summer.

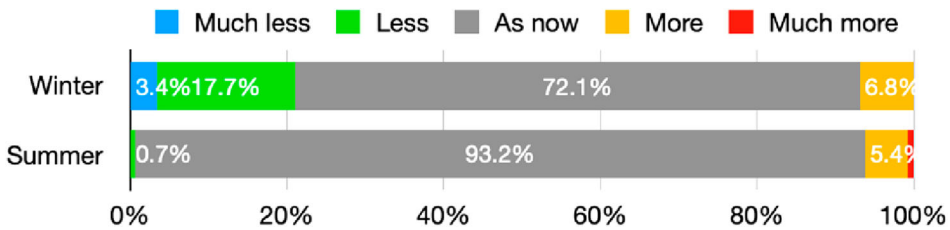


Figure 13. Ventilation preference winter/summer.

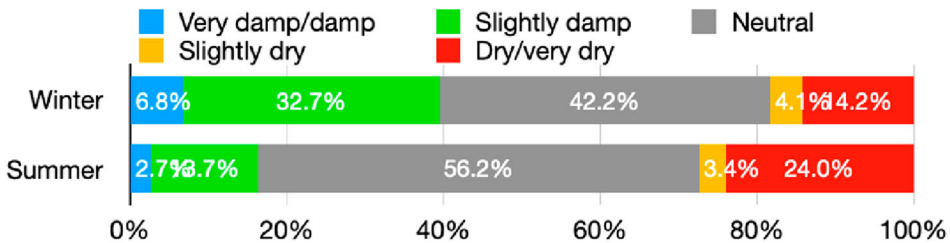


Figure 14. Perceptions of humidity winter/summer.

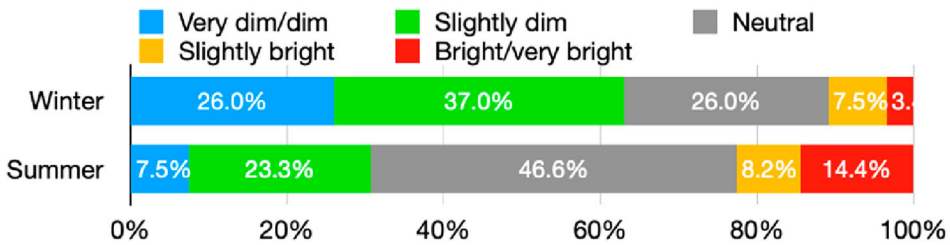


Figure 15. Perceptions of illuminance winter/summer.

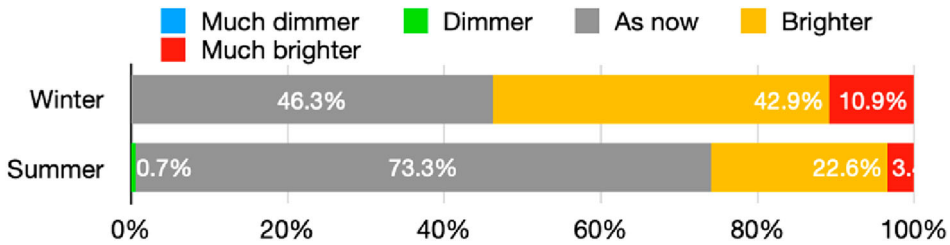


Figure 16. Illuminance preferences winter/summer.

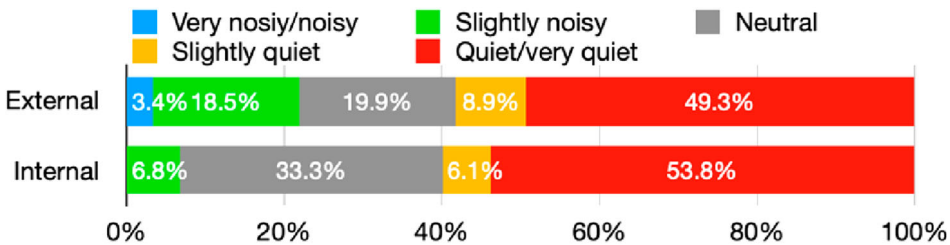


Figure 17. Perceptions of internal and external noise levels.

reduction potential in their own buildings, they felt that it was limited. There was however a strong desire to reduce emissions (Figure 18).

Governments were seen to have the highest levels of responsibility for reducing emissions from buildings, although residents generally felt that all groups, except interestingly Historic England (previously English Heritage), shared a high level of responsibility for emissions reduction (Figure 19). This may be because homeowners perceive Historic England as only having responsibility for larger and more significant heritage sites and do not recognise their wider historic remit.

Residents also clearly felt that they held some of the responsibility, but identified a number of barriers including cost, knowledge of suitable options and the availability of heritage sensitive options (Figure 20). Time, disruption and things already achieved did not appear to be significant barriers to the majority of respondents, perhaps another indication of their desire to reduce carbon from their buildings.

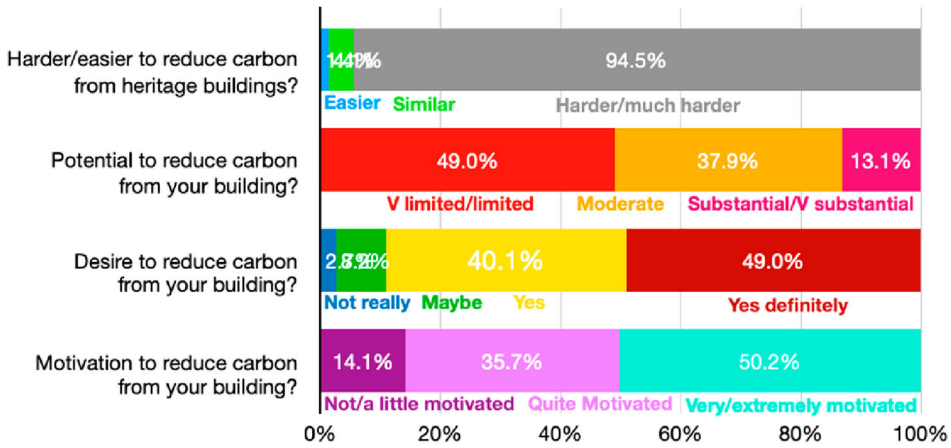


Figure 18. Motivation and ability to reduce emissions.

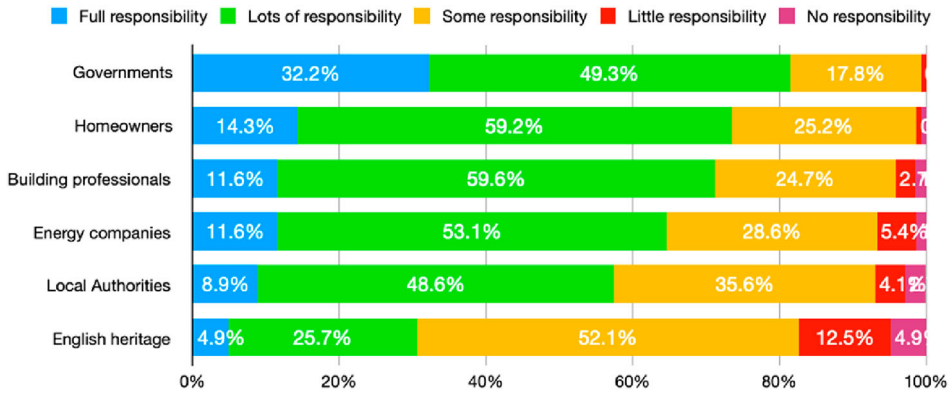


Figure 19. Stacked bar graph of responsibility to reduce emissions from heritage buildings.

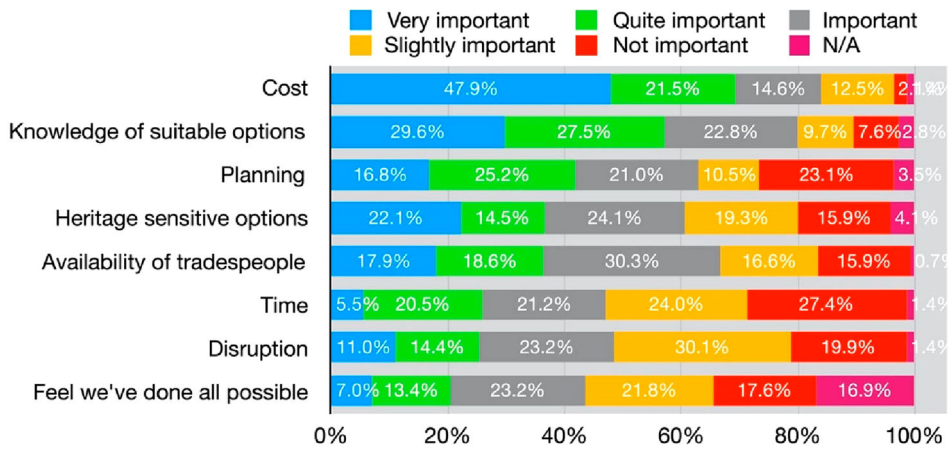


Figure 20. Barriers to reducing carbon emissions.

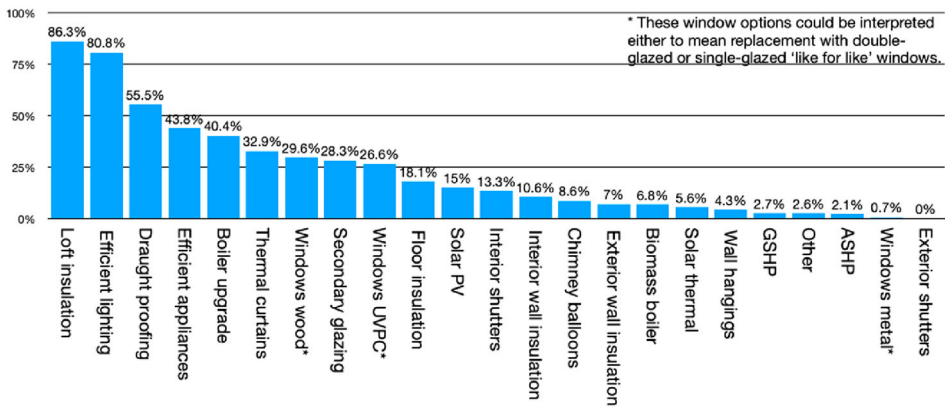


Figure 21. Percentage of respondents that already have a retrofit option.

Retrofit options

Respondents were asked to indicate whether they already had any of 22 potential retrofits. The majority of respondents have already installed common retrofit measures such as loft insulation (86.3%), energy efficient lighting (80.8%) and draught proofing (55.5%) (Figure 21).

Respondents were then asked to consider the acceptability of the retrofit options that they did not already have. Ignoring any planning and cost implications and thinking only about their effect on heritage values, Figure 22 shows the acceptability of these different options to the respondents who had not already implemented them.

There are clear preferences for various energy saving alterations. Of the 22 options 6 were unacceptable to the majority of residents: Biomass boiler; Wall hangings; external wall insulation; exterior shutters and new windows with UPVC or metal frames. While loft insulation, efficient appliances, draught proofing and efficient lighting are the most acceptable solutions, the majority of respondents, as shown above, already have these options, indicating a need to go beyond these solutions to reduce emissions.

Windows are often a particularly contentious topic. 13.6% of respondents mentioned the importance of their original windows in comments on heritage values and 43% of respondents still have at least some of their original windows. Residents were strongly opposed to new UPVC or metal framed windows (Figure 23) Wooden frames and secondary glazing were viewed more positively but there were still concerns about the impact of window replacements on heritage values.

The need for affordable, heritage sensitive solutions that preserved original frames and/or glass was also identified in the comments, for example:

Would love to replace draughty windows if it were possible to keep old glass and still make them double glazed.

[Someone needs] to design Georgian wooden sashes that are draught proof and double glazed ... that are affordable.

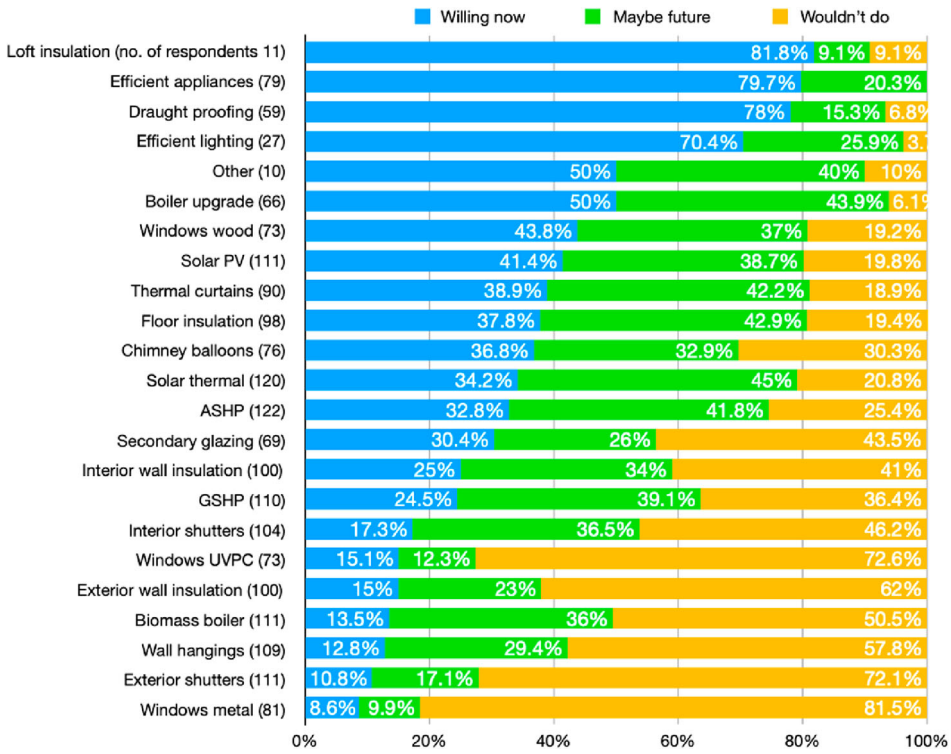


Figure 22. Stacked bar graph of acceptability of retrofit options.

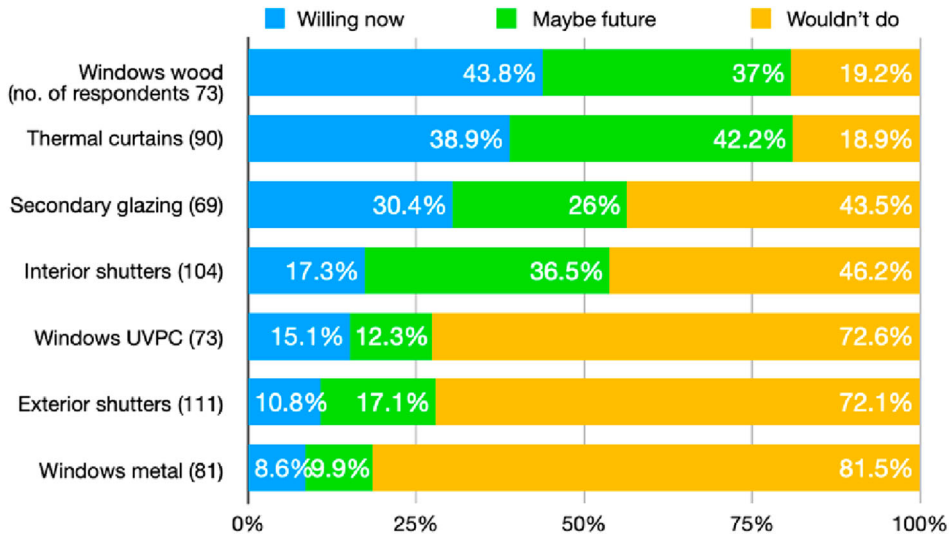


Figure 23. Focus figure on acceptability of window alterations.

Comparisons between respondents with different perceptions of heritage value

A number of inferential statistics and cross tabulations were developed to examine if there might be any substantial differences between respondents who perceive heritage

value in their buildings (referred to from now on as HY) and those who do not (referred to from now on as HN). The null hypothesis in each case is that there is no difference between the two groups.

It should be noted that only 28 respondents (19%) fell into the group who did not perceive their buildings to have heritage value, so there is only limited statistical validity to the following findings, and they are intended more to inform the discussion and point to areas for further research than to produce definite conclusions.

For the aspects that respondents valued about their buildings, mean values were compared for the two groups (Figure 24). As can be seen there appears to be a clear difference between the two which maps well onto the aspects considered to relate specifically to heritage value. Aspects shown in green text are those which showed a statistically significant difference between the two groups when assessed using Mann–Whitney U tests (see appendix 2 for details).

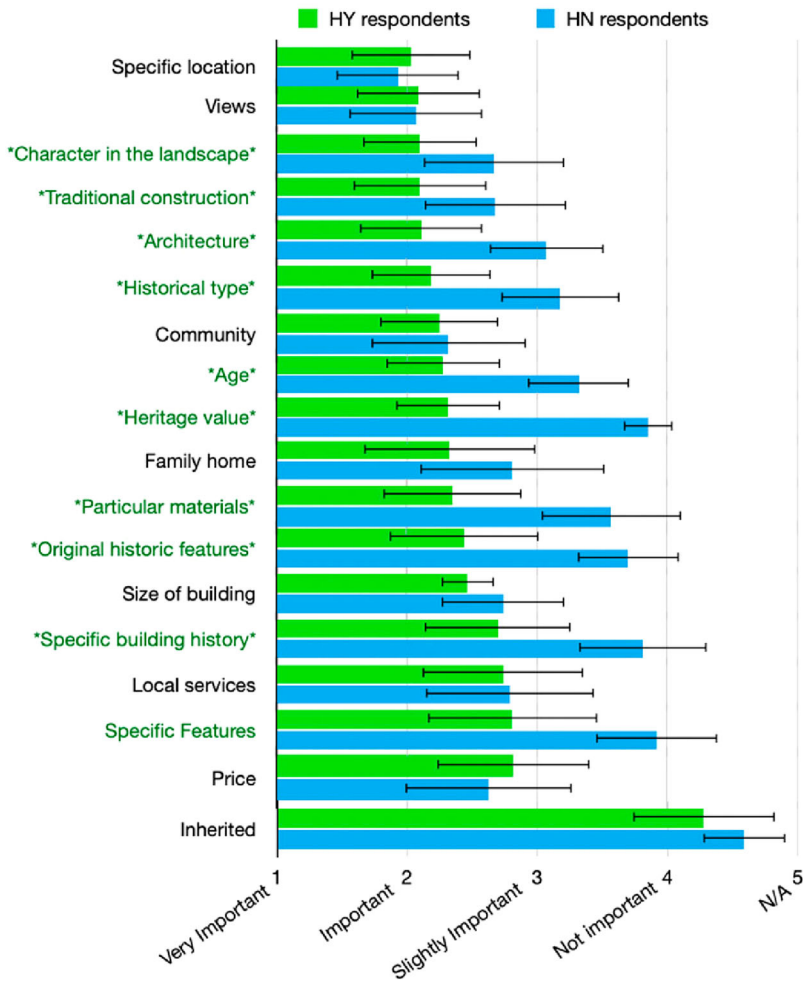


Figure 24. Cross tabulation of mean values for valued aspects, showing standard deviation as error bars.

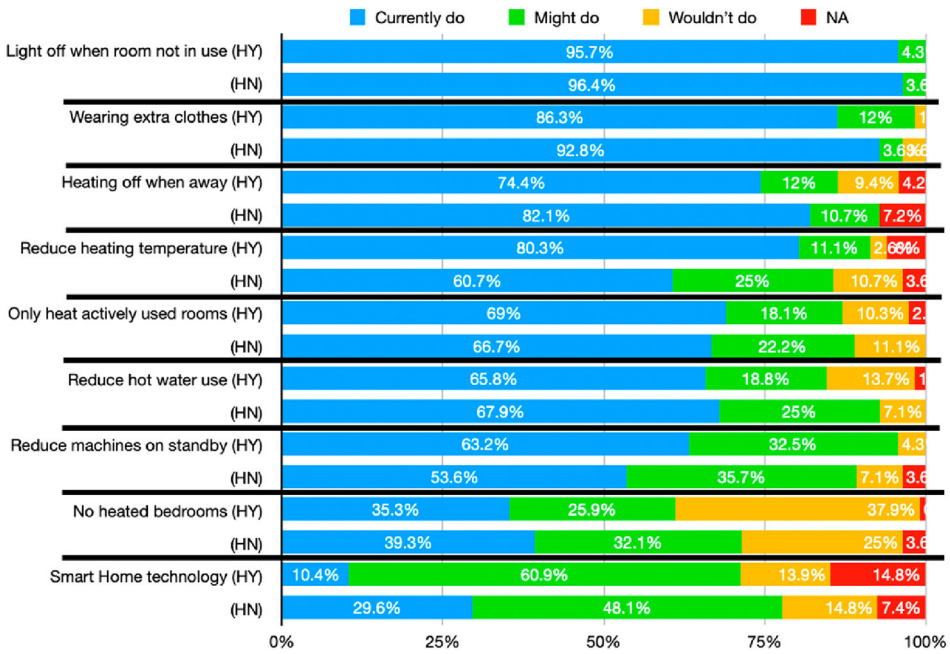


Figure 25. Comparison between energy behaviours for the two groups.

For energy behaviour differences between the two groups, a cross tabulation showed a mixed picture (Figure 25). Most differences were small, and results are inconclusive either way. However, more of HY group felt that they already had lower heating

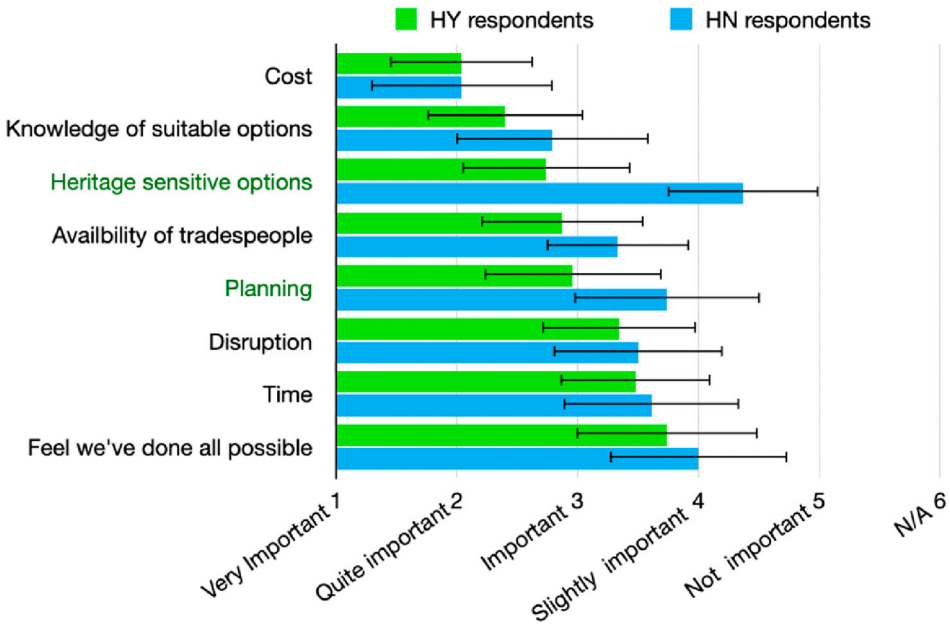


Figure 26. Comparison of mean values for barriers with standard deviation shown as error bars.

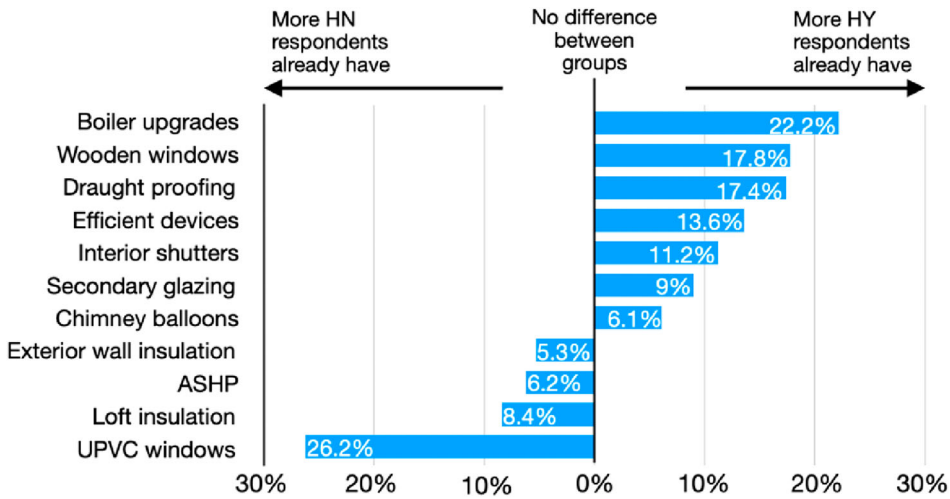


Figure 27. The percentage difference in retrofits that respondents already have between the two groups. Only differences greater than 5% are shown.

temperatures and less machines on standby, although they were less likely to have smart home technology.

There also seemed to be very little difference between the groups for heating and cooling sources with only two statistically significant differences (appendix 2), which indicated that the HY respondents were more likely to have or use ‘other’ heating sources but less likely to have or use ‘electric fires’.

Interestingly, HY respondents appeared to have a slightly higher level of satisfaction with their overall comfort (very satisfied 45%) compared with the small HN group (very satisfied 32.1%). The difference was not statistically significant (appendix 2) in this data set, but this might be an area to be investigated further.

Comparing attitudes to responsibility for carbon emissions there were no statistically significant differences (appendix 2). In terms of barriers for carbon reduction it appeared that the HY group were more likely to consider that the availability of heritage sensitive options, planning and the availability of tradespeople were barriers than the HN group (Figure 26). Heritage sensitive options and planning (green text) showed a statistically significant difference (appendix 2).

Considering retrofitting options, it appeared that the HY group were more likely to already have retrofits that were unlikely to have an external visual impact, while the HN group were more likely to already have ‘less sensitive’ alterations (Figure 27).

There were several differences in the acceptability of window alterations (Figure 28), the most obvious being that many more of the HY than the HN group would *not* consider UPVC window replacements (43% compared to 15%). In addition, those perceiving heritage value are more likely to already have wooden replacement windows, secondary glazing and interior shutters- which could all be considered more sensitive window alterations -and they are less likely to already have UPVC windows. This perhaps adds weight to the suggestion that the heritage sensitivity of window alterations is an important consideration for these respondents.

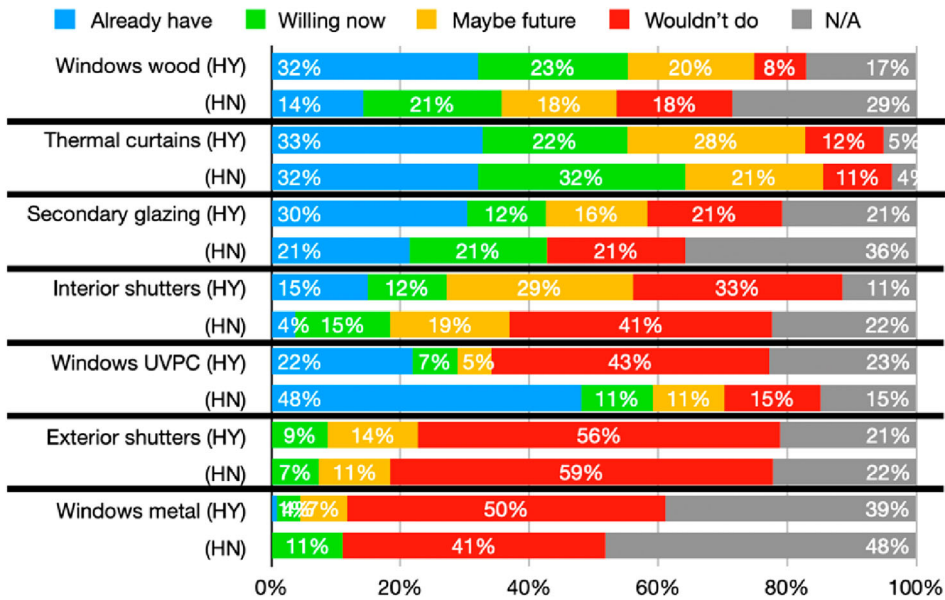


Figure 28. Comparison of the acceptability of window replacements.

Discussion

The first research question for this study was: How do the views, values and behaviours of heritage building residents differ from official assumptions? Firstly, it was found that almost all older buildings are considered to have heritage values by their residents, even if they are not officially protected. This has major implications as it could suggest that up to 8 million (28%) of the UK’s residential building stock are perceived by their residents’ as heritage buildings, with ramifications for how they should be treated. Residents were also shown to value aspects other than the traditional heritage features often identified by policy, such as ‘character in the landscape’. In particular, residents’ values related to a sense of ‘place’, traditional construction and local materials, highlighting the importance of the building in its context and landscape. In addition, those respondents who did not consider their buildings to have heritage value came from a range of building types, designations and ages, adding evidence to the suggestion that heritage values are not only related to specific characteristics of buildings but are specific and contextual to individuals. These findings suggest that official designations and protections do not currently strongly influence, or necessarily reflect, the perceptions of residents and that these perceptions differ from official and expert assumptions in several aspects.

Although residents felt that reducing carbon was harder in heritage buildings, they nevertheless had a strong desire to do so, and in fact many were already engaged in positive, energy saving behaviours. These included a range of active and individual heating strategies which are not currently acknowledged in official and standard assumptions on energy and heating behaviours. Simple comparisons between those recognising heritage in their older buildings and those not doing so, did not produce a clear picture and further research would be needed to explore whether certain energy behaviours could be

correlated with perceptions of heritage value or are related to the more general characteristics of older buildings.

For the majority of respondents these behaviours appeared to be a conscious choice, rather than a result of other, extrinsic factors (such as fuel poverty), as there was general satisfaction with thermal comfort among residents. These satisfaction levels did appear slightly higher amongst those perceiving heritage in their buildings. This general satisfaction with thermal, and other, comfort parameters calls into question the portrayal of heritage buildings as 'cold and uncomfortable' which is often assumed in the literature and current retrofitting approaches.

In response to the first question this study has therefore demonstrated that residents' perceptions of heritage and comfort, and their energy behaviours, differ significantly from policy assumptions. In particular: extending heritage value to many more buildings; challenging assumptions about heritage buildings' comfort performance, and engaging in distinctive and individual energy and heating behaviours. This supports other recent findings about the gap between residents' values and policy assumptions.⁷⁶

The second research question is: what influence do these views, values and behaviours have on the acceptability of different retrofit options to residents? This study found that, when presented with a list of common retrofit measures, residents expressed clear views about their preference for those which require minimal alterations to the building's fabric or visual appearance. However, many residents had already implemented the more heritage sensitive options such as loft insulation, energy efficient lighting and draught proofing. It is positive that these measures have already been implemented by many residents and may suggest that official programmes and campaigns over the last few decades have had an effect. However, it also suggests that the potential for these options to offer significant additional carbon reductions across the built environment is likely to be limited.

More visible measures such as external wall insulation and window replacement were not acceptable to the majority of residents, including to those in unprotected buildings. Although the heritage impact of these options is recognised for designated heritage buildings, they are often promoted as relatively simple and effective solutions for unprotected older buildings.⁷⁷ However, their unacceptability to residents implies that promoting these options is unlikely to substantially reduce carbon from the older building stock due to limited take up. This finding suggests that residents of unprotected buildings apply similar restrictions to external changes as those imposed on listed buildings.

In contrast to planning restrictions however, residents' dislike of external changes did not appear to hold true for renewable energy technologies, with solar PV and solar thermal panels potentially acceptable to a large proportion. In addition, non-permanent fixtures, such as thermal curtains, secondary glazing and interior shutters, were also more acceptable window adaptations, compared with complete replacement. This seemed particularly evident amongst respondents already perceiving heritage value in their buildings. Targeting these types of changes to a wider range of older buildings could therefore lead to significant carbon reductions with a low impact on heritage and high resident take up.⁷⁸ This suggests that conservation approaches to retrofitting may need to be applied to a broader range of older buildings and that investment in promoting these solutions is likely to lead to higher take up than less sensitive changes.

The mostly positive comfort perceptions also suggest that commonly promoted motivators for retrofitting, such as warmer and less draughty buildings, may not be sufficient to overcome residents' concerns about heritage impact. Some residents, however, desired secondary glazing on the grounds of auditory, rather than thermal, improvements. This adds to the evidence that residents' decision making is complex and involves a negotiation between many factors. Given the predicted climate change induced increases in UK summer temperatures and heat wave events, the ability of heritage buildings to stay comfortable in hot weather is an equally important finding. It is essential that this positive performance is taken into account in retrofitting decisions to ensure it is not adversely affected by alterations.

In response to the second question therefore, it was found that residents' views of unacceptable retrofits were in many ways similar to official restrictions for listed buildings, namely a strong dislike of external alterations and window replacement. This significantly expands the number of buildings for which such issues are a relevant consideration, up to around 28% of UK homes compared with listed buildings which make up 1–2%. In contrast to official restrictions however, residents were more accepting of visible renewable technologies. These findings imply a need to promote sensitive retrofitting approaches to existing buildings in general, not just designated buildings, and to take account of residents' views, values and behaviours.

The final research question was, what implications does this have for common retrofitting approaches to buildings with heritage value? These results have major implications for policy and approaches to the retrofitting of heritage and older buildings. This research has shown that sensitive retrofitting approaches need to be applied to many more buildings than is currently officially acknowledged, because residents will not make changes unacceptable to their heritage values. It has also found that residents' range of choices and behaviours around heating, energy use and retrofitting measures demonstrates that they 'negotiate' these solutions, mediating between many factors to make decisions. Support in terms of policy, advice, or other energy and carbon initiatives may be needed to help residents negotiate these solutions and to overcome cost and knowledge barriers, which residents identified as key challenges when it came to reducing carbon from their buildings. It appeared that cost and knowledge were equally important to both groups but those perceiving heritage value gave greater importance to the availability of heritage sensitive options, consistent with their desire to protect their buildings' values. Currently support is not provided in a targeted way for residents in undesignated heritage buildings who do not fall into the either historic or 'modern' building categories.

Importantly, this study has identified that residents of heritage buildings do not display energy and heating behaviours in line with standard assumptions. If the performance of older buildings is not accurately modelled before retrofit, subsequent retrofit measures are unlikely to lead to expected savings, which could put both environmental and financial targets into jeopardy. The widespread use of adaptive thermal comfort strategies, designed to keep people, rather than buildings, warm ⁷⁹ suggests that a rethinking of the standard models is needed, away from a focus just on the building. Expanding models to include specific user behaviours would better reflect real energy use, and, could help residents negotiate appropriate and heritage sensitive carbon reduction strategies for their buildings. The targeting of measures must also take local conditions and context into account.

Therefore, in response to the final question, many issues with current approaches have been identified. However, there are a number of positive points that can be taken when considering ongoing implementation or creating new policy. Firstly, residents have the desire to reduce emissions and many of them already take, or have taken, positive steps towards emissions reduction. Secondly, the retrofit results suggested that there *are* retrofits that are acceptable to a large proportion of residents but that have yet to be adopted, indicating routes forward. Thirdly, heritage buildings have better perceived comfort performance than often assumed. These positive aspects can be built on in a sustainable and heritage-appropriate manner to help reduce carbon emissions and mitigate climate change.

Conclusion

This paper has examined the results of a survey of heritage building residents in Cumbria and used this to draw conclusions about residents' values, views and behaviours and their implications for carbon reduction strategies.

The research has shown that residents have the desire to reduce emissions from their buildings, if they can be supported to do this in a heritage sensitive manner and to overcome cost and knowledge barriers. It has identified a significant gap between residents' perceptions and official assumptions about heritage values, energy behaviours and acceptable changes, especially in unprotected older buildings. It has also demonstrated that residents' perceptions of comfort in their buildings are often better than portrayals in policy or literature might suggest.

A number of key recommendations are made from this research. Firstly, more consideration of the values that residents invest in their older buildings, and how this affects their retrofit decisions, is required when designing carbon reduction initiatives, to encourage higher levels of uptake. These should be informed by further research into values and acceptable retrofits.

Secondly, there is a need to acknowledge that insensitive solutions such as external wall insulation and window replacement are unlikely to be acceptable to most residents of older buildings, including those that lack formal protection. Other options for achieving carbon reductions from these buildings should be explored through more detailed qualitative research, and subsequent information should be specifically tailored to these residents, who may not access information designed for designated buildings.

Thirdly, the energy behaviours, perceptions of comfort, and perceptions of heritage value, as well as the potential links between the three, should be investigated further to better inform the tailoring of standard energy performance simulation models. A larger scale, statistically representative, survey of residents in older buildings compared to modern buildings in the UK would be extremely valuable to inform concepts of heritage building performance and identify drivers for retrofit. This could identify positive elements of current performance such as good summer comfort, as well as areas for improvement, to provide a more balanced picture and inform policy going forward.

Retrofitting of existing buildings is a key strategy to reduce carbon emissions and therefore mitigate climate change. In order to make a serious effort to reduce emissions from older buildings, this paper has demonstrated that a consideration of residents' values, motivations and current energy behaviours is critical in order to define suitable

retrofitting programmes. Retrofitting policy and legislation needs to extend beyond current definitions of heritage, acknowledging that residents identify heritage values for a much larger group of buildings than currently defined, and take residents' energy behaviours and perceptions of comfort into account.

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