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Retrofft information challenges and potential solutions: Perspectives of households, retrofft professionals and local policy makers in the United Kingdom

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ABSTRACT

Rapidly scaling up energy retrofit for existing buildings is critical to help meet climate targets. Information is frequently identified as a key barrier to residential retrofit. This paper explores the role of information sharing in accelerating retrofit market transformation, through interviews and photo elicitation with homeowners ($N = 9$) and two workshops with stakeholders ($N = 33$) in a local authority retrofit project in Gloucestershire (UK). Findings are thematically analysed and suggestions for future local and national policy action are identified. The research finds that even for engaged, knowledgeable homeowners, accessing appropriate information is still a significant retrofit barrier. Two themes around the nature of information and information delivery are identified and key issues include information overload, a lack of context-specific information and in-person engagement, and a need for trustworthy, local information sources. Local authorities have potential to act as trusted intermediaries for structured, relevant retrofit information but require support from national governments to increase capacity and resources at local levels. National governments also have a critical role in providing clear and consistent messaging and leadership on the importance and benefits of retrofit. Policies around financial incentives are not sufficient alone and must be accompanied by strategies to overcome informational and other barriers if retrofit is to be accelerated in this decisive decade for climate action.

1. Introduction

The global buildings and construction sector account for around 37 % of carbon emissions annually [1]. Current levels of energy retrofit for existing buildings in developed nations must be massively upscaled to reduce carbon emissions and achieve critical climate targets [2–4].

Much 'low-hanging fruit' for retrofit has been addressed over past decades through subsidy programmes targeting individual retrofit measures [5]. These programmes were often cost-effective and successful within their remits but limited in addressing the full potential for carbon reduction. To access deeper reductions, policies have increasingly sought whole-house approaches to energy and carbon reduction, as well as the wider transformation of markets. These policies aim to create supply chains for these whole-house services which do not rely on public subsidy [6]. This type of market transformation is well described in academic theory and requires coordinated action across multiple policy instruments over an extended period [7]. However, in reality retrofit policy has been identified as piecemeal, often involving short-term, single-measure schemes focusing on financial incentives and neglecting other barriers [8].

Alongside cost, retrofit information is frequently identified as a key barrier to uptake [9,10]. Many retrofit policies include the stated objective of creating lasting retrofit market transformation over the longer term. This requires a more comprehensive approach to addressing cost and informational barriers together.

This paper investigates the role of information in accelerating retrofit market transformation. It examines how homeowners currently access retrofit information, what barriers they encounter, and how these could be overcome. These questions are examined through nine interviews and photo elicitations with homeowners and two workshops with homeowners, retrofit professionals and local policy makers, in the county of Gloucestershire, UK. The paper offers increased understanding of informational barriers to retrofit through the lens of market transformation in a UK context. It uses mixed methods -including a novel photo elicitation method to explore households' lived experience- and makes recommendations on overcoming informational barriers.

This research formed part of a larger project funded by Innovate to Renovate (I2R), a partnership of seven local authorities (LAs) in

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Gloucestershire. The project centered on designing retrofit services through research into local needs and is a good example of LAs taking a market transformation approach and considering ways to drive demand for wider, long-term market effects.

The majority of UK housing is single-family homes and over 60 % is owner occupied [11]. These homes present significant carbon reduction opportunities but can be challenging to engage in retrofit as they require individual approaches [4]. The I2R project targeted these single-family, owner-occupied homes.

In the rest of this paper, section two briefly reviews the literature, section three describes methods, section four analyses the results, section five discusses the findings, and section six presents' conclusions and implications.

2. Background literature

The challenge of upscaling retrofit can be usefully viewed through a market transformation lens [12–15]. Its core principle is that public funds can be spent in ways which strategically transform markets, creating more impactful changes than traditional rebate-style interventions [16]. Rebate-style interventions can be very effective in achieving specific goals but are generally not designed to address the underlying barriers that impede the longer-term uptake of retrofit products and services [7].

Nadal and Latham (1998) described the adoption curve characterising market transformation, from early research to widespread adoption. This fits within wider literature on the diffusion of innovation [17], and has been widely adopted as a narrative tool for describing the journey retrofit markets must take (Fig. 1).

[18]. Permitted reproduction under article 4, EU commissioned documents policy)

While market transformation principles have been consistently and reliably applied to product-based markets [7,15,19], their application to more complex, process-based and fragmented markets such as retrofit [20–22] is less established [23].

A portfolio of policies must create supply push and demand pull to enhance stagnant markets [24,25]. Fig. 1 highlights that climbing the steepest part of the curve, from early to mass adoption requires both information and incentives [18]. Significant policy attention has focused on required financial incentives [5,26]. However, there is less study on the quality and nature of the information required to transform retrofit markets.

Much of the market transformation literature occurred in the early-2000s i.e. [27], with high profile efforts such as the US BBNP [28], the Canadian EcoEnergy Program [29], and the UK Green Deal [30], all targeting market transformation objectives with similarly high profile, national scale policies.

The UK Green Deal represented market transformation in name only. While its stated objective was creating self-sustaining changes to retrofit markets, it lacked many of the policy pillars which experts consider fundamental to market transformation. Most notably, skills development and information campaigns [30]. This program's failure has acted as a deterrent to further transformational initiatives, and subsequent attempts have been more modest in scale and retreated to focus again on measure-based programmes. At present, the UK Government's own policy evaluations remark on the inability to learn from past policy failures [31].

In the decade since the Green Deal, market transformation has also retreated from common parlance in academic literature. A recent review was carried out by Killip et al., [32] and explored how the market for repair, maintenance and improvement can be transformed so that retrofit opportunities are integrated into everyday practice and market activity. It also reinforced the now decades old call for more joined-up thinking in retrofit policy.

While this joined-up thinking is largely missing in the UK at national levels, there is much local activity. Three quarters of UK LAs have declared climate emergencies and created action plans, typically including ambitious retrofit agendas. These plans generally echo market transformation blueprints described by the literature over recent decades. Most local authorities access subsides for measures through government funding programmes such as the Energy Company Obligation, Public Sector Decarbonisation Scheme, or Local Area Development funding, among others. The I2R programme, which forms the context for this research, exemplifies LAs developing complementary programs to address non-cost barriers and leverage subsidies to drive wider market effects. A more subtle and detailed understanding of informational barriers can help improve LA programmes like I2R.

While significant literature identifies information as a barrier, this has mainly been within wider retrofit studies and has received limited detailed attention. There is a related body of literature exploring the impacts of social relations on retrofit decision making. It finds that how actors share information plays a critical role in the uptake of retrofit measures see e.g. [33,34,35], This paper focuses on characterising specific informational barriers and solutions in the context of the UK retrofit market. It is acknowledged that, without appropriate and accessible information, financial incentives are insufficient to drive mass retrofit

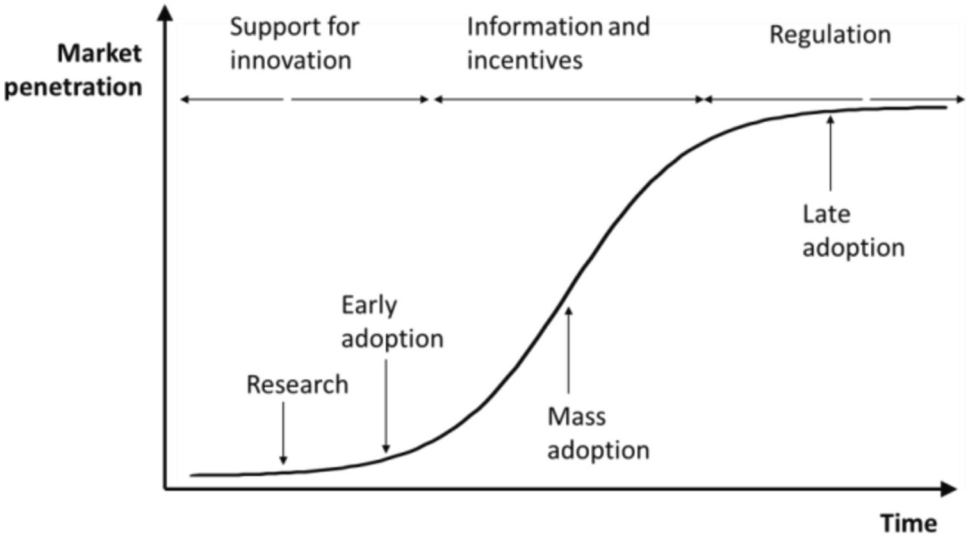

Fig. 1. Market transformation adoption curve.

adoption [3], with greater knowledge and awareness increasing households' willingness to undertake deeper retrofit [36,37].

A recent literature review has highlighted that retrofit's complexity means it is subject to information asymmetries, where the full benefits can never be fully predicted by the household [21]. Consequences of these asymmetries may include sub-optimal combinations of retrofit measures, variable installation quality, especially for 'hidden' work, and potentially less effective retrofit subsidy targeting. However empirical data on these asymmetries are limited and acknowledged to require further research [21].

A lack of appropriate information has been identified as a greater retrofit barrier than the availability of technical solutions across Europe [38] and information gaps contribute to perceived lack of control and confidence for households [36]. This informational paralysis has been identified as a key psychological barrier, even when households desire to undertake retrofit [39–41].

Significant generic retrofit information is readily available in many countries. However, it is not necessarily specific enough to be useful to households, with a recent review of thermal retrofit suggesting:

> This [information proliferation] has resulted in the production of choice environment(s) which are often structured in such a way that they produce confusion rather than enlightenment [39].

Thus, highlighting the complex, fragmented nature of the retrofit market. Other studies highlight the importance of tailoring information for different audiences and contexts [20,36,41], suggesting a need for more consideration of the content and quality of information.

In the UK, when specific information *is* available, it often focusses on single measures, with households who engaged in substantial retrofit identifying challenges accessing information on interdependencies between different measures [42]. This is partly due to the fragmented nature of the construction industry [2,21] which has been exacerbated by previous policies incentivising single, rather than multiple measures [43] and failing to transform markets.

In addition to information quality, information *sources* have been frequently identified as important, with trusted messengers key factors in whether households will act on information [20,39,40]. In numerous European countries, households have been shown to be more likely to seek information from family, friends and personal networks rather than official sources. [10,41,42,44].

Research across Europe has also found that homeowners often express frustration about poor clarity on green transitions, with policy support and messaging for retrofit often lacking stability and consistency [36,43,45]. Increasing informational accessibility and emphasising retrofit co-benefits is also considered important for increasing adoption [40,45].

Information is therefore a well-known barrier to retrofit market transformation, with several potential information asymmetries, and challenges with both information quality and sources identified. However, only limited attention has focused on categorising households' experience of these barriers and considering how to overcome them. Most policy and industry efforts to date have focused on creating a body of information and there is only limited evidence for how this information is actually used and whether it's fit for purpose. However, it appears that addressing these informational barriers is likely to be critical for driving mass retrofit adoption and achieving market transformation.

3. Methodology

3.1. Research approach

This research took a mixed methods approach, combining workshops with interviews and creative methods to develop a fuller understanding of informational barriers from the perspectives of homeowners, professionals, and local policy makers. Mixed methods research can provide both breadth and depth of understanding [46].

This research considers informational barriers through a socio-technical understanding of retrofit, reaching beyond the view of households as rational actors who merely require information on the economic rationality of retrofit to drive uptake, a view that has been widely challenged [36,47,48]. This paper therefore considers information provision from a broader, socio-technical perspective, acknowledging that households' retrofit decisions are complex and shaped by their experiences, values, contexts and emotions [33,48,49].

The project focused on Gloucestershire in the southwest UK and all participants lived or worked here. For the sample size targeted in the study, a representative sample was not realistic. It was agreed with the council to focus on a subsection of the population within the 'self-financing' market. It targeted single-family, owner-occupier households with access to sufficient capital to self-finance retrofit. While cost is a key retrofit barrier [26,44,50], significant research has found other barriers to be equally important [36,51,52]. This research focused on information as one of these non-cost barriers.

3.2. Workshops with professionals and local policy makers

Two online workshops took place in late 2022. Workshops are useful for bringing together different views and rapidly gathering insights from multiple participants [53]. Open invitations for both workshops were shared with I2R partnership contacts.

Workshop one (WS1) in November, included staff and councilors from LAs, retrofit professionals and homeowners. Framing information was presented, then the 14 participants separated into small groups for researcher facilitated discussions of triggers, influences, and barriers at various depths of retrofit (Supplementary information: Appendix A).

Workshop two (WS2) was held in December with 18 retrofit professionals, mainly architects and designers. Based on WS1 findings it considered retrofit as a design and lifestyle decision, aiming to emotively engage homeowners. Participants were split into facilitated groups and discussed retrofit messaging, language, triggers, and barriers (Appendix A).

Both workshops were audio recorded and participants added comments to a Mural board. Recordings were auto-transcribed using Otter.ai [54]. Researchers cleaned and checked transcripts. Written comments and transcripts were assessed using thematic analysis following Braun & Clarke [55]. Two researchers independently analysed the data, identifying and refining themes through several iterations. The team then discussed and collectively agreed the main themes.

3.3. Homeowner interviews

Nine, semi-structured, online homeowner interviews were undertaken in December 2022, allowing in-depth exploration of homeowners' views. Participants were asked about their homes and comfort, whether they had made or were planning any retrofits, and how easy they found accessing information (Appendix B).

Participants were recruited via email invitations requesting homeowners willing to discuss home comfort and energy. The term 'retrofit' was avoided because it was identified as intimidating in WS1. The intention was to recruit participants with varied buildings, opinions and

Table 1
Interview invite dissemination.

Dissemination streams for interview invites	
All seven local authority partners	Invites included in internal communications to all LA staff
All seven local authority partners	Encouraged to share with local community groups, churches, women's groups etc.
Two local authority partners	Shared invites on social media

knowledge for a maximum variation sample [56]. Invitations were disseminated through multiple channels (Table 1). Recipients were encouraged to snowball invites to their own contacts for wide dissemination.

Responses were received from 11 homeowners who were sent study information and consent forms. Two homeowners had to withdraw before the interview, leaving nine interviews. Interviews were audio recorded, recordings were transcribed using MS Teams or Otter.ai and checked and cleaned by researchers. Interview summaries were created and thematically analysed as described in section 3.2.

3.4. Photo elicitations with households

To supplement interviews, homeowners were invited to complete an optional photo elicitation (PE) activity. PE is valuable for elucidating concepts that are challenging to convey verbally [57] and was previously used for retrofit research by Wise [41]. PE provides opportunities for a more reflective approach than instantaneous interview responses. The visual method encourages in-depth thinking and helps investigate connections between lived experience and energy performance. This approach also supported and enhanced data from the other methods.

Participants were invited to take 1–4 photographs of comfortable/uncomfortable spaces in their home and send them, with a short description, to the researchers before the interview. Seven homeowners completed this optional activity, sending 2–4 photos each. PE results are presented in Section 4.3 and several of the themes illustrated issues associated with informational challenges by centering the conversation on the homeowner and their own building.

3.5. Ethical details

All participants gave informed consent before participating and agreed to anonymised data being shared (Appendix C). The research was approved by the University's Research Ethics Committee. Participants gave specific permission for PEs to be shared.

3.6. Interviewee characteristics

Most interviewees live in rural areas (Table 2) -reflecting much of Gloucestershire- and lack access to the national natural gas grid. Natural gas is used to heat around 72 % of UK homes [58–60] but rural areas have limited gas grid access, with households instead using oil, bottled gas or electricity.

Most participants live in traditional, solid walled properties, although many have more modern extensions. Only one home has official heritage designation. However, four participants felt their homes had heritage values which influenced their retrofit decisions (Interviewee 1 (I1), I5, I6, I7). Seven participants have renewable energy technologies.

The workshop and interview transcripts were analysed to inductively develop themes and sub-themes relating to informational barriers [61]. These were iteratively discussed among the research team as the analysis continued. A table summarising which themes appear in which data points is available in Appendix D (supplementary information). These themes are explored in the following sections.

4. Results

The workshop and interview results are presented thematically, with two main themes divided into sub-themes (Table 3). The PE results are then presented, followed by participant suggestions on improving information provision.

4.1. Nature of the information available

A consistent theme was discussions around the increasing volumes of information available on retrofit, with participants suggesting this is itself a barrier. Four sub-themes emerged regarding information overload, conflicting information, the need for context specific information, and how retrofit information must link to wider household decision making. This analysis explores each sub-theme.

4.1.1. Information overload

Despite all the information available, participants feel it's hard to identify appropriate measures or remain aware of technical developments, grants, and other support (I1, I4, I5, I9). I5 noted that substantial effort is required to assimilate and synthesise retrofit information (extended quotations in Appendix E, Supplementary information):

Table 3
Themes and sub-themes.

Identified Main themes	Identified Sub-themes
Nature of the information available	Information overload
	Conflicting information
	Context specificity
	Holistic information
Information delivery	Understanding the audience
	Bringing information to people
	Trusted messengers

Table 2
Interviewee characteristics.

Participant	District of Gloucestershire	Building type	Building Age	Renewable energy	Location	Years of occupancy	Occupants
I1	Forest of Dean	Solid wall stone cottage, detached.	1700s	None	Village	26	1
I2	Forest of Dean	Solid wall stone house, detached.	1850s	Solar PV, Ground source heat pump (GSHP)	Rural	40	2
I3	Forest of Dean	Detached bungalow	1960s	Solar PV, Air source heat pump (ASHP)	Village	30	2
I4	Tewkesbury	Semi-detached cottage.	1850s	Solar thermal and solar PV	Village	12	2 adults, 1 under 18
I5	Unknown	Detached Victorian house	1896	Solar PV and battery	Unknown	5	2 adults, 1 under 12
I6	Forest of Dean	Semi-detached house	1935	Solar PV, ASHP	Village	Not stated	2 adults, 2 under 18
I7	Forest of Dean	Grade II detached farmhouse, timber frame	1700s	Solar PV,	Rural	35	2
I8	Forest of Dean	Solid wall stone cottage, detached	1900	None	Rural	21	3 (1 at university)
I9	Stroud	Detached house	1995	Solar PV, ASHP	Hamlet	5	2

I5: I've got to go out, find all that information and put it all together and then work out how it's all going to work for me… it's always going to be challenging.

This quote highlights the complex analysis and evaluation homeowners must negotiate to create meaningful knowledge from the information they encounter. This was also identified in I7's PE (Section 4.3) Even some professionals found remaining aware of new developments challenging, with one architect commenting:

WS2: I think I've done more continuing professional development… on everything to do with low energy buildings… it's a minefield.

If finding time to remain aware of developments is challenging for professionals, it is unsurprising that interviewees highlighted that many households lack time to conduct the level of investigation and information sifting required to identify appropriate measures. This is exacerbated by the volume of information available feeling overwhelming (I1, I2, I5, I6, I7). WS1 participants also suggested that households 'don't have the time and space to think about it,' with retrofit identified as sounding 'scary', off-putting, and overwhelming.

The sheer amount of available information may therefore be a barrier in-itself and even professionals can suffer from 'information overload'.

4.1.2. Conflicting information

Increasing volumes of information inevitably lead to cluttered messages. Another theme was the challenge of conflicting advice from different experts (I2, I5, I7, I9).

An energy consultant told I2 solar thermal would be a good addition to their new thermal store for their GSHP but when they asked the installer:

I2: He said 'don't go down that route… the complications that result are awful.' Yeah, so two conflicting pieces of advice…

This episode resulted in informational paralysis, with I2 unsure what action to take.

Participants in both workshops identified conflicting information as causing confusion and discouraging homeowner action. One professional in WS2 related how a friend installing a heat pump called them in a panic, needing reassurance, when the plumber said heat pumps made it impossible to have baths because they provide insufficient hot water.

Therefore, even homeowners with the time and commitment to research and consider different measures can still be thrown off course by conflicting information.

4.1.3. Context specific information

While it's easy to find large volumes of generic retrofit advice, homeowners find it much harder to access useful information to inform good decisions specific to their own home and circumstances (I1, I2, I3, I4, I5, I6, I9). WS1 participants also felt 'solutions per home are very nuanced'.

I3 for example was concerned to reduce thermal bridging of their cavity wall insulation, which was causing black mould in some rooms, they were struggling to find information on how to rectify the situation.

I3: It's probably that they were never able to get in there [parts of the cavity] properly… it's going to be very difficult to deal with.

They are considering internal insulation for those areas but are concerned about masking damp problems without addressing the underlying issue and are unsure how to proceed because identifying the exact cause is challenging. I9 also noted difficulties identifying suitable, bespoke measures, which are also generally very expensive.

Identifying suitable solutions for personal circumstances is challenging (I1, I5, I6, I7). I1 for example, lives alone and heats their home frugally. They were therefore concerned about any new heating system being oversized for their needs.

It is also challenging to move from theoretically identifying measures to enacting them. I6 found substantial information on the benefits of reflective radiator backing and was keen to install it but failed to find local suppliers and was becoming frustrated. They felt that often for potential measures:

I6: There're great videos about how it works… there's all the things you in theory could do, but we're not going to help you *actually* do it.

This suggests that while theoretical advice on measures is available, it can be challenging to understand how to operationalise it in individual contexts. Participants in both workshops felt the difficulties of finding context specific information made it hard for homeowners, and often professionals, to identify carbon savings and costs of individual retrofits.

Identifying and selecting the most appropriate measures for individual contexts, and finding actionable information is therefore considered challenging by the research participants.

4.1.4. Holistic information

The final sub-theme in section 4.1 relates to information siloes. Most available information has a narrow focus on specific topics or measures, with insufficient context for how they interact with other measures or wider household decision making.

I2 for example has already made significant performance improvements to their home. However:

I2: I'm aware that the walls aren't very good, and I don't really know what to do… it's the embodied energy [in external wall insulation] …I'm sure someone with the really correct equipment and able to calculate can work all this out but I'm afraid it's not going to be me.

They were concerned about the lifecycle energy and carbon of external wall insulation but were unsure how to find information. They were also concerned about designing retrofits which function effectively in future climate scenarios, given predicted temperature increases and extreme heat events. This was something they felt currently lacked consideration and where there are still: 'a lot of unknowns'.

I7 also felt that decisions should be assessed from a lifecycle carbon perspective and that more information on larger system effects was required.

I7: With climate change, people are saying, 'yes, if you do this, you're making a saving.' But quite often what they don't do is go backwards… take the big picture and think 'oh, hang on a minute.' This is actually costing a lot more [carbon] than you're thinking.

The workshops meanwhile identified that it's generally difficult to find holistic retrofit advice in sufficient detail which considers the interdependency of different measures. For example, heat pump engineers often know little about fabric retrofit and vice-a-versa 'because they've got these siloes, you know?' (WS2).

I5 avoided a costly solution for addressing damp in the living room of their 1890s house when a drainage specialist looked holistically at their home and suggested the main issue was that the garden had been built up above the damp proof course.

I5: He said: 'put in a French drain, get everything below the damp proof course and give it six or seven months'… We did exactly that… and, touch wood, we've not had any dam. it was so obvious.

They appreciated the solution's simplicity and effectiveness as they previously thought they would need to have all the damp plaster chipped away and replaced with an expensive specialist product. They feel they are now: 'in a much better position' (I5) with damp generally, thanks to this holistic approach improving conditions throughout their home.

Meanwhile, several WS2 participants noted that retrofit co-benefits were:

WS2: Not something that the industry knows enough about or tries to give to people necessarily.

Other participants thought this reduced uptake of retrofit measures because households were often unaware of the wider benefits that good quality whole house retrofit can provide.

WS2: So, there is that lack of experience of aspiration [for retrofit] because people don't know what they should be aspiring to.

This was considered an important barrier and emphasises the need for improved information on retrofit's holistic effects, instead of a narrow focus on energy and cost, to increase demand among households.

More holistic retrofit information, including lifecycle carbon, reduced siloes, and better understanding, engagement and messaging around whole house retrofit, which allows homeowners to assess options for their whole system is therefore considered important.

The first theme on *the nature of information* therefore finds a clear need for context specific, individual, and holistic information for retrofit, as an antidote to information overload and often conflicting and siloed information. This research finds these needs are not currently being met.

4.2. Information delivery

The second broad research theme relates to information delivery and tailoring. Three sub-themes cover understanding the audience, taking information to people, and finding trusted messengers.

4.2.1. Understanding the audience

This theme refers to the stage households find themselves at on the market transformation curve. Either as *early adopters*- who are willing to make changes and accept risks but require significant support; *the early majority* -who are open to new ideas if they are becoming mainstream and if markets can provide a straightforward service; or the *lagging majority* -who make changes because they have become normalised and even mandated by policy. There are numerous segmentation approaches and messaging strategies for each audience. The need to dramatically accelerate retrofit rates to address the urgency of climate change means many policies are targeting the early majority to drive a higher volume of retrofit projects.

As described in section 3.3, the interviews in this research engaged a wide potential participant pool. However, actual participants are in fact better described as early adopters rather than early majority. A key distinguishing characteristic is that early adopters are typically more motivated to navigate the informational barriers identified in section 4.1. Most interviewees were actively engaged in local climate action, including transition groups and community renewable energy projects. Several had substantial knowledge of retrofit and low carbon technologies (I2, I3, I6, I7, I8). I2 for example, installed a GSHP in 2004 and runs open home events to share learning. Seven of the nine participants have solar PV and four have heat pumps (Section 3.6).

Another characteristic is that early adopters are often willing to pay more for new measures before economies of scale reduce costs for the early majority. I1 switched from LPG to bottled biogas several years ago to reduce their environmental impact:

I1: I thought that at least I can do that, and I'm happy to do it, although it does cost more.

Showing that their motivation to reduce carbon emissions is sufficient for them to accept a financial premium.

These interviewees can thus be considered early adopters. It is worth investigating their views because if *they* struggle to access appropriate information, it's very likely less engaged homeowners will also struggle. Most interviewees felt they could access the information they needed but still encountered challenges, and even these engaged homeowners generally felt: 'you have to be quite determined to be green' (I1).

It is thus important to understand who the audience is for retrofit information to help increase the pace of market transformation and move more households from early adopters towards the early majority.

4.2.2. Bringing information to people

This sub-theme identifies that information must be *bought to* households rather than waiting for them to seek it, including through in-person advice and experience.

Interview participants highlighted current good practice in both bringing information to households and using varied forms and mediums (Table 4). These examples all involve LAs or local groups who may be better placed to provide context specific information than national organisations.

Workshop and interview participants emphasised the importance of in-person advice (I1, I2, I4, I5, I7). I2 felt 'You do need somebody you can talk to who's got experience', while I4 noted the local energy agency (who were mentioned positively by eight homeowners) used to have an excellent service where they:

I4: Could send someone to chat to you for a few hours. They probably don't have the budget to do that anymore. But it used to be good when it was a very individual service.

They felt it was useful to have information come to them, and for contextualising and personalising information. I5 also felt personal interaction would be excellent but was concerned its provision might not be resource efficient. Meanwhile WS2 participants felt that homeowners are nervous of the risks and uncertainty associated with retrofit, and: 'want a professional advisor to help'.

Participants also emphasised the benefits of seeing and experiencing a measure, either by visiting someone who has already installed it (I1-I3, I6-I8) or if there is a showroom. I5 for instance is investigating an air-to-air heat pump, similar to a friend's system.

I5: It makes a real difference if you can go around and see it, touch it, feel it, and experience the difference it's making to the house.

They found this in-person experience useful to help them decide whether this system could work for them.

WS2 participants also noted the benefits of in-person engagement and that homeowners want 'to be able to experience it' (WS2). Importantly however, they felt this was generally impossible for retrofit, unless homeowners have personal connections, like I5.

WS2: If you're investing say £10 k or £15 k in a new kitchen, you'd go into a showroom, and you'll actually see what you're getting. With things like solar panels it's not as if you can just pop in somewhere and actually visually see [the retrofit].

They felt this lack of opportunity to experience things physically was partly because there is no clear market sector driving retrofit, and partly because supply chains are very fragmented.

In person advice and experience is therefore still an important area lacking for retrofit and leads to reduced adoption of measures, even by homeowners wanting to retrofit. In-person experience is a key method of bringing retrofit information to people and making it more accessible,

Table 4
Examples of current good practice.

Source	Current examples
I1	Retrofft information shared through Parish Council notice boards and websites, including context speciffc successes
I3	Local energy agency previously ran drop-in advice sessions at village hall or village shop
I4	Building control provided useful expertise on local vernacular construction
I2, I3, I7	Local green groups have monthly meetings on topics including retrofft
I2, I6, I7	Open home events well received
I2, I7	Local green groups and local Green Party try to provide information and/or have stands at public events, including on retrofft

visible, and immersive.

4.2.3. Trusted messengers

The final sub-theme emphasises that while availability, content and quality of information is important, so is its perceived trustworthiness. All interviewees (except I9 who has recently moved to the area) would begin seeking information from friends and local networks.

> I7: We do have a lot of friends that have that information… we share a lot of information.

These personal sources were generally considered trustworthy providers of context specific advice, and personal testimonies can increase diffusion of different measures and technologies.

However, reliance on personal networks can present challenges if systems do not perform as expected. I1 for example is not currently considering a heat pump because several friends have had negative experiences:

> I1: I'm not yet sold on [heat pumps] because I know people who have them and they've had a few problems. I think I'm waiting to see what the technology brings out in the next couple of years.

This demonstrates that the experience of early adopters can both encourage and discourage action among their networks.

Workshop participants also highlighted challenges finding skilled, trustworthy tradespeople to provide high quality retrofit. They noted homeowner vulnerability around distress purchases (WS1) and limited regulation and quality assurance (WS2).

> WS2: There's still so much installation failure going on because it's the wild west out there.

This was supported by interviewees (I1, I2, I6, I8, I9) who were wary of being 'sold to' and found identifying skilled tradespeople and retaining awareness of legitimate government retrofit schemes difficult (I1, I2).

> I9: There're very few places where you feel that they know what they're talking about, and they're giving you factual information that isn't just there to sell you something you probably don't really need.

This challenge with finding trustworthy advice may also encourage homeowners to rely heavily on personal networks and local recommendations:

> I8: It's quite comforting… Locally there's a reputational risk. If they do a bad job or give you the wrong advice or overcharge you. It gets passed around.

As well as local tradespeople, homeowners were more inclined to trust local organisations and LAs, rather than central government. Seven interviewees (I1, I2, I3, I5, I7, I8, I9) were negative about central government's record on climate action. Several (I1, I2, I3, I5, I7) noted a dichotomy between the, then recent, decision to open a new coal mine in Cumbria, and government messaging on homeowners' responsibility to retrofit without providing coherent structural support.

> I5: It all revolves around doing the right thing. The idea that *we* should make an effort to be green, to recycle, to save energy… yet they're not doing things that sit within *their* remit.

Interviewees also felt central government should be doing much more to support retrofit, skills development, and tighter standards for new buildings in their climate change response (I2, I3, I7, I8). The need for national retrofit conversations, clear leadership, and consistent messaging was also highlighted in WS2.

> WS2: The need for consistency in language and leadership, and we mean from the top, from central government.

Trust was a theme in both workshops, being identified as a key factor in market transformation, with participants emphasising the importance of trustworthy, authoritative messengers.

> WS1: I need an authoritative voice to reassure me… like Martin Lewis [UK consumer rights expert] for retrofit!

Participants in WS2 felt LAs could be useful messengers: 'I think the LA are trusted. And they do have that potential.' Information *sources* therefore appear as important as *content*, and trust underpins homeowner retrofit decisions.

PE results are presented before synthesising participants' suggestions on improving informational provision.

4.3. Photo elicitation

The seven participating homeowners provided 22 photographs with associated comments. These were classified into five themes, and three sub-themes (Table 5). Themes on comfortable spaces and previous retrofit actions often set the context for where homeowners were on their retrofit journey and sometimes identified previous barriers that had been overcome. Meanwhile themes on challenging areas and potential actions highlighted several informational barriers which helped to develop the themes identified in this paper.

Five participants highlighted their wood burning stoves as sources of comfort which also provided resilience during power cuts (I2, I4, I6). Comfortable spaces were often associated with previous retrofits homeowners had taken, with photos emphasising actions to create comfort (Fig. 2).

I2, I3 and I7 have glazed extensions, and their PEs highlighted using them for solar gain and seasonal occupancy, with other spaces used in cold conditions. Four participants (I2, I3, I4, I6) also took photos showing building development and commenting on different construction eras and extensions.

Three participants identified uncomfortable spaces in their homes, such as I6's 'freezing' kitchen extension but are not currently considering changes to these areas.

The PE themes around challenging areas and areas for potential action were found to support the broader theme around the nature of information (Section 4.1). A PE from I1, for instance, shows concern about reducing damp on a wall built into a bank. However, they are unsure what could resolve this context specific challenge (Fig. 3) (Section 4.1.3).

I7 meanwhile was struggling to pick the right solution from the numerous options available to improve their draughty, single glazed windows (Fig. 4) (section 4.1.1).

In a final example, I4 provided a photo of their lounge wall, suggesting a potential action (Fig. 5).

When prompted in the interview, they expanded on their struggle to find context specific information (Section 4.1.3) on insulating traditional stonework that has suffered previous maladaptation:

> I4: It was easy to find out that you can put… insulation board on your wall… But what was difficult was that this is more of a stone wall, and it's not helped by the fact that it's rendered with concrete on the

Table 5
Themes from the PE.

Themes/sub-themes	Participant photos
Comfortable spaces (8)	I1, I2, I3, I4, I5, I6, I7
Wood burner emphasised as comfort element (5)	I1, I2, I4, I6, I7
Solar gain (from glazed extensions) (3)	I2, I3, I7
Seasonal use of space to maximise comfort (3)	I2, I3, I7
Previous retrofit/comfort actions (6)	I1, I2, I3, I4, I5, I7
History of building/extensions (4)	I2, I3, I4, I6
Uncomfortable spaces (3)	I1, I5, I6
Challenging area (unclear what action could be taken) (5)	I1, I2, I4, I5, I6
Area for potential action (3)	I4, I5, I7

Fig. 2. I4 PE of comfortable space with previous retrofit actions.

Fig. 3. I1 PE of the rear wall damp challenges.

outside… I just couldn't find anything to read that would tell me what to do in that circumstance. You know, do I cover it in polythene? Do I not use the wood-based thing?

Several PE themes therefore provide additional evidence to support the themes and sub-themes identified in interviews and workshops. The other PE themes provided more detail on comfortable spaces and previous retrofits. The elicitations thus provided additional understanding of households' lived experience and links between energy and comfort. Because the homeowners chose the subject of the photos based on what matters to them, the PE acted as a catalyst for sharing relevant information. For both I7 and I4 the photo elicitation identified situations with barriers, relating to informational overload and context specific information respectively, which would not have been discussed in the interview without the PE prompts.

Fig. 4. I7 PE of potential secondary glazing.

Fig. 5. I4 PE of potential action for a concrete rendered solid wall.

4.4. *Future suggestions*

This section presents participant suggestions on improving the provision, relevance, accessibility, and curation of retrofit information (Table 6). Suggestions were compiled from answers to questions on whether information provision could be improved. Suggestions reference informational themes and are divided for different actors.

Suggestions emphasise information proximity and direct local support, highlighting the need for increased 'retrofit literacy', underpinned by a mainstreaming of information, increased national leadership, and structural change. Participants identified a clear role for local authorities in information delivery and other local groups and national actors for the nature and delivery of information to support market transformation.

Table 6
Suggestions for retrofit information provision improvement.

Source	Suggestions for future initiatives	Theme/sub - theme
	Local authorities	
WS1, I2, I3, I5	There is a 'Citizen Advice type' local information centre for retrofit, and retrofit information is available at LA information points including notice boards, in council leaflets and at local libraries and hubs.	Information to people
I5, WS1, WS2	LAs provide information about potential measures, tailored to different priorities: cost reduction; carbon reduction; health and wellbeing; energy security etc. Facts remain the same but contexts differ. Audio-visual as well as written information is provided.	Understanding Audience
WS1	Advice, especially about low cost, quick win measures is taken into communities by a 'retrofit van' based on the 'library van' or 'pop-up post-office' principle used successfully in rural areas	Info to people & Trusted messengers
WS2	Pop up warm home shops are run by LAs where people can discuss retrofit as part of community initiatives	Info to people & Messengers
I8	LAs have some form of trusted trader scheme, with pre-vetting to enable recommendations for trusted tradespeople	Messengers
	Other local groups	
WS1 & WS2	Local anchor organisations, (police, National Health Service, large employers) act as trusted gatekeepers to retrofit advice. Maternity services engage with co-benefits around health and well-being.	Info to people & Messengers
WS1	Large local employers host retrofit advice sessions for staff in the same way they host pension advice sessions.	Info to people
WS1	Information sources include community groups, Women's Institutes, churches, any formal/semi-formal group where trust is built. Groups are supported to provide relevant information	Messengers
WS1 & WS2	As part of increased emphasis on green finance, banks/building societies and estate agents provide or signpost retrofit information as part of house purchases/mortgages/re-mortgages	Context specific info
	Nationally	
WS2, I5,	Retrofit is included in popular media/culture and ideas become mainstream. Including home lifestyle programs, competitions (retrofit 'bake off format') soap operas, Blue Peter, The Archers, etc.	Audience & Info to people
WS2	Homeowners have higher levels of education on retrofit and have more confidence in decision making, they understand key terms.	Info overload & Audience
WS2	Instead of 'dumbing down' technical language around retrofit, it is explained and becomes mainstream so that: 'CO_2/m^2 and kWh/m^2 measurements are as much a part of our common language as miles per gallon and data speeds'	Info overload & Audience
WS1	Advice services are free because UK homeowners are often reluctant to pay for advice	Info to people
I5	LAs have access to national information resources provided by central government where they can cherry pick relevant concepts, tailored to local needs	Context specific & Messengers
WS2, I1, I3, I5, I7,	Central government provides clear leadership, coherent national retrofit policy, structural support and clear messaging on the importance and benefits of retrofit.	Holistic information & Messengers
WS2	Embodied carbon or 'carbon footprint ratings' are included on products in home, building and DIY stores to allow homeowners to make informed choices	Context specific & Holistic information

5. Discussion

5.1. Findings

This research has identified substantial challenges around both the nature of available information (section 4.1) and how information is delivered (section 4.2) which present barriers to transforming retrofit markets.

The first sub-theme supports suggestions in the literature [39] that the sheer quantity of information available is itself a barrier, creating bewilderment and confusion among households and making significant demands on their ability to synthesise and evaluate different retrofit options. This process involves a substantial time commitment. Several studies have highlighted that most households successfully engaging in deep retrofit have significant pre-existing knowledge and commonly undertake phased retrofit, with time between phases to complete the substantial research required [42]. Homeowners in this study also display these characteristics.

The volume of information also increases the likelihood of conflict between different sources, which households must try to resolve. Conflicting information can delay or discourage action and increase risk perceptions. The workshops highlighted the well-known [20] fragmented, siloed, and sometimes unregulated nature of the retrofit market as one cause of information conflict, and indeed *mis*-information and a lack of trust in tradespeople.

The antidote to information overload and the conflicting advice it can create was found to be context specific information which takes a holistic, whole house, whole system approach, rather than focusing on individual measures in a vacuum. Participants desired more information and awareness (Section 4.1.4 and Table 6) on the lifecycle implications of retrofit, something also emphasised in the literature [62,63]. However, the need for this context specific information is not consistently met and finding it is complex and often expensive.

Previous policy and industry action has emphasised increasing information availability, without always considering its quality, coherence, and usability. This means that, although there is more retrofit information than ever before, the nature of this information does not fully meet the needs of those trying to use it.

Energy Performance Certificates (EPCs) provide a case in point. For existing homes, they provide an efficiency benchmark ranking -based on a short assessment and standardised assumptions- and a list of potential building improvement measures with their potential impact on efficiency. In theory, EPCs should be an excellent way to provide context specific information to drive retrofit. However EPC accuracy has been challenged across Europe, especially for older buildings [44,64–66], and the recommendations they produce are often too generic to be useful, failing to account for actual building conditions and usage. It is telling that only I6 mentioned EPCs and then only because they required one to access a government grant for their heat pump. This supports previous findings that households do not utilise EPCs for retrofit information [36,44].

Currently available information therefore needs to become more individual and context specific while also including whole life effects, independencies between measures and retrofit co-benefits, to enable market transformation. Participant suggestions to address this include increased 'retrofit literacy' for households, coherent national messaging, embodied carbon labelling, and retrofit inclusion in popular culture.

Information delivery was also found to be important, with many suggestions on the need to actively bring information to households via local outreach, which could be orchestrated by local authorities. Increasing households' opportunities for first-hand experience of retrofit was also considered important. Participants drew comparisons between the ease of purchasing a new kitchen, with a showroom, salespeople and a curated process including physical experience of different options, design, installation, and financing options: with the often-challenging process of choosing retrofit measures. This issue is exacerbated because many retrofits are effectively 'invisible' once installed, making their conceptualisation challenging for households [36]. The well documented past focus on techno-rational and economic arguments for retrofit has also often failed to engage households around important emotive issues of comfort and quality environments [45,49,67].

This research supported previous findings on the importance of trusted messengers in delivering retrofit advice, and the relevance of local and personal networks as trusted information sources [10,44,52]. However, it also found that negative, not just positive experiences, could be amplified through these informal networks, with one person's bad experience leading to another deciding not to install or delay installing the same measure.

Trust in local institutions and tradespeople contrasted with general discontent with national government's perceived lack of leadership on retrofit and the climate crisis generally. This is supported by a recent Danish study where participants expressed discontent with inconsistency from policy makers on climate action [36]. It emphasises the need for stronger, consistent policy action and consistent communication from national governments. A general suspicion of tradespeople attempting to 'sell' retrofit measures was also evident and households desire reassurance from 'disinterested' sources of information to confirm decisions as well as quality standards for retrofit work.

The effectiveness of market transformation programmes is determined not only by the direct quantity of retrofits undertaken but also the enabling market effects such as levels of information and knowledge across the supply chain. In the ideal case, the workforce become retrofit ambassadors and trusted messengers, and homeowners sufficiently knowledgeable to ask the right questions. This paper focused on some of the characteristics of the information campaigns that councils can use to catalyse these transformations. The findings above support the wider literature in arguing that the quality of information in these campaigns requires greater focus if governments wish to transform retrofit markets in the longer term.

5.2. Limitations

This study focused on single-family, owner-occupied households within the 'self-financing' area of the housing market, as such, other household types such as renters and households in multi-family buildings are not covered by this study and further research would be required to explore if the findings were relevant for these groups.

Despite using varied dissemination channels to reach a variety of homeowners, participants all had substantial knowledge and engagement with retrofit and can be classed as early adopters (Section 4.2.1). Studies with self-selecting participants are likely to suffer selection bias towards those interested in the topic who are likely to be more knowledgeable. This research did not achieve the designed maximum variation sample. However, post-analysis, the sample can in fact be classed as a 'critical case' as defined by Flyvbjerg (2006). Because these homeowners are interested, knowledgeable and have already undertaken various retrofit measures, it can be assumed that they are the most likely to be able to overcome informational barriers. The fact they still encounter significant challenges implies these barriers are likely to be extant for the majority of homeowners with less retrofit knowledge.

In transitioning from early adopters to the early majority in the market transformation curve, information campaigns will need to significantly refine the *quality* of their messaging and work to reduce informational barriers to make it much easier for the early and late majority to overcome these barriers and engage in retrofit. These groups are likely to be less willing or able to overcome the multiple informational challenges identified in this paper.

Despite this, this research is limited because it only involves a small sample in a specific area. Individual findings and thematic information barriers appear to be supported by literature investigating other areas of the UK and European countries with similar contexts. However, further research could investigate to what extend these findings hold true in

other settings -for example in countries with less centralised government. It could also explore the linkages between informational and other barriers such as industry skills development, finance, and technical challenges.

This work acknowledges the importance of educating and upskilling the retrofit workforce and highlights the need for improvements in this area to reduce information barriers. However, this paper focusses specifically on homeowners' experience of informational barriers and many of the recommendations focus on local and national actions. Further research could explore the actions required to upskill the workforce to reduce informational barriers in more detail.

5.3. Photo elicitation

A novel aspect of this research was the use of PE for home energy research. The PE supported and added to interview and workshop data. It elicited a stronger, more emotive and specific response from the homeowners and highlighted several additional examples that strengthened the development of the paper's main themes. It also improved understanding of homeowners' wider contexts and helped encourage them to formulate linkages between comfort, lived experience, and retrofit and to contextualise this link for their own homes. It is therefore considered to have been a valuable research method in the context of this study.

One insight that developed during this research is that PE could be used, not just as a valuable research method but as a tool to help retrofit programmes address informational barriers. It could offer benefits for personalisation, contextualisation and communication, opening up retrofit discussions. Photos are, by definition, specific and reflect individuals' views and opinions, requiring them to think about their home, encouraging reflection on what is important and potentially helping them express their priorities more clearly. Because the photos are of individual features, they are contextual, encouraging discussion of specific aspects and how they interact with other building elements and households' everyday practice.

This method could help promote bilateral conversations between technical experts/advisors, and the homeowner, who is the expert in how they use their home and what they value. This could help move discussions to a place where they consider how retrofit can enhance the existing value that homeowners invest in their dwellings and work to improve and resolve negative aspects. As identified above, this paper acknowledges the need for broader workforce upskilling and capacity building to help reduce informational barriers, improve homeowner trust in the sector and transform the retrofit market. The use of PE is just one potential tool that could help to promote homeowner-professional engagement and understanding. PE could be a useful tool to enhance retrofit discussions and is worthy of further investigation for this purpose.

6. Conclusions and implications

This paper investigated informational barriers to retrofit market transformation through interviews, photo elicitation, and workshops with homeowners, professionals and local policy makers in Gloucestershire, UK. It examined how homeowners currently access information and the barriers they encounter, presenting suggestions for how these barriers could be overcome. Interviewed homeowners were all knowledgeable and engaged early adopters. Whilst they mainly felt they could find information when needed, doing so was difficult and they encountered barriers relating to both the nature of available information and how information is delivered. If this is the case for these homeowners, less engaged households are highly likely to encounter much greater challenges, implying significant informational barriers exist to market transformation.

The numerous options and quantity of available information was found to create information overload and challenges with conflicting, often siloed advice, which fails to encourage whole house and systems thinking. Available information was often too generic, lacking context specificity which homeowners could readily apply to their own buildings and circumstances. Local information was considered more trustworthy and relevant, supporting previous findings, and emphasising the need to translate national messages into local delivery. Good practice examples and future suggestions from participants emphasise the need for more active information provision *to* homeowners instead of simply providing information and waiting for people to find it. While this research focusses on a UK context, similar findings around the importance of information for retrofit in other Western European countries suggests that the need for high quality information with appropriate delivery is likely to be transferable to different contexts.

The use of photo-elicitation was valuable to gain a deeper more nuanced understanding of the relationship between techno-economic discussions of energy and more emotive social issues which have been shown to strongly influence household decision making. This method helped increase energy 'visibility', encouraging participants to consider their homes and energy demand differently. It gave researchers a better understanding of homeowners' lived reality in the context of virtual interviews and helped develop informational barriers identified in the analysis. Photo elicitation may also have applicability in practical retrofit programs to encourage bilateral communication between households and professionals, although this needs more investigation.

Despite varied efforts over the past decade, many retrofit markets are still near the bottom of the adoption curve (Fig. 1). This paper identifies requirements for substantial and sustained action at local and national levels to overcome informational retrofit barriers. Retrofit markets are still largely limited to early adopters with limited, inconsistent informational support for households to make informed whole house retrofit decisions. The current UK retrofit market is dispersed and siloed without a coherent driving force, and there is insufficient information, guidance and support to drive mass adoption.

There is a clear role for policy makers to provide high quality, objective retrofit information to drive market transformation. Based on the findings, recommendations are made for local and national policy makers on overcoming the identified informational barriers.

LAs have the local knowledge and position to act as intermediaries delivering retrofit information and were perceived as generally trustworthy by homeowners. LAs can also work with local organisations and the retrofit sector to develop context specific informational resources. However, at present LAs lack the support and capacity to enable these critical actions.

National government meanwhile needs to enable local action by sufficiently resourcing LAs to scale up and maintain retrofit information services, and by providing a common quality backstop and clear direction in national policy. National government also has a critical role in providing clear, concise and streamlined, high quality retrofit messaging and consistent leadership, and to facilitate national retrofit conversations and strategies. They should encourage skills development, quality assurance and silo reduction in the retrofit sector to help drive market transformation. This training should seek to develop the workforce as ambassadors and trusted messengers on retrofit. A national skills strategy and agenda for the retrofit workforce, developed in consultation with industry would be valuable. They should also clearly acknowledge the collective, not only individual, responsibility and urgency of mass retrofit adoption at national levels.

The retrofit sector also has a role providing more holistic and systemic retrofit information. It should move away from purely techno-economic discussions and give more attention to the emotive and co-benefits of high-quality retrofit, working to increase homeowners' retrofit literacy and the visibility and opportunities for households to experience retrofit. Information is by no means the only barrier to be overcome to transform retrofit markets, with other barriers including workforce skills and capacity and the financial cost of retrofit also vital. However, this paper argues it is nonetheless a substantial one, and that

reducing informational challenges could contribute to the significant acceleration in retrofit uptake required among owner-occupiers.

In conclusion, to drive retrofit market transformation, policy makers must provide not only financial incentives but also high quality, trustworthy and context specific information. Without addressing the informational barriers identified in this research it is likely that retrofit market transformation will fail to advance at the necessary speed and scale in this decisive decade for decarbonisation.

CRediT authorship contribution statement

Freya Wise: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Aaron Gillich:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Pippa Palmer:** Methodology, Investigation, Formal analysis.

Data Access Statement

The context specific nature of the research means it was not possible to fully anonymise the interview and workshop transcripts. To protect participant anonymitity the underlying data cannot be shared openly. Details of the workshop and inteview structure, ethical details and fuller versions of the quotes used in the paper are available as a supplementary file.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2024.103866.

Data availability

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