Home energy renovation: UK owner-occupied householder uncertainties, information and data needs

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Abstract. Homes must become low energy, resilient to climate change and provide comfort for households, as part of the European renovation wave. Renovation involves millions of decisions and actions. Owner-occupied households are a key group of decision-makers, but with conflicting demands on their time and finances. Householders collect information from multiple sources. However, previous research has found that the detail of available information and data on renovation is difficult to find. Therefore, this paper aims to identify householder uncertainties and related information and data needs, to support early-stage energy renovation decision-making. Co-design has been found to be beneficial in designing energy demand reduction strategies, leading to meaningful outcomes for householders, however, it was found to lead to further information requirements. The open virtual information exchange reported here, inspired by co-design and virtual workshop approaches, was effective in identifying uncertainties and gathering feedback on information types and data to address them. Householders' require trusted specialists to visit the home in-person. The information identified could be shared via trials at renovation information hubs, potentially using digital apps to connect renovation opportunity, householders' and trusted practitioners. There is much householder uncertainty around housing renovation and more work is needed to move able-to-pay householders from renovation planning to renovation in practice.

1. Introduction

Homes must become low energy and resilient to climate change, while providing comfort, as part of the European renovation wave. Targets to decarbonise and achieve net zero rely on building transitions to low carbon heating and energy efficient building envelopes [1]. This transition involves millions of decisions and actions [2]. Retaining existing buildings helps protect social value, preserve the embodied carbon and avoid carbon costs associated with new-build [3]. However, there is a need to move from what level of carbon reduction can be achieved, to how, and who can enable it [4].

Householders are decision-makers with conflicting demands on their time and financial resource [5]. With over two thirds of UK households being owner-occupied [6]. Householders collect information from multiple sources at different stages in the decision-making process to build knowledge and capacity that can lead to renovation uptake [7]. However, previous research has found that the detail of available information on renovation is either difficult to find, contradictory, or insufficient to householders [8]. Trust is required in the interventions and practitioners [9] and this takes time to develop. As a consequence, it is easier to not undertake renovation and remain in the present state, unless something such as a heating system requires urgent repair [8].

The decision to move towards the install stage in renovation is a process that unfolds over time and is situated within everyday life [10]. According to [10], the first two stages of renovation decision making are 1: householders start thinking about renovation; triggers can lead to this, and 2: householders start planning a renovation. Similarly, these stages can be considered as 'sensitize' and 'advice', followed by tender, install, evaluate and inspire [9]. Where a lack of sufficient information is gained, this can delay action, by several years [8], leading to missed opportunities for carbon reduction. Therefore, this paper aims to identify householder information needs, based on uncertainty toward energy renovation and examine how information and data specifically relating to the participants home, and relevant to but beyond energy use, can support early-stage decision-making. This starts with a review of previous domestic energy renovation research, starting with a focus on householder motivation and information needs, followed by the approach, insights, discussion, and conclusion sections.

2. Householder motivation, uncertainty, and information needs

Householders' offer particular value in the knowledge of their home and can be considered as agents of urban transformations [11]. In order to reduce household environmental impact, the role of the householder should not be under-estimated [12]. A survey of 341 participants in Norway [13] found that householder motivations for improving their home relate to social drivers such as improving aesthetics and comfort, and environmental drivers such as reducing energy costs and improving environmental friendliness. Similar motivations were found by [14] in a review of 18 sources of literature, with economic drivers, such as: cost savings commonly identified and property value occasionally identified; social drivers such as thermal comfort commonly identified and draughts, condensation, air quality, health, aesthetics and appearance occasionally identified; with environmental benefits commonly identified. Research by [15] found that energy savings can be considered a side impact for other motivations for renovation, such as enhancing the market value or to meet lifestyle aspirations [15]. Therefore, while housing renovation is required to reduce energy demand, the underlying motivations for householders to upgrade their homes are far more complex and sole focus on energy and carbon information could fail to motivate householders to undertake renovations.

Householders' finding ideas and inspiration for the home from external sources and sharing and transmitting information about renovations, has previously been considered as a motivating condition to undertake renovation [14]. Previous research has found that householders have uncertainty around the measures, materials, costs, installers, suppliers, preparation stages and sequencing [8], but addressing this uncertainty with information and data was not explored. The opportunity to find new information fits within the sensitization and advice stages. Engaging householders with tailored information relating to energy data and renovation options in the homes, which are often invisible to

householders, can lead to further information needs [16]. A service opportunity, generated through the research with householders immersed in personal energy data by [17], incorporates energy audit data and a detailed householder consultation process to provide contextually relevant renovation advice. This can help people think about how much energy they use, based on real personal energy data, which can otherwise be intangible to discuss. As part of this process, comparisons can be made with other similar homes and households with similar needs, who may have previously undertaken a renovation. This would include a survey of the property construction and potential interventions that could assist saving energy [18]. However, this approach primarily focused on energy, rather than uncertainties around renovation detail and suitability of measures, identified by [8]. Therefore, this paper aims to examine uncertainties beyond, but relevant to energy use, that relate to early-stage decision-making toward renovation in practice.

3. Approach

The approach taken to identify householder uncertainties, information and data needs, toward renovation solutions, with householders, was innovative virtual knowledge exchange sessions. This could be considered both an intervention in their planning process and an opportunity to collect insight during their decision-making processes. Four previously identified steps can enable non-designers to enter a creative design process in an interactive way can include: immersion; activation of feelings, dreaming and bisociation (blending two elements that were previously unrelated) [19]. These were translated into an iterative process relevant to home renovation decision making, as follows: 1. Knowing the home and data; 2. Aspirations for the home; 3. Imagining how the home could be and 4. Integrating ideas and systems, as summarised in Figure 1, inspired by co-design processes and virtual workshops.

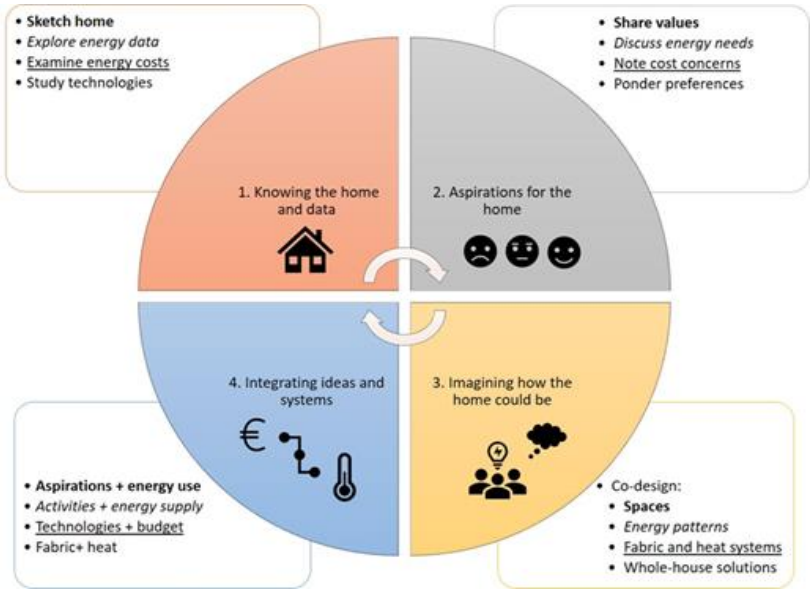

Figure 1. Process diagram moving from 1 to 4 of the co-design process, with **social**, environmental, economic and technology drivers considered during immersion, feelings, dreaming and bisociation co-design stages

The four virtual sessions ran between October and December 2022 and lasted approximately 1.5 hours each. Each took place using Zoom video calling software and information was shared between the research team and participants using one open file on Googledocs, to enable mutual learning. This approach and the content was informed by the virtual session design canvas V.01 [20]. Within the canvas the ADIDS format for content delivery was used: Activity, Discussion, Input, Deepening,

Synthesis [20]. For example, the session plan in Table 1 was used in session one, to stimulate interest, discuss and develop understanding:

Table 1. Activity planning for session one

Time	What	Description
18:30	Introduction	Project overview then open circle meet and greet
18:40	Activity	Sketching the home!
19:00	Discussion	Aligning aspirations: What would you like to improve? (mark on the sketch)
19:20	Input	Customer journey stages toward renovation and information types
19:30	Deepening	Information sources
19:50	Synthesis and plan	From today and onwards!

Session one focused on getting to know the home, with the householders' sharing information through floorplan sketches and verbal discussion. This was followed by a discussion on aspirations for the home and pointing out areas of discomfort, such as draughts or problem damp areas, on the sketch. Input included a graphic of the renovation decision making points, such as what measure to opt for, what product to specify and how to integrate it with other technologies, and common information types that might assist. Following this, householders' shared information sources they are aware of and gaps they have noted. The synthesis summarised what the householders shared and set out a plan for the following sessions together, as follows: Session two: environmental considerations and open energy modelling of their home; Session three: information feedback and considering suitable measures; Session four: synthesis and feedback. The open energy modelling, to compliment other information, used a combination of tools created by Open Energy Monitor [21] and Loughborough Building Energy Research Group [22].

Four householders responded to the virtual session call and two householders signed up to all four sessions. The two participating households were owner-occupiers based in Nottinghamshire and Suffolk. One was in a wattle and daub home, built in the 16th century and the other in 19th century home, both solid wall and primarily detached, one slightly semi-detached. Recruitment was via an e-newsletter via a local environmental group and following a radio panel discussion. Both participants made contact following a radio panel discussion, seeking information toward renovation. The project was approved by the Science, Engineering and Technology Research Ethics Committee (SETREC), Imperial College London (21IC7110) and informed consent provided.

4. Insights

The insights are presented in the order of the process diagram: 1. Knowing the home and data; 2. Aspirations for the home; 3. Imagining how the home could be and 4. Integrating ideas and systems. The insights focus on the home and renovation uncertainties householders' have, plus the process of the virtual process as an intervention to address these uncertainties.

Knowing the home and data

The initial activity of sketching the home, and sharing details of the home layout, naturally led to a conversation about design features, geometry, challenges and quirks. One participant sketched their home and one shared the floor plans. Both sketching and sharing a floorplan were effective in communicating details of the home. For example, the wattle and daub home had particular damp challenges on an internal wall and the location of this could be explained using a floor plan. The other home was *"damp and cool on North side",* leading to window condensation and water dropping onto the window sill, which was pointed out on the sketch.

One property was both listed and in a conservation area. The solid-walled 19th century home had heritage features the householder valued. As both participants lived in older detached and semi-

detached homes, with relatively large floor areas, they considered their energy consumption to be quite high and both felt a duty to reduce this. In particular, one home had an oil heating system that the householder did *"not want to run all day".* Both homes were considered to be "*cold"* and *"draughty"*, and improving comfort was a strong motivation. Both participants had smart meter data and this was used to calibrate the open energy modelling, both were interested in this process and provided energy and building data and insights to inform it. While based on estimates, both participants were surprised at the impact solid wall insulation could make compared with other fabric measures, in theory. However, this did not address their uncertainties around damp and the most suitable insulation materials to select.

Opportunities to learn from further data collection methods were discussed, including air leakage testing, u-value testing and thermal images. One participant had seen air leakage and smoke testing methods in Australia and suggested this would be interesting for their own home. They were both open to data collection available, through research, to learn more about their home. However, one participant felt they already knew they had a *"leaky"* home and measured data would not provide a great deal of extra insight. However, both were interested in u-value measurements, particularly when the researcher suggested this could allow comparison between their fabric and the standards for new build, and the potential via insulation upgrades.

Aspirations for the home

Both householders' had motivation to do whatever they could to reduce the environmental impact of their home and improve comfort, as previously stated. One participant felt as a *"custodian"* of the home, they should do what they can to make it fit for the future, they were *"aware of the global challenges"* around energy security and climate change, partly due to working in finance and interest in *"green investment"*. As each home held heritage value, they were keen to work with that and preserve it where possible, without adding risk to the property structure or value. Neither householder was primarily motivated to save money on energy bills, however, one was keen to move away oil fuelled heating, partly due to *"barrel of oil price"* increases and a partly a motivation to move away from fossil fuels. They stated that the cost of interventions would dictate what they proceeded with.

In terms of renovation measures, both householders were considering window replacements and solar photovoltaic (PV) systems. One had windows that were *"beyond repair",* and very *"leaky"*, leading to heat loss. This householder was also keen to find out whether a ground source heat pump was suitable for their home, or if they needed to improve the fabric first. They felt external wall insulation (EWI) was not suitable for their home due to it being listed and of a wattle and daub construction. The other was unsure whether EWI was a good idea for their solid walls, in relation to damp risk and solid masonry walls and was seeking, but struggling to find, expert judgement.

Both householders were interested to learn as much as possible about potential technologies and what the best options were for them. However, some measures were prohibitively expensive, such as replacing all windows, in keeping with the style of the property, and this led to indecision on whether it was worth it. Options such as secondary glazing and thick curtains were discussed. Neither household used curtains, one as the walls were too crumbly to attach curtain poles and one had not considered it important since they live in a semi-remote location. In terms of finance, both would be willing to borrow money, especially via Government led schemes, *if* they felt the options were suitable for their home. One participant suggested a *"shopping list"* approach for the available budget of a householder, so they could *"tick off"* measures as they installed them. One had gained quotes for PV via a friend working in solar energy, but was not sure how this fitted with plans for a heat pump.

Imagining how the home could be

While both households had interest in energy renovation technologies, there was a gap in whether measures they were reading and hearing about were suitable for their home, and this prevented full consideration of the renovation potential. While both participants knew some of the questions they

needed answers to, both had struggled knowing who to trust to provide the answers, specialists had not *"offered confidence"*. Uncertainty related primarily to building condition and damp. Some quirks such as can an air source heat pump be installed in a historical water well? What is the cost of a whole-house renovation and in what sequence should the work be done? One roof had not been touched in over 100 years, therefore would it be safe to install solar panels there, structurally? Information sources they found most useful were impartial such as forums and radio or podcast discussions with a variety of speakers. Both were interested in open home approaches and found properties and householders to visit near their home to learn from *"their experiences"*. They both felt information via energy websites and via local authorities could be *"quite general"*, *"not often updated"* and lacked detail for older properties with heritage value, and suitability of measures.

Integrating ideas and systems: Information and data needs
The uncertainties surrounding full house renovation had led to one participant *"procrastinating for 20 years",* since they moved into the property. Both had been to individual companies about specific technologies but struggled to find an adviser able to think through a whole-house plan for their home. Both were keen to gain trust in what to do and in what order. One felt it was a *"leap of faith"* with installers as they can be *"too bullish"* and don't often consider legislation or future energy and material price changes. The other suggested that digital technology could be better used to identify savings per measures and house types, then connect to local installers, as a *"smart way forward"* for the sector. Table 2 summarises the uncertainties discussed and suggests potential information, data needs and recommendations for the renovation sector.

Table 2. Renovation sector uncertainties, information, data needs and recommendations

Uncertainty	Information need	Data need	Recommendation
Who to trust	Local information portals with examples of previous work for householders to see	Professional accreditation and past renovation project data on parameters client requested	Policy-led funding to enable local hubs across the country to advise impartially
Sequence of work	Digital technology to identify suitable measures per house type then link to advisers to sequence	Energy estimates per measure, plus wider experience insights tailored to property	Research to explore whether digital technology can inform householders & practitioners
Appropriate costs	Examples of previous renovations with cost data shared	Open cost data estimates	Local information hubs could share renovation case studies and where possible cost data
Damp *(in walls)*	Surveyor, with energy efficiency knowledge, to visit and assess	Relative humidity, air temperature, observation and photographs	Surveyors need robust training in energy renovation
Structural suitability *(of roof for PV)*	Structural surveyor and solar photovoltaic specialist visits	Load, structural capacity and condition survey	Structural surveyor and Solar PV installers to collaborate
Heat pump sizing *(Ground source & well)*	Heat pump installers to visit, equipped with relevant sizing information	Geometry and location of the well, fabric efficiency, heat preferences and property volume	Creative solutions to placing heat pumps could be further examine and shared

While the householders were interested in the energy and carbon data, this was insufficient to answer their queries around installer trust, sequencing, appropriate costs, damp, structure, location and sizing of heat pumps. Their information needs and data needs were identified partly through discourse with the householders and what they would like to see, and partly from researcher and industry insights.

5. Discussion
This paper aimed to identify householder information and data needs, based on their uncertainty toward energy renovation, via virtual information exchange sessions with householders. The process was effective in identifying householder uncertainties and some relevant information, such as

literature on risks around damp and mould, or on how previous renovation measures have been sequenced in similar case studies, can begin to address in the early stages of decision-making. These included who to trust, sequencing, costs, what is suitable for the individual home, how to deal with complicated damp issues and heat pump planning. It was possible for householders to communicate the challenges virtually. In addition, aspirations for their home were shared. Challenges were primarily around conflicting information and knowing who to trust, as in previous research [8]. For future renovation processes, one participant suggested starting with building energy data and framing planning and decision-making discussions around each intervention in the home with specialists for each measure available to answer common questions, beyond energy use. Tailored information relevant to both the property and the householder aspirations is essential, as previously recommended [16]. Whilst there are energy renovation measures that are most commonly considered, householders need information and reassurance that the measures are suitable for their home and preferences.

Developing a local network of practitioners who can advise on specific queries would be a positive step forward for the local renovation industries. Both householder participants would ideally have liked one recommended impartial adviser they could trust to guide them through the process, but that one adviser would need a network to refer to and collaborate with. The sample informing this trial was small, at two households, however, that enabled a meaningful conversation over time with the participants and detailed discussions relating to their queries, uncertainties and experiences.

Future research could trial a structured co-design process to align known uncertainties with specific information, for a larger sample of householders. This could incorporate the delivery of information within the process. In developing this, the co-creation of meaning around renovation uncertainties, from the householders' perspective could be explored. Once householder uncertainty is better understood, it can then inform the training content of energy renovation advisors. Interactive and engaging tools could assist, as suggested by [13]. There are opportunities for digital technologies to link householders with suitable measures for their property, followed up with specialists to advise on the detail, via local renovation hubs. The following section concludes this paper.

6. Conclusion

This paper aimed to identify householder uncertainties and related information and data needs, to support early-stage energy renovation decision-making. The uncertainties primarily related to the themes of who to trust, sequencing, costs, how to manage damp (in the walls), whether the property structure was suitable for measures prior to remediation work and the sizing of heat pumps and whether fabric measures were needed first. While energy data and the impact measures could make on energy use were considered both interesting and valuable, householder uncertainties relating to the suitability of the property for specific measures, exceeded these. Trusted advisers who understand building structure and risks are required. Digital technologies could be trialled to link householders and their queries with local accredited advisers. There is much householder uncertainty around housing renovation, beyond energy use, and more work is needed to move able-to-pay householders from initial renovation ideas to renovation in practice, to deliver the European renovation wave.

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