

The Future of Energy Efficiency in the Home: Using Innovative Methods to Assess the Acceptance of New Technologies by Vulnerable and Non-Vulnerable Groups

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Abstract

Energy related technologies can play an essential role in the journey to net zero, reducing the carbon emissions of UK housing stock, while maintaining acceptable levels of thermal comfort. However, progress in this area depends on the actions of those who own and/or live in these properties and may face barriers to installation. This research explored how people respond to new technologies, with a particular focus on those dealing with different aspects of vulnerability. Specifically, it used an innovative setting – the Futures Close demonstrator site – to showcase eight different energy related technologies in situ and analyse feedback from 27 members of the public. Findings indicate some shared concerns around practical, hedonic and risk factors across both vulnerable and non-vulnerable groups with differences lying in the reasoning behind prioritisation. The research also demonstrated the importance of in-person engagement and the persistence of uncertainty around new and ‘untested’ ideas.

Keywords: Energy efficiency, technology adoption, user engagement, vulnerability

1. Introduction

Technologies that can help improve energy efficiency in a home or reduce the amount of gas or electricity that is necessary for daily activities can play an important role in achieving net-zero targets (Rowe and Rankl, 2024). We can lower our carbon emissions, while maintaining an acceptable level of comfort and convenience, the latter being particularly important for vulnerable individuals who may have additional thermal requirements and be more at risk from changes to the cost of energy (NEA, 2024). Energy related technologies and smart devices are a standard feature of many modern homes but, in the case of older housing stock, there is a requirement to retrofit. Action in this area often relies on the initiative, funding and time of those who own and/or live in these properties. It is therefore crucial to understand how individuals respond to new technologies, what factors may encourage or prevent installation in the home and if there are any discernible differences between individuals based on vulnerability.

While there is a wealth of literature considering the factors that influence technology acceptance and adoption in general (e.g., Billanes and Enevoldsen, 2021), there is limited research into user engagement with technology and a tendency to overlook the complexities of vulnerability in the context of energy use. Moreover, policy in this area often prioritises “rational” considerations (e.g., cost), neglecting the nuances of individual lives (Emden, 2023). The current research addressed these gaps by using an innovative setting – a purpose-built test site in the Northeast of England – to showcase a range of energy related technologies to members of the public. 27 participants were invited to experience the technologies installed in

situ in fully furnished demonstrator houses and spend time discussing their personal circumstances and feedback with the research team. The sample included both vulnerable and non-vulnerable individuals in order to assess the impact of this distinction. The work focused on three main objectives:

1. To examine the factors affecting adoption and potential benefits realisation of new technologies.
2. For smart products and services, to study the factors related to information and communication technology (ICT) adoption and acceptance
3. To examine any similarities or differences between vulnerable and non-vulnerable groups in the context of Objectives 1 and 2

2. Background and Research Context

Many studies have considered the factors that affect the adoption of technology. These include perceived usefulness, perceived ease of use and compatibility of new technology with the existing infrastructure (Ande et al., 2020; Ahn et al., 2016). Some research contends that hedonic expectancy (perceived enjoyment or fun) will make people more willing to adopt (Strengers et al., 2020), while familiarity with the concept, device or system is expected to play a similar role (Baudier et al., 2020). In contrast, concerns around privacy and security are reported to have a negative effect on intention to adopt (Milchram et al., 2018). There are also a number of factors that have been reported to have both positive and negative impacts. In some studies, environmental concern was found to increase willingness to adopt (Gimpel et al., 2020; Stopps and Touchie, 2021). However, Girod et al. (2017) argue that the most environmentally conscious are likely to hold a post-materialistic worldview and may therefore reject new ‘green’ technologies. Similarly, trust can lead to a positive attitude when associated with the belief that a smart home will work reliably in the way it is supposed to (Shuhaiber and Mashal, 2019). Alternatively, it can have a negative effect on intention to adopt when companies are not trusted to be fair (Bugden and Stedman, 2019). Finally, cost can be a driver for adoption where devices are perceived as a tool to help people save money (Larsen et al., 2020), but also a barrier where the upfront price is prohibitive (Sovacool et al., 2021).

There has also been some research into technology adoption and various aspects of vulnerability. Typically, however, this has focused on one aspect of vulnerability at a time, rather than exploring the complexity of individual lives. For example, studies by Shirani et al. (2020) and Brown and Markusson (2019) both look at vulnerability and acceptance of smart energy technologies but focus solely on low-income families and the responses of “older adults”, respectively. There is no consideration of vulnerability as a multilayered concept. Similarly, Sovacool et al. (2021) consider three different aspects of vulnerability (age, income and homeownership) in their mixed methods study but analyse the impact of each in isolation.

The current research explores the relative influence of different factors affecting technology adoption, including the role of vulnerability as a concept defined by various different aspects of a person’s life. In addition, while previous studies in this area have relied on methods such as surveys (Chen et al., 2017;), experimental scenarios (Ponce et al., 2016) and literature reviews (Milchram et al., 2018), this research assesses technology adoption and user engagement in the context of ‘real-life’, as simulated by the experience of the technologies in actual houses.

3. Research Process

This section will provide background on the research facility, the sampling process and the engagement of research participants.

3.1. The research facility

Futures Close is a purpose-built test-site of nine properties in Winlaton, Gateshead, commissioned and owned by Northern Gas Networks (Photograph 1). There are five types of property, each built to original building standards and employing materials commonly used at that time, to fully reflect the building fabric and challenges that exist with buildings of each era. The property styles have been designed to be representative of UK housing stock from 1910 through to modern day.

Photograph 1: Futures Close



The current project – the first to make use of the test-site – involved the commission and installation of eight energy related technologies in different house styles across the site (Table 1). The products looked and operated as they would in a typical house, providing an immersive and representative experience for the exploration of energy related technologies in real life. Inviting members of the public to visit Futures Close and share their thoughts about the products that had been installed was therefore a unique way to address the research objectives.

Table 1: List of vendors and technologies tested

Code	Description	Type	Smart
V1	Automatically open/close according to temperature and humidity.	Ventilation	Yes
V2	Reflect heat from radiators back into living spaces		No
V3	Use radiant heat as an alternative to conventional heating systems.	Heating	Yes
V4	Heat retaining window coating	Insulation	No
V5	Reduces heat loss by sealing the gaps around windows		No
V6	Insulated liner for internal walls	Insulation	No
V7	Automatically turns off devices, provides information on energy use	Behaviour and Energy Related Choices	Yes

V8	Uses residual heat from wastewater to preheat incoming cold feed	Hot Water	No
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3.2. Sampling and sample profile

The study was advertised via a mailing list as well as a social research platform at Newcastle University (Voice). The advert called for people who lived in the Northeast of England and were interested in energy efficiency and new technology. 30 applicants out of 53 were invited to take part in the project. Five site visits took place over three days in September 2024, with participants split into groups of between four and six (27 participants attending in total).

The sample included 17 men and 15 women from different areas across the Northeast of England and represented a diverse range of personal circumstances. As can be seen from Table 2, 11 individuals live alone, nine live in two-person households, and seven live in houses with three or more members. The sample consisted of mostly older individuals, with the average age of the oldest person living at home being 63, and the average for the youngest person living at home being 51. Eleven households include a member with a health condition and/or disability and 21 own their homes compared to four who rent.

Table 2: Sample information

Characteristics	Frequency
Number living alone	11
Number with 2 people living at home	9
Number with 3 or more people living at home	7
Average age of the oldest person living at home	63
Average age of the youngest person living at home	51
Number with a household member living with a health condition and/or disability	11
Number who own their home	21
Number who rent their home	4

Note: N=27, Due to the small sample, percentages have not been used.

One of the key aims of the project was to capture differences in the motivations for technology adoption between vulnerable and non-vulnerable groups and, as such, the sample was also specifically analysed for vulnerabilities by means of a participant survey. Given the project focus on energy related technologies, the survey used a subjective measure of fuel poverty, asking respondents to assess whether or not they feel they can keep their homes warm when they wish or need to. This was followed by a question that examined the reasons why this might be the case, covering three principal drivers of fuel poverty (cost, efficiency of the heating system, and how well the home retains heat). This data was then examined alongside other indicators of fuel poverty risk, including energy rationing, and certain demographic indicators of vulnerability like household composition and age. Taken together and examined alongside the data captured in the introductory interviews, this data provides a holistic assessment of who in the sample might be considered at risk of experiencing fuel poverty or vulnerable in an energy context.

The sample demonstrates aspects of vulnerability, with a proportion facing financial strain, energy insecurity, and challenges related to aging demographics and health. 11 in the sample can be classed as at risk of experiencing fuel poverty, or ‘vulnerable’, with 16 classed as ‘non-vulnerable’. This data was collected via a follow-up survey after the fieldwork was carried out.

3.3. Research design and process

Once recruited and before visiting the site, participants were asked to engage with a mock website, which took the form of an online shop and advertised the eight technologies as ‘energy saving products’. The website was designed and constructed by the research team using information and images from the actual product websites, as well as interviews conducted with some of the manufacturers.

The mock website provided information about the cost of the technologies, how they worked, the installation process and any expected benefits and energy savings. Participants were asked to use the website to research the technologies and then select and “*purchase*” the items they would potentially be interested in for their own home by placing them in the website shopping cart. These responses were recorded by the research team to be used in the next step of the research process. Participants were then invited to visit the site in-person and experience the technologies installed in the demonstrator houses.

Upon arrival at the site, each participant engaged in a short introductory interview in the main meeting room to discuss the energy efficiency of their own home and the products they had selected from the website. These initial interviews lasted for about 15-20 minutes and explored the appeal of the chosen products, and the challenges participants faced when engaging with new technology (e.g., what was your main consideration when making your choices?).¹ Participants were also asked to rank the different technologies from one to eight.

After the initial activities, participants were given a tour of the demonstrator houses by a member of the research team and a representative from NGN. They were shown the technologies one by one in situ in a furnished demonstrator home and invited to ask questions and provide any feedback. Additional members of the research team listened to the discussions during the tour and noted any relevant comments.²

The research process continued with a return to the main meeting room for a focus group discussion (up to 30 minutes depending on the length of the walking group)³ and the opportunity for participants to reassess their initial ranking of the products. Alongside discussion of the specific technologies, the focus groups explored energy related technology more broadly (e.g., by considering questions such as how confident do you feel about purchasing new technologies?) and how participants perceived the process of obtaining a relevant product for their home (e.g., where would you begin looking for energy related products?). The site visit lasted three hours in total and those who took part received a £60 shopping voucher as a thank you for their time.

3.4. Data analysis

All introductory interviews and focus groups were recorded and transcribed for analysis. Given the unique nature of the site tour, recording of the walking groups was not feasible and, as specified above, three members of the research team joined each session and made note of the

¹ Data from the initial interviews will reference the individual (e.g., Participant A, Participant B etc.).

² Hereafter referred to as data from the ‘Walking Groups’.

³ Hereafter referred to as data from the ‘Focus Groups’

comments and conversations. The team members discussed and confirmed their observations after the sessions.

The analysis of the data was an iterative process with a preliminary identification and agreement of factors by two members of the research team, followed by a more in-depth exploration of the themes and nuances using organisational software (NVivo, MindView). Findings were validated by all team members who took part in the site tours.

4. Findings

Based on discussions during the initial interviews, walking groups and focus groups, the research team identified four areas of interest that pertained to the appeal of new technology and the barriers to adoption, thereby addressing the first two research objectives: i) practical factors; ii) experience factors and user expectations; iii) uncertainty and risk; iv) personal and household circumstances.

4.1. Practical Factors

Unsurprisingly, cost was one of the most common practical factors discussed by participants, with a myriad of different aspects to it. First, there was concern about the cost of the product itself, with many reported to be very expensive, sometimes prohibitively so:

*“I looked at the infrared panels [on the website] but then I looked at the cost!”
(Participant H).*

Similar comments were made during the walking groups about QC and the AirEX Smart Brick (AX). There was also the suggestion of reducing this cost by “making do” with less than a complete retrofit (e.g., switching a percentage of the AX to the smart version) (Participants in WG2, WG3 and WG5). To some extent, however, expensive was a relative term. Most participants added the “cheap” V2 to their shopping cart on the website, but many also selected higher value items. For example, Participant Q felt that V3 was “worth a punt”. For some participants the higher initial outlay was not as prohibitive.

Concerns about the cost of a product were then accompanied by those relating to the cost of installation, maintenance and replacement and these were more widely shared across the groups. Even if the initial outlay was affordable, the additional costs became problematic. Many participants talked about the expense of professionals or specialists who would be required to install the products while others were worried about having to replace a product that did not “stand the test of time” (Participant in FG2).

Taking all of these expenses into account, many participants were keen to talk about return on investment (ROI):

“You’ve got to balance off what you’ve got, yourself, to spend and what you think you’re going to save” (Participant R).

Some were willing to invest in something expensive “if that’s going to save on your energy” (Participant N) and some were more interested in the environmental impact of improving energy efficiency and trying to “do their bit” (Participant Y). Generally, however, participants were sceptical about the claimed energy savings reducing their costs and reluctant to adopt new technologies without a guaranteed return on investment:

*“I wouldn’t save that much money to merit spending that amount of money”
(Participant V).*

Finally, the process of installation was a frequently discussed practical factor. This varied depending on the specific technology but concerns were linked not only to how much it would cost but also how disruptive and messy it would be, how long it would take and what additional requirements it would entail (e.g., the switch to V3 may also necessitate the installation of a hot water tank). For example, Participant W was put off by anything that required “*building in*” or “*ripping out*”. Many people were more comfortable with add-ons (e.g., V2 or V4), which did not require “*fundamental change*” (Participant R).

4.2. Experience Factors and User Expectations

Participants talked at length about how the products looked and how well they fit within the house from an aesthetic point of view. The focus on aesthetics was much more prevalent once participants had actually seen the technologies in situ, with lively discussion about visible products such as V3. Some people were “*most impressed*” by this modern looking product (Participant in FG2) and felt that the panels were “*classy*” (Participant in WG3), while others did not like their appearance at all (Participant in WG4). Similarly, there was disagreement about the appearance of V6 in Walking Group 5. One participant thought it could improve the internal walls by covering cracks, while most were not impressed by the way it looked pre-decorating.

It may be the case that expectations around a particular product played a role in people’s perception of how attractive it was. V2 was the product that most people were familiar with, having experienced an earlier version in their own or someone else’s home. Many were impressed with the aesthetics of the product compared to earlier/different versions. It was “*really neat, like a proper product*” (Participant in WG5). Similarly, after looking at the products on the website, a number of participants thought that V4 was a plastic film that was applied to the window; they expected it to look messy:

“If I’m paying all this money for a double-glazed window, and then I stick something like that on, that’s going to spoil the whole effect” (Participant N).

Reactions to the barely visible product were very positive, particularly from those who had anticipated disappointment:

“It looks better than on the website, you wouldn’t know it was there, I thought it was a film” (Participant in WG5).

Perceptions of the ‘feel’ of products also factored into their appeal. For example, V6 was something that divided opinion. Many participants felt it was “*cosy*” and “*comforting*” (WG5), while a few people commented that it made the room feel “*stuffy*” and “*unnatural*” (Participant in WG4). Similarly, the noise made by the V8 pump (akin to a pulsing sound) was not a problem for some people. The shower itself made a noise during use and you would just get used to the additional sound (Participant in WG2). For others, the noise would get on their nerves (Participants in WG5) and they could not tolerate it in their home.

Generally, perceptions of products varied widely across the five different groups but what was particularly interesting was that, for some people, perceptions of the products made them reassess the practical barriers to adoption. For example, V3 would be “*a nightmare to put in*” and had been dismissed during one participant’s initial interview. However, positive perceptions of comfort in the demonstrator house made them overlook the installation issue: the expected disruption would be “*worth it*” (Participant in WG4). Another participant had chosen V6 based on ease of installation and ROI but reassessed this during the focus group discussion:

“I changed my mind with the wallpaper. I thought it sounded like a really good idea, but when I actually looked at it, it put me off” (Participant in FG4).

After the site tour, the appeal of the different technologies was affected by both practical considerations *and* how people had felt after experiencing them in ‘real life’.

4.3. Uncertainty and Risk

Another set of factors related to a sense of apprehension around the adoption of new technologies. For many participants this was underpinned by a self-reported lack of awareness and understanding. Many participants said that they had not understood the information on the website and were sceptical about the claimed energy savings. In addition, aside from V2, the products were generally unknown to the participants prior to the project. This led to many conversations about the risks associated with new and innovative technologies.

First, there was the risk that the product would not produce results. Participant R said they were *“not averse installing things if [they] could see the benefit”* but *“at the moment, they’re too much of an unknown quantity”*. Similar comments were made across the various groups about how much difference the products would actually make in terms of saving energy:

“I am pretty sceptical...I read that it would make this much saving, and I’m thinking: How would you measure that? How would you prove that?” (Participant F).

Second, there was the risk that something would go wrong. There was a lot of discussion about the reliability of technology and participants were particularly nervous about products that required WiFi:

“I have reservations, should I say, about everything connecting to Wi-Fi. I prefer things to be a bit more mechanical” (Participant G).

Finally, some participants talked about the risk that regulations would change. Again, they relayed stories they had heard about people installing new technologies and then being refused mortgages or facing new rules around boilers and heating systems:

“You need an element of bravery being at the forefront of it” (Participant Y).

Hence, there was a strong relationship between risk and practical considerations. Participants could not afford to *“drop £10,000 on something”* without guaranteed energy savings (FG1) and they could not afford to get things repaired:

“What if something goes wrong? The cost!” (Participant in WG5).

Similarly, significant changes (*“breaking the fabric of the house”*) were too risky if you were not confident about the efficiency and credibility of the product (Participant R). Moreover, the perceived complexity of repairs to something technological was far too much hassle in the context of thermal comfort:

“When it comes to warming my house, I do not want technology. I want something that I know how to fix it” (Participant in FG1).

The aforementioned risks were also linked to the trustworthiness of companies and manufacturers more generally. As one participant put it in Focus Group 1, *“you don’t trust the new kid on the block”*. Even if people went looking for new technologies, it was difficult for them to know where they could find reliable information. Across all of the groups participants talked about the importance of trust and reassurance. They wanted to see feedback and reviews

of the products, real-world case studies of people who had tried and tested these new technologies in their homes (including friends and family). They also talked about the importance of evidence-based data from a reliable source (e.g., government, an energy provider or a 'reputable' company).

The site visit gave participants the opportunity to not only look at the technologies but also see some of them in operation and have their questions answered by the NGN team member. This provided clarity about what the products did and how they worked, the impact of which was evident amongst the different groups: *"Oh, I see, it warms the fresh water going to the shower head"* (Participant in WG1 after an explanation about V8). Across all of the sessions, comments were made about the importance of being introduced to these technologies, to seeing and experiencing them in real life. For many, however, while they had a clearer understanding of the technologies and a better sense of whether or not they liked them, they were not necessarily more confident about adoption. Most of the discussions around risk and trust took place after the tour of the site. Understanding and appeal aside, *"a lot of people wouldn't buy things initially until it's been tested for a while"* (Participant in Focus Group 2). Their apprehension was not fully alleviated by their visit.

4.4. Personal and Household Circumstances

The factors outlined so far were then underpinned by personal and household circumstances. For example, many participants talked about their age in the context of practical considerations. Some of the older participants were financially secure and could afford the initial outlay of the products but were concerned that, at their stage in life, they would not see a return on the investment:

"The older you're getting the less time you're here, so are you going to make that money back?" (Participant N).

In addition, several people talked about age in the context of uncertainty. For example, when discussing smart technologies, one participant said they did not like *"apps or anything like that"* referring to themselves as *"a bit of a dinosaur"* (FG1).

Others felt that the products were not suited to their own habits and routines. For example, V7 was totally unnecessary for people who turned appliances off as standard and participants who did not shower very often would not get any benefit from V8. These participants did not feel there would be any return on investment. In addition, the degree to which someone was proactive in the area of energy efficiency had some interesting effects on their response to the products. On the one hand, some participants who were already engaged in this area were receptive to products that would build upon their efforts. For example, V7 was appealing to people who were actively trying to minimise their energy use. On the other hand, participants who had already taken the initiative to install things questioned the claimed energy savings in the context of their own homes:

"[V1] said 15% improvement but, I am assuming, that's with an uninsulated suspended timber floor? Mine is now insulated so I'm not going to get 15%. I might get, I don't know, 2% or 3%. I have no idea" (Participant T).

Dealing with this kind of uncertainty in addition to other factors compounds the challenges participants faced when trying to assess the appeal of the various technologies.

Household Composition also introduced a number of different considerations. For example, some people who lived alone talked about being less financially secure and nervous about the

sole responsibility of sorting out any faults or problems with the products (Participants in FG2). Others acknowledged that living alone gave them time to research and look into things:

*“Living on my own, I’m a big one for Googling...that’s what I tend to do on a night”
(Participant V).*

This was in stark contrast to Participant W who had not had a lot of time to consider the products due to family commitments:

“I think I might have gone on [the website] whilst I had a toddler running around!”

A busy family life would presumably pose the same barrier to looking at technologies and energy efficiency outside the context of the project. In addition, a younger household introduced concerns around safety (e.g., the perception of V3 as a burn risk to children) and damage to the products. One participant envisioned “*little fingers shoving stuff down the back of radiators*”, and breaking V2 (WG3), another thought V6 was prone to “*kid damage*” and would be easily marked (WG5). Finally, a larger household would be advantageous for some products. V7 (which could automatically switch things off when they were not being used) made sense in a busy home with lots of appliances left on:

“When you’ve got teenagers in the house who leave everything plugged in...I think it would save me a fortune, I really do” (Participant in FG3).

4.5. The Impact of Vulnerability

This section will focus on the third research objective, examining the same motivations and barriers to technology adoption but with a specific focus on vulnerability.

4.5.1. Practical Factors

For participants at risk of fuel poverty, cost was the most significant factor influencing decisions. High upfront costs and uncertainty about long-term savings often acted as barriers, making affordability and clearly advertised returns on investment (ROI) essential for this group. Vulnerable participants frequently highlighted the importance of practical solutions to retain heat, particularly in poorly insulated or drafty homes. This was reflected in the survey responses: four out of eight participants who reported struggling to keep their homes warm attributed it to their homes’ inability to retain heat. Products like V6, or the V2 were seen as potential solutions to this issue.

Installation challenges were another common barrier. Vulnerable participants preferred simple, minimally invasive technologies that were easy to install and affordable to repair or replace, such as the V2. Several respondents were interested to know whether or not ongoing maintenance could be managed themselves, and if they would even know where to begin if something went wrong:

“If something went wrong, could I sort it out?” (Participant J).

Cost aside, some of the products stood out for their practicality and usability. For example, the **SS** appealed to participants for tracking energy use in larger households, especially those with children, while the **QC** was valued for its straightforward ability to reduce heat loss:

“[I chose] the coating to stop heat escaping through the big window” (Participant P).

For participants not at risk of fuel poverty/energy vulnerable, cost remained important but was less of a barrier. Non-vulnerable participants focused more on long-term efficiency and were open to higher upfront costs if the ROI was clear:

“Expensive is ok if [I’m] saving money” (Participant N).

Non-vulnerable participants also prioritised ease of installation, avoiding products that required significant disruption or effort. There was also less discussion on maintaining products themselves, and so the cost of installation and ongoing care was important to some within this group. Products that could seamlessly integrate into their homes were preferred. For instance, V3 were praised for their efficiency and ease of use but were often seen as disruptive to install:

“[I’m] not keen on ripping things out and redecorating afterward” (Participant W).

Despite this, products with a more complex installation process were seen as worthwhile if the home was already undergoing renovation works or could improve the value of the home.

While heat retention was a shared priority, it was less urgent for this group since, in some cases, their homes had already undergone energy efficiency upgrades and so were better insulated.

4.5.2. Experience Factors

For vulnerable participants, comfort was a key motivator, closely tied to health and age-related needs. Many participants linked warmth to their well-being, with 11 out of 27 survey respondents reporting either having a health condition or living with someone who did. In the interviews, one participant highlighted the impact of heating on daily life:

“I’m getting old and arthritic, and I need the heating on a lot” (Participant K).

Specific products, such as V6, were chosen to address health-related risks. One participant, who lived with a respiratory condition, selected V6 to insulate a frequently used outbuilding that lacked insulation, as they were concerned about mould and the associated health risks. However, aesthetics also posed a barrier for this group. Products perceived as unattractive could deter adoption, even when they offered practical benefits. One participant, for example, described the V2 as making the house look like ‘student housing’.

For non-vulnerable participants, comfort was also valued but was more readily balanced against aesthetics and home design. Some participants weighed visual appeal alongside functionality, expressing concerns about how products might affect the look of their homes and impact its overall value. For example, the V3 were described as neat and modern, as well efficient, making them preferable to bulkier, traditional radiators.

4.5.3. Risk and Uncertainty

The amount of information provided on the website was important for both groups, regardless of whether they could be classed as vulnerable or not. Not being able to compare products or fully understand how they work left some hesitant to invest. Many commented on the importance of being able to seek straightforward guidance from trusted experts or organisations to address concerns about scams or misleading claims. The value of clarity was especially important when considering expensive or complex products:

*“You don’t know if you’re paying that high amount, is it really going to work”
(Participant B).*

Across both groups there was also value placed on being able to see and test the products in person to better understand their effectiveness and fit.

Both groups expressed a shared need for better communication on products, and support. Potentially vulnerable participants sought reassurance and transparency to reduce financial risks, while non-vulnerable participants tended to focus on evidence of effectiveness and opportunities for hands-on experiences. Many also commented on the importance of external validation in the form of straightforward guidance from trusted experts or organisations to address concerns about scams or misleading claims.

5. Discussion

The responses collected from both vulnerable and non-vulnerable participants at Future Close provided a wealth of data through which to address the three research objectives.

5.1. Research Objective 1: Technology Adoption and Benefits Realisation

The analysis illustrated a multitude of different factors affecting the adoption of new technologies and how these changed as a result of the research process itself. After engagement with the products on the website, most participants answered introductory questions with reference to practical considerations, concentrating on cost, return on investment and the disruption of their home. There was some acknowledgment of the potential for products to save people money but more often there was a perception that the initial outlay or installation costs would be a “major barrier” (Rihar et al., 2015, p.44).

Factors such as aesthetics had some bearing on initial appeal, but played a more important role in discussions during the walking groups and focus groups. Once participants had looked at the products in situ, they had much stronger opinions about the way they looked and felt, often reassessing their practical concerns in the context of a product they found particularly attractive or unappealing in real life. The desirability of the products was dependent on them “generating a particular mood, or appealing to the senses” (Strengers et al., 2020, p.6). This kind of engagement with the technologies affected the weighting of the different factors placing much more emphasis on hedonic considerations. Underpinning both sets of factors, however, uncertainty about new, unfamiliar and untested products remained a concern throughout the sessions, accentuating the challenges associated with risk, cost and disruption and, for most people, overriding the positive impact of the engagement process. As research suggests, people are much more comfortable with familiar brands and products (e.g., Boudet et al. 2021). Moreover, personal circumstances and proactiveness had a significant impact on how appealing the different products would be for each individual household. As illustrated by other qualitative studies of energy use and technology, family circumstances are complicated and have multiple different impacts on the way people respond to new products and devices (e.g., Larsen and Gram-Hanssen 2020).

5.2 Research Objective 2: ICT Adoption and Acceptance

Three out of the eight technologies on site could be considered ‘smart’, with features including automation, machine learning and information provision (V3, V1 and V7). These products were subject to the same concerns as the others regarding cost, disruption and hedonic appeal, with none of these factors playing a more or less important role on the basis of the product being ‘smart’. Rather, it was factors associated with uncertainty and personal circumstances that had a bigger impact on the adoption and acceptance of smart technologies. According to the literature, the perception of a smart home as ‘reliable, competent and controllable’ creates a higher intention to adopt (Shuhaiber and Mashal, 2019). Some participants were less confident about the reliability of products that required WiFi (with specific reference to V1) and more concerned about their ability to fix them or find someone else who would be able to

assist with this (with specific reference to V3). Underpinning both of these things was the perception that smart technologies were more complicated and therefore a riskier investment.

Based on previous research, it could be assumed that reservations about smart technologies were more pronounced due to the slightly older make-up of the research sample (e.g., Brown and Markusson 2019). However, only one or two participants made a direct association between their age and technology acceptance. Indeed, several ‘older’ participants were very enthusiastic about the benefits of V7 in terms of information provision and energy monitoring. Generally, concerns about these technologies were about their reliability rather than their usability.

Finally, positive feedback about smart technologies such as V7 was influenced by a personal interest in energy savings and the context of a larger household that made automated technologies an advantageous investment: Perceived benefits were “dependent on factors relating to lifestyle, household makeup, and house characteristics” (Oliveira et al. 2020).

5.3. Research Objective 3: Comparing Vulnerabilities

In terms of vulnerabilities, there were some differences between the two groups. Participants that could be categorised as vulnerable emphasised affordability and practical solutions for heat retention, highlighting their heightened financial- and health-related concerns. Those categorised as non-vulnerable, though still conscious of costs and efficiency, placed greater weight on aesthetics and longer-term convenience and value.

Where there were shared priorities, it is the reasons for prioritisation that distinguishes the two groups. Most participants were concerned about cost effectiveness, comfort, ease of install and the importance of clear and trusted information. For vulnerable participants, however, cost is an immediate concern related to affordability in the first instance and the necessity of guaranteed ROI. For those who are non-vulnerable, a higher initial outlay can be weighed up against long term benefits. Taking a “*punt*” on something a little more expensive (as one non-vulnerable participant had done), is only an option for those who are more affluent (Sovacool et al. 2021). Similarly, minimising installation disruption emerged as a common concern but for non-vulnerable participants a more complex installation process could be worthwhile if it improved the value of the home or could be done alongside planned work.

While comfort was universally valued, it was seen as a necessity for more vulnerable participants, closely tied to health and age-related. For these groups of people thermal comfort was non-negotiable (Brown and Markusson 2019), whereas non-vulnerable participants tended to weigh it against other considerations, such as aesthetics or lifestyle fit. In addition, heat retention was less urgent for the non-vulnerable group since, in some cases, their homes had already undergone energy efficiency upgrades and so were better insulated.

Finally, both groups expressed a shared need for better communication on products, and support but potentially vulnerable participants sought reassurance and transparency to reduce financial risks, while non-vulnerable participants tended to focus on evidence of effectiveness and opportunities for hands-on experiences.

6. Conclusion, contributions and future research

The Futures Close project was a unique opportunity for participants to learn about a range of new energy related technologies and experience them in the context of ‘real life’. The process provided insights into how vulnerable and non-vulnerable people respond to energy related technologies but also had a direct impact on those responses, increasing understanding and challenging low expectations or preconceived ideas. Overall, however, despite increased

familiarity with the technologies during the site tour, the impact of in-person engagement was not influential enough to alleviate concerns about innovative products. While strong feelings about visual appeal and thermal comfort did lead to some reassessment of barriers such as cost and disruption, for most people the risks associated with a new and untested technology remained an insurmountable barrier. This was the case for both vulnerable and non-vulnerable groups, albeit for different reasons.

The research supports much of the existing literature, highlighting practical and hedonic factors as barriers to or motivations for adoption and the importance of trust in the face of uncertainty. Interestingly, given the environmental implications of energy saving technologies, there was little mention of ecological concern or motivation. From a theoretical point of view, the research has provided an innovative way to explore ideas and findings that have previously been tested in a more hypothetical way. It has also investigated the importance of context for the prioritisation of influencing factors.

From a practical point of view, increasing the uptake of energy related technologies is dependent on the public becoming more aware of the range of options available for their home and more confident in the reliability and trustworthiness of new products and innovations. As a first step, exposure to new technologies through projects like Futures Close is essential for people who are unaware of the problem and unfamiliar with alternative options for improving energy efficiency. It is also important for those who are already proactive in this area and may be open to new ideas and their additional benefits.

Further to this, and crucial for acceptance and adoption, is clear and transparent evidence about the effectiveness and value for money of energy related technologies. Government-backed endorsements, independent reviews and recommendations of people who have tested the products themselves would also help to build trust and reduce concerns about risk and reliability. Finally, tailored solutions should be developed based on household circumstances, ensuring different groups have access to information about technologies that best meet their needs. For vulnerable groups in particular, financial support such as grants and subsidies, would improve accessibility and encourage investment.

Future work in this area might usefully consider the long-term impact of exposure to new technologies and the engagement of users with these products in their own homes. In addition, large scale survey work could provide further insights into the range of factors explored in this paper, building on the qualitative work with data that can be applied more widely across the UK population.

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