



CRITICAL FACTORS FOR THE ADOPTION OF SMART HOMES FOR ENERGY EFFICIENCY

IMPLICATIONS FOR CONSUMERS AND PROVIDERS

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For more information about this report contact Jessica Cook (jess.cook@nea.org.uk) or Prof Savvas Papagiannidis (savvas.papagiannidis@ncl.ac.uk).

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Executive Summary

Given the UK's target of achieving net-zero by 2050, this report presents the results of a project providing a review of the factors influencing the adoption of smart home technology.

The focus of this project is on users/consumers and energy consumption at the household level, in terms the data and digital technologies for smart-home energy management. The main aim was to understand what the key factors are that aid or hinder consumers' energy consumption reduction, assisted by the adoption of smart technology. This is important because consumers can act as vital actors in achieving the net-zero target. Still, they do not necessarily have the capacity to engage, the opportunity to participate or willingness to take the risk related to innovation adoption. The above challenges are more likely to apply to low-income and/or vulnerable consumers.

In order to address this aim and knowledge gaps, we conducted a literature review of both academic and industry sources on this topic. A wide range of factors were identified as drivers of smart energy technology adoption, and these have been grouped into six main categories: consumers' perceived costs and benefits; environmental factors; perceptions and characteristics of the smart home systems; users' characteristics; support networks and communities; and, finally, policy, industry and regulation.

Subsequently, based on these factors, we synthesised and developed a framework that is underpinned by corresponding pillars and that depicts the multiple interactions believed to concomitantly influences users' evaluation and adoption of smart home energy technology. Following the findings of this project and the developed framework, a series of recommendations are made below.



Recommendations

1. Both financial and non-financial benefits of smart technologies should be presented to the customer/user, alongside an honest assessment of the known risks, at all points of the adoption journey.
2. High functionality of smart home systems need to also be accompanied by appropriate controls and safeguards to allow tailored use, dependent on individual needs.
3. Smart home systems should be built with flexibility and interoperability, with added reassurance that health and wellbeing needs will not be detrimentally impacted.
4. Manufacturers of smart home technologies should follow the principle of inclusion by design and ensure that their products are designed with users to address a wide range of needs and barriers.
5. Organisations should have a strategy to engage with users experiencing digital exclusion and/or technology anxiety, implementing appropriate mitigating actions to improve accessibility.
6. Manufacturers should provide reassurance that the “adjustable green defaults” will work in the most efficient way possible, and that software will encourage users to become more efficient through machine learning, behaviour nudges, and small adjustments to levels of comfort over time.
7. Frontline workers and installers should be trained to give appropriate advice and education to users before, during, and after the installation of smart technologies. This advice should be accessible and tailored to the specific needs, preferences, and vulnerabilities of each user.
8. Further research should be undertaken to better understand the optimal matching of different user groups to the advice providers that they are most likely to consider trustworthy and expert, and appropriate support needs to be offered to maximise the value of smart home technologies.
9. Government policies need to consider the accessibility of smart home technologies for fuel poor, low-income and/or vulnerable users to ensure they are not left behind and can fairly access the benefits these technologies can provide.
10. Data security and privacy statements should adhere to data protection regulation (s) and be provided at all stages of the smart home process in an honest, accessible, comprehensive, and easy to understand manner.
11. To mitigate the risks of miscommunication or misselling in a growing market, future regulation need to include standards for communication, customer redress, a code of conduct for interacting with customers, and the mechanism to share good practice.
12. As a participant in the energy industry, the smart technologies sector should adopt an enhanced definition of vulnerability to ensure that no products or services detrimentally impact consumers.
13. The framework should be further developed through stakeholder and user testing, to ensure that the identified factors are accurate and appropriate solutions are proposed.

Introduction

In order to meet the challenge of achieving net-zero by 2050, the UK needs to decarbonise 20,000 properties each week for the next 25 years to meet its goal. This includes work to improve households' energy and water efficiency, taking into account the technologies and appliances, as well as the building fabric itself. Even small changes at the household level can result in a significant impact on the energy network when aggregated. Such a large-scale implementation requires influencing household behaviours.

The ability to engage with the transition to net-zero is not something that customers universally possess. Individuals may be limited by their capacity to engage, the opportunity to participate, or their willingness to take the risk. Low-income and/or vulnerable households, often considered the hardest to reach, can often be left behind due to one, or a combination of, the above points being the case.

The adoption process may not be directly relevant to these households, as the decision is made for them at the first stage based on the barriers to entry they face. As such, the majority of those who are currently engaged with the journey to net-zero and may already be using low-carbon technologies are not those who would benefit the most from the potential bill savings derived from these technologies. The decarbonisation agenda must therefore address this, ensuring that nobody is left behind or disadvantaged.

To this end, this project provides a state-of-the art review of the factors related to the use of smart home technologies, when it comes to energy management at the household level. Our review of smart-homes covered both the academic and industry literature, synthesising the findings. Our review comprehensively covered the factors that affect user/consumer behaviour, paving the way for recommendations and interventions that could result in the adoption and diffusion of smart home technologies.





Methodology

The review was a stream-based systematic one producing robust results that synthesise and map the knowledge related to smart-home adoption in the context of energy management. In order to ensure that the findings were reached in a reliable and valid manner the study followed a three-stage approach, namely: planning the review, conducting the review by analysing papers, and reporting emerging themes and recommendations.

The planning stage of the review included the preliminary survey of the literature in order to develop and refine the review protocols. The review teams first agreed the high-level strategy to follow. The criteria were then refined, making it possible to proceed to the next stage.

In the next step the protocol for the review was developed. The protocol included the search criteria, the papers selected for the review and the method of conducting the analysis. We formulated the exact review questions, which facilitated the decision on the inclusion criteria.

The themes identified guided the qualitative review, which was undertaken by each team. The review identified the important themes from the academic and industry perspectives, prioritising factors of importance and highlighting the relationships among them.

The synthesis of these findings made it possible to create a framework for understanding the technology adoption when it comes to smart-home technologies applied to energy management. Questions from the point of view of the user have been provided to demonstrate how the framework could be used, but this is only one viewpoint. Such questions can be posed from other stakeholders' vantage points.

Finally, we put forward a comprehensive set of recommendations for each of the framework's key areas.

Academic Sources: 70

Industry Reports: 69



For more information about the methodology and the sources covered please refer to the Appendix.

Key Adoption Factors

Costs and Benefits

Perceived Costs

Perceived cost refers to the ownership cost, i.e., the prices individuals have to pay to own smart homes [39, 43]. The cost of owning smart homes has a great influence on smart homes adoption [62]. When it comes to smart homes systems, the factor of price, particularly its affordability aspect, plays an important role in influencing individuals' purchase decisions as consumers are inclined to opt for a cost-effective option, especially those who are price-conscious [43]. However, the current market prices for smart homes automation systems are often perceived as high and hinder individuals' intention to establish their willingness to pay [29, 45]. If the costs of such smart homes systems are perceived as excessive, individuals will have a negative attitude toward smart homes adoption [27, 30]. To own a smart home, the buying/purchasing costs are not the only aspects to consider, but so are the running and maintenance costs, including energy bills [25, 26, 28, 62]. Individuals are reluctant to spend their money to pay for the excessive costs associated with smart home adoption [31, 39].

This was also found in industry and policy research, with some studies noting that the high capital cost of low-carbon and energy efficiency technologies, including smart technologies, was prohibitive, especially for fuel poor, low-income and/or vulnerable users [11, 131]. Excessive costs were not just considered prohibitive for individual users. Research suggested that the upfront costs of (e.g.) smart solar PV and battery storage technologies acted as a barrier to social landlords and housing developers installing these technologies in their housing stock and housing developments respectively [141]. These costs were so high that financial support from the government, such as purchase and energy rebates, might be required to cultivate smart home adoption [11, 31, 39]. Some literature also emphasised that it would be necessary to ensure that adequate and appropriate finance packages are made available to support different types of customers to access and make the most of new technologies [135, 139, 141]. More generally, these findings suggest that providers always have to pay attention to the pricing schemes of smart home technologies by ensuring the costs are perceived as reasonable, so that cost barriers can be minimised [43,59].

Perceived Monetary Value and Saving

Perceived monetary value refers to the economic value and savings gained from the costs paid in owning a smart home. The purpose of a home energy management system within a smart home environment is to achieve cost-effective energy through its smart automated energy control system [38, 63]. The use of smart home technologies in the home environment provides efficient energy control through smart homes systems, resulting in energy saving, which eventually reduces energy costs [26, 30]. Such energy saving within the smart homes brings economic value and monetary savings to the householders who adopt them [31, 43].

For smart homes users, their initial intention to adopt smart homes is driven by their interest in achieving energy savings in the home environment, and they have perceived economic value, i.e., monetary savings from their actual adoption [34]. However, such economic and monetary savings depend on users' consumption patterns [28]. For example, the configuration of the lowest temperature setting for heating during the winter and cooling during the summer will bring potential monetary savings [28]. The features of energy consumption monitoring integrated with smart devices are beneficial in achieving monetary savings. Users can learn about and monitor their energy consumption patterns on a real-time basis, thus helping them to control their energy consumption to achieve financial savings [29]. Other than that, the automation system integrated with smart home technologies also plays a big role in providing energy savings for the economic value for householders [54]. With such smart energy control through an automation system, the energy waste can be minimised, improving monetary savings [54].

However, industry and policy studies, especially those stemming from real world trials of specific technologies, show that smart home technologies are not guaranteed to result in financial savings for users [15, 113, 119, 121]. Evidence from the rollout of smart meters in Scotland found inconclusive evidence of the impact of smart meter installations on energy bill reductions [119], and a systematic review of smart heating controls also found little direct evidence of energy savings or cost effectiveness [121]. Another study, which reported on the outcomes of installing and testing different smart technologies (e.g. smart metering solutions, Time of Use tariffs) in fuel poor households, reported relatively little saving; participants in one trial saved an average of £14 annually, and participants in a Time of Use trial saved an average of £6.24 annually [113]. Indeed, it is noteworthy that the observed energy bill savings in experimental studies tend to diverge from projections or estimates of energy bill savings that could, in theory, be achieved by smart technologies [28, 29, 15].

Functionality / Perceived Features

Functionality refers to the individual's perceived features regarding the practicality and usability of smart home technologies. Smart functionality and features integrated with smart home technologies provide a solution for individuals to automate their homes, especially for convenient energy control with remotely controllable features [25]. Remote control functionality is useful for managing energy consumption, as it enables users to control and configure energy for optimum settings, including programmable flexible scheduling, such as home temperature configuration [26, 29, 30, 33, 39]. Research has found that such smart features can increase willingness to pay [39, 45]. In addition, controlling features on mobile apps was also found to develop individuals' interest in investing in such functionality, for example, a mobile app to configure smart thermostat settings remotely [38]. Such functionality is useful for managing home energy practically and conveniently [45]. In addition to that, smart features such as WIFI connectivity and digital display functions maximise users' experience of energy control in the home environment [45]. Wi-Fi connectivity linking smart home devices to personal devices (e.g. smartphones) can provide control of energy in a more effective manner [27]. In addition, there is also a voice-controlled feature through virtual assistants like Amazon Alexa and Google Nest Speakers that will be useful and practical for energy control in smart homes. Such features enable users to set their required home configuration with a voice control system, such as turning on or off the home system, e.g., lighting, heating, cooling, etc.

Perceived Benefits

Perceived benefits refer to the advantages gained by individuals from the adoption of smart home technologies in the home environment. Perceived benefits have a positive influence on smart home adoption [25, 27, 45]. The adoption of smart technologies in the home environment creates benefits, such as security improvement, energy efficiency, monetary savings, comfort, and convenience [25, 31, 43]. For example, in terms of security, smart home technology provides reliable security systems to the users through wireless technology such as cameras and sensors [43]. A prominent advantage of smart home technologies in the home environment is energy conservation, which would benefit householders and eventually benefit ecological well-being [29, 28, 30, 40, 41]. Energy conservation is achieved through smart home energy management systems that provide efficient energy control and energy waste reduction that brings economic benefits, i.e., monetary savings [31]. Such benefits can foster individuals' attitudes toward adopting smart homes.

Health Benefits

Health benefits refer to positive health advantages gained by individuals from adopting smart technologies in the home environment [21, 24, 36]. Health-related smart technologies in the home environment enable individuals to monitor their health [22, 23, 25, 36, 40] and seek health information [27]. Both the academic and industry and policy literature noted that this was especially the case for vulnerable user groups, older user groups (especially over the age of 65), and users living with chronic illnesses and disabilities [24, 31, 36, 40, 132, 151, 158].

A particular opportunity for this demographic was the potential to close the gap in accessing health and technology services for older people living in rural and remote locations [151]. Those that can make use of battery-storage solutions, for example, and which will operate during a power cut, could be particularly attractive to households in rural areas or those with health conditions requiring more time in the home or where management of a condition requires the use of electrical equipment [116]. Overall, in these studies, it was made clear that smart technology has the potential to support people's health, wellbeing and independence, as well as leading to a greater likelihood of adoption among user groups that would stand to benefit the most from its introduction [27, 31].

The industry and policy strands of the literature discussed several other significant themes relating to the relationship between smart technologies, the health and social care sector, and the maintenance of good health and wellbeing. Echoing the principles of inclusion by design [122], the review highlighted how it is important to listen to and respect patient voices when designing and providing health-related smart services [146, 151]. Health-based smart controls, devices and services need to be designed in consultation with the residents/households *and* the health and care-related professionals that will be using them to ensure maximum usability, and that the intended benefits can be derived from them. This increases the likelihood of the intended health-based outcomes being achieved by enabling appropriate and adequate engagement by all relevant stakeholders [150].

At the same time, technologies need to be able to be embedded within family/carer dynamics and other household members/carers need to be enabled to understand, use and support smart health devices and services [151, 158]. For instance, one study found that smart technologies are useful to caregivers that live together with vulnerable individuals, such as patients with severe mental illnesses [1]. In parallel, and linked to other themes identified in the report, the evidence reviewed highlighted that it is important to ensure that the intended beneficiaries/users of the technology (i.e., householders/residents) are provided with the tools and knowledge to use, understand and control the technology/service in question. Such an approach would not assume digital capabilities amongst all users, nor would it seek to bypass users with no or limited digital capabilities by transferring control to relatives or carers who do have digital capabilities (rather than looking to build user capability).

Other studies emphasised the importance of smart home technologies in tele-healthcare solutions. In a 2018 report, smart meters were regarded as having the potential to become a 'ubiquitous tele-healthcare solution' [158]. Relatedly, the report set a series of recommendations for action to better align energy and health outcomes in the context of smart systems, smart meters and tele-healthcare. For example, it was noted that there is potential to explore opportunities to share data related to energy and health through portals such as the Smart Energy Research Lab and the UK BioBank. Additionally, smart energy and water data could provide insights into daily living and the health risks associated with, for instance, personal neglect. Reiterating other findings from the review, the involvement of families and carers is again considered crucial.

Lastly, a call for further public and media awareness campaigns was noted, specifically outlining the need to highlight the importance of smart meters in tackling fuel poverty and health inequalities. Critically, "*...campaigns should clarify the potential health benefits of a smart meter infrastructure, not just financial and environmental benefits*" [158].



Feedback about Energy Consumption

Feedback about energy consumption consists of giving households information about their energy consumption, or energy savings, in such a way that it can be seen and observed by and through the smart technology [39]. Typically, this has been a key feature of smart meters that are installed with an In-Home Display (IHD), which enables the user to monitor consumption and cost on different temporal scales (e.g. hourly, monthly, annually). Energy providers now also offer a range of alternative methods of visualising energy consumption data, such as smartphone apps, and some providers are beginning to trial and market innovative ways of visualising the interaction between different smart technologies in the home (e.g. the savings obtained through the smart charging of battery technologies by solar PV at times of low electricity cost, mediated through Time of Use tariffs such as Octopus' Agile). The purpose of such displays is to provide energy feedback to users to foster changes in energy behaviour that reduce consumption and consequently improve energy sustainability [26,31]. This makes it possible for users to understand their daily energy consumption patterns, thus helping them to manage and alter their use effectively [28, 31, 39].

Visualisation, visibility, and control were also important themes identified across all the literature [12, 113, 119, 123, 125, 129, 131], with smart meters a key focus, primarily because they make users aware of their energy consumption on a real-time basis. For example, a review of the lived experience of fuel poverty in Scotland found that research participants, especially those using prepayment meters, considered their IHDs an important means of visualising how much energy they were using and the typical consumption of different appliances in their home when used (e.g. kettles, washing machines) [119]. This review noted that some used their IHD to help budget their electricity, for example by setting an indicator on their IHDs to change colour if they exceeded a pre-set spend on electricity per day [119]. Academic studies also found that energy consumption feedback can influence behaviour in different ways, especially because it can be a way of communicating benefits, outcomes and energy savings [1, 26, 28]. In particular, feedback monitoring and display systems enable users to remotely monitor the condition of their house when they are away from home, which provides convenience and practicality [27].

The smart metering market and rollout is relatively mature, with IHDs a core part of the offer put forward by energy providers. With regards to other smart home technologies, the review found that similar levels of visibility, visualisation, and control could significantly shape their adoption and optimal use, especially for fuel poor, low-income and/or vulnerable users [119, 123, 125, 129]. In particular, one study demonstrated that existing heating controls tend to provide insufficient visibility or the kinds of control that such users require (e.g. they do not facilitate heating certain rooms for certain periods of time to specific temperatures) [125]. The study subsequently showed that the installation of smart heating controls, combined with a smart meter or smartphone app, not only achieved this, but led to other co-benefits such as enhanced energy management [125].

Other studies noted that not including smart meters or other means of visualisation in the trialling of smart technologies was, in hindsight, a significant drawback, and potentially led to lower levels of user engagement [123]. Similarly, it has also found that users who are already anxious about their energy bills sometimes report heightened anxiety after the installation of a smart meter because it increases the visibility of the unaffordability of their energy consumption [129]. Increased visibility was also suggested to lead to user disengagement if the observable energy or cost savings did not match the savings that were promised or expected prior to the installation of the technology [119]. These findings suggest that while visibility, visualisation, and control are important, they need to be paired with wider benefits to remain a positive factor shaping the adoption and use of smart home technologies.

Environmental

Pro-Environmental Beliefs

Pro-environmental attitude that is reflected when individuals act in a way that brings less harm to the environment by reducing environmental degradation, such as using an energy-efficient smart system to minimise energy waste [30, 42, 48]. Research found that energy-conscious individuals with pro-environmental attitudes have a high tendency to adopt smart homes [31, 27, 32, 30, 42, 50, 62]. When it comes to how such attitudes can be manifested in tangible gains, smart homes can be used to power devices only when necessary [29]. Similarly, the adoption of smart home technology such as smart thermostats can be influenced by individuals' pro-environmental attitudes because such smart devices have the potential to optimise energy usage in lowering energy waste [30, 39]. From the perspective of smart home developers, one of their selling strategies for smart homes is to create environmental awareness through online platforms such as social media to foster individuals' pro-environmental attitudes. Such pro-environmental awareness and in turn behaviour is expected to positively influence potential buyers to buy smart home kits [62].

Perceived Green Value

Perceived green value refers to the benefits, particularly related to energy efficiency values, that individuals gain through the adoption of smart homes technologies [28, 41]. People are inclined to opt for smart homes because they want to achieve energy savings [33]. Energy efficiency in the home environment can be achieved through an automation system integrated with smart home technologies [43, 51]. Such an automation system is a part of the Home Energy Management System (HEMS), which manages users' energy consumption to reach energy efficiency by controlling energy demand and supply efficiently based on users' energy consumption patterns [28, 41, 53, 58]. It is helpful to create sustainable energy management in the home environment [52, 59]. The Home Energy Management System (HEMS) can dynamically manage the balance between energy production and consumption smartly and efficiently [54]. The aim of a home energy management system is to achieve energy savings that will eventually benefit environmental well-being [66]. Energy efficiency consists of energy-saving that involves less energy waste to deliver optimum energy production to the users [36, 37, 42, 63]. For instance, when space heating becomes digitalised and automated within a home automation system, energy production and consumption can be managed efficiently based on users' daily consumption patterns [34, 39]. Such digitalised and automated features can eliminate energy wastage. In the diffusion of smart home technologies, perceived green value has a major influence on smart home adoption, especially for individuals aiming to achieve energy savings in the home environment [31].



Environmental Knowledge

Environmental knowledge refers to individuals' understanding of current environmental issues and the cause of environmental degradation from humans' activities, especially in the home environment, such as energy consumption [59]. Environmental knowledge can be developed through the understanding of one's impact, when considering the interaction of daily energy consumption behaviour [28]. Research has found that individuals' energy-related behaviour, such as their approach towards achieving energy sustainability (e.g. energy efficiency and energy reduction) through smart home technologies, is strongly influenced by environmental knowledge [26, 30, 50, 31]. Such behaviour is driven by individuals' understanding of their daily energy consumption through energy consumption monitoring systems as well as their concern about the environmental impact [25]. Hence, with sufficient environmental knowledge and an intention to reduce impact, individuals can have a positive attitude toward smart home adoption.

Adjustable Green Defaults

Adjustable green defaults refer to the adjustability or control of smart home automation systems in green default configurations to maximise energy efficiency in a smart home environment [21]. Embedded adjustable green defaults in smart home technologies have a great influence on individuals' behaviour to achieve energy efficiency through smart home adoption, as the default is perceived to function as a "green/energy-efficient" configuration [21]. The adjustability of smart home automation systems in the green default setting, i.e. optimum energy setting, is useful to reduce energy consumption for environmental sustainability [21, 22, 23, 24, 25, 29]. To maximise energy saving, the smart home systems have to be set to "green" as the default configuration [21]. The "green" setting means the optimum configuration that fits the need of users without energy waste [21]. For example, green default settings are adjusted according to different times at home, e.g. the day and night, with varying temperature settings to conserve energy consumption. Even though smart home technologies are likely to achieve energy savings, people might not know what the appropriate configuration is to set to achieve such energy-savings through the home's automation interfaces. Therefore, if there is a default green setting for energy-efficiency performance, it will be convenient for users to select it [29, 30]. For instance, the default can be adjusted with optimum temperature settings and programmed with self-adjusting room temperatures to maximise energy performance [29].



Smart Home Systems

Perceived Usefulness

Perceived usefulness is the subjective view held by people who believe that using a particular technology will enable them to do their jobs more effectively [71]. Perceived usefulness in the context of smart home adoption is associated with the ability of technology to improve daily lifestyles as perceived by individuals [23]. Past research suggests that perceived usefulness has a positive influence on the adoption of smart homes [9, 15, 16, 17, 27, 48]. One of the most essential features of smart homes, namely the automation, is perceived as ultimately useful in three ways [15]: [i] it helps the residents proactively without human intervention, [ii] it provides auto-adjusted control for home systems, and [iii] it provides control of home appliances through a simple operation. Such ways can help people better oversee the energy consumption of heating and appliances, resulting in more effective energy management. For instance, a smart meter that functions autonomously with a monitor display helps users control the energy flow and consumption [18, 41, 11]. Users are subsequently able to predict and plan their energy usage and thus manage their consumption better [2, 3, 37, 42]. Energy consumption and system status are monitored in real-time and displayed on the smart meter screen to provide users with all the necessary information [19, 25, 26, 28, 29, 31, 33, 34, 37].

Similarly, a smart lighting system is useful in managing energy consumption intelligently, by making it possible to automatically control light without human intervention [22, 43]. Lights will turn on and off when the sensor detects motion within its range. The same concept can be applied to a smart thermostat [30]. A smart thermostat provides a useful control system that enables users to programme the temperature of their house automatically throughout the day [45]. Smart thermostats can manage temperature based on pre-defined rules, resulting in an optimisation of heating spaces [4, 8, 29]. Such automation and intelligence can be useful for users living in both cold and hot climates that require either a fast-heating power or air-conditioners for space cooling, respectively. Smart home technology is not merely limited to general home operations and purposes. In fact, a specific segment of users tends to reach out to smart home technology for more specific and personal purposes.

Perceived Ease of Use

Interviews with industry experts indicated that despite being critical to success, the ease of use and usability of smart home systems and technologies had not to date been considered a key priority in the journey to a smart energy future [151]. Perceived ease of use is defined as the degree to which a person perceives a system to be easy to use and effortless [71]. In smart home adoption, perceived ease of use is the degree of operating complexity associated with smart home technology as perceived by individuals [2]. Practically simple, uncomplicated, and convenient to operate are features that potentially motivate an intention to adopt Smart Home technology [13, 19, 25, 22, 27, 15, 48, 34]. For example, the control system of a certain technology should be straightforward and without unnecessary complicated settings, which can be perceived as hard to configure [7, 12, 21, 24]. A selling strategy to attract potential house buyers to smart homes is therefore by designing it with flexible and convenient features that enable users to fit the technology usage according to their preference with an effortless set-up [62].

Apart from operational aspects, the configuration element of the smart home system may create a positive perception and adoption intentions if it requires a simple, straightforward and easy-to-understand installation [33, 1, 28, 62, 45, 111, 114]. This 'out of the box' experience is crucial, and should include maintenance as well as installation. Some practical aspects of installation that encourage greater adoption and increased confidence among users include: having a single point of contact for support and advice; being able to book weekend and evening appointments for installation; the provision of clear information and advice in advance, on the day, and afterwards; and considering local, cultural or religious traditions and events [113]. These early steps of engagement are important in establishing trust early in the user journey. Also, a number of studies also noted differences in consumer preferences with regards to having smart home technologies

professionally installed or to self-installation. Surveys revealed that many households prefer to have technologies, such as water and heating controls, security systems, smart switches and bulbs, installed professionally [168]. However, there is a critical need to avoid errors in professional installation, which can further inhibit householder engagement, usability, and realised benefits [152]. Alongside this, however, a need for tailored digital and energy systems was highlighted as critical to the future of smart homes, where diverse “digital DIY” will be as common as DIY more generally [152]. These issues are vital at this early stage because they may not only prevent devices being set up correctly, but may also cause users to be wary of engaging with smart devices once they are in operation. As one study stated, *“the best way to introduce smart technology is to replace everyday devices with a device that is simpler to use and does more for you than you do for it”* [114]. Optimising this early step in the customer journey is therefore likely to be highly impactful in promoting increased adoption and optimal use.

Beyond this, smart home devices with automated configuration and easily remote controllable functions can provide users with convenient and efficient energy control [4, 6, 8, 20, 36, 43, 59, 68]. The user experience can be understood in relation to three overlapping factors : convenience, control and safety [167]. Examining usability and user experience, according to a study which explored older people’s use of smart home systems and technology in Australia, suggested that benefits could not be isolated to single pieces of technology. Instead, the benefits should be explored as a whole system when connected, specifically considering how such services and technologies ‘enhance one’s life’ [167]. For example, smart thermostats can monitor and assist users in calculating their energy consumption, thus ensuring convenience in planning energy consumption in real time [29]. In addition, IoT-enabled and remote-controlled devices with easily managed settings can help users achieve energy savings. This is because such devices help to concentrate energy usage at scheduled times when users are at home, and automatically reduce or stop energy consumption when users are away [40]. With such convenient features, smart home technologies are expected to be widely adopted in the near future [67]. As a recommendation, when developing or improving smart home technologies, providers should embed practical functions (e.g. features increasing ease-of-use) in order to meet users’ expectations [23].

Perceived Risks

From the perspective of the adoption of smart homes, perceived risk represents the potential consequences faced by individuals as a result of their decision to adopt smart homes. The findings suggest that perceived risk can have a moderate effect on adoption.

The dimensions of risk associated with perceived risk are privacy, performance, time, security, and financial risk [27]. In terms of privacy, individuals are exposed to the risk of losing control of personal data saved on smart home devices, for example, when their private data is obtained and collected by providers without their knowledge and consent. When it comes to the performance dimension, there is a possibility that smart home devices may not fulfil individuals' needs and expectations. The perceived risk regarding the time dimension refers to the possibility that using smart home devices may take too long or consume too much of the user’s time. Regarding the security risk, adopting smart home devices might make users vulnerable when it comes to the security of their homes or data [43]. The financial risk relates to the costs of purchasing, operating, and maintaining smart home technologies, which may end up being too high. Such perceived risks as those outlined above can hinder the adoption of smart technologies.

The key findings from the reviewed articles indicated that privacy and security concerns are the major concern with respect to individuals' perceived risks [27]. Individuals' perceived risks have a significant influence on individuals' attitudes toward smart home adoption [2, 3, 27]. In this case, perceived risk in terms of privacy and security is related to their concerns about possible personal data leaks and security breaches, respectively [25, 31, 34, 39, 45, 29]. Nonetheless, research indicates that individuals have a tendency to disregard their perceived risk and divert their focus to the potential benefits of adopting smart home technology [28]. Hence, practically, providers should aim to reduce these risks in order to strengthen the likelihood of smart home adoption [30, 27]. There are several ways that providers can achieve this. For instance, given that the dimensions of privacy

and performance contribute to individuals' perceived risk, providers could aim to demonstrate more actively the security prevention measures they implement (including how any collected information will be used in order to preserve people's privacy) and also the expected performance that the device can deliver [27]. Providers could also design their devices in a convenient and straightforward manner, thereby reducing the installation and operation time and effort [27].

Finally, the policy and industry review also revealed a number of other risks that are important to note. Specifically, some studies noted that different property characteristics may affect the performance of smart technologies [15, 121], and this in turn may impact upon user satisfaction should performance not meet expectation. Consideration of the barriers that different domestic infrastructure types may present to the installation and/or functionality of a smart technology is therefore essential, as is the communication of specific limitations to consumers before point of purchase is reached. This would help customers to feel both empowered and confident that the choice they are making is the right one for them and their property, rather than waiting until the point of installation to find out (risking poor subsequent uptake of new or alternative technologies). In addition, one study found there was a risk that smart technologies might be unsuitable for some users depending on their design. For example, smart kettles may be too heavy for users to lift or users with a hearing impediment may find it more difficult to interact with voice assistances [151]. As emphasised elsewhere in the report, this points to the importance of inclusion by design and ensuring that smart technologies are developed with different user groups, vulnerabilities, and needs in mind [122]. Finally, there is also a risk that the real or perceived hassle and disruption of technology installation could prevent a customer from opting into smart options [15].

Trust

In the context of smart home adoption, the concept of trust is defined as individuals' confidence and belief in the ability of smart home technologies to serve their purpose as expected [48]. Emphasis on trust in smart homes has been identified in three cases, and in each of these it was considered to be of great importance. Firstly, users have more trust and confidence in using familiar brands and products of smart technologies [32, 168]. Secondly, users prefer to consider technology that has been adopted and reviewed by other users [34]. Finally, for users that have used a specific smart home technology, they usually have high trust in the same smart home technology providers and their capacity, and are reluctant to switch to different providers [48].

Reliability and Interoperability

Reliability is the consistency and usability of smart homes systems and technologies and their ability to function as expected without any the possibility of any undesired malfunction [33]. Research suggests that reliability plays a significant role in affecting individuals' attitudes towards smart homes adoption [33]. When it comes to smart home technology, users expect that the smart system will be reliable and face no device failure due to Internet glitches or a malfunction that could sabotage the smart home system [33]. The Home Energy Management System [HEMS] particularly is likely to create an unpleasant user experience if it suffers a major fault and error [33]. This would lead users to perceive such technologies as unreliable, when the goal is actually for smart technology to be useful and make life a lot easier.

In the industry and policy literature, interoperability emerged as a key theme that may affect the usability and reliability of smart home technologies. In cases where a technology would not be interoperable with other devices, or where there is a risk that initial interoperability may be lost, users may not be able to derive the full range of expected benefits from it or use it in the way that was intended [19, 128, 135]. It is therefore essential that providers, retailers, installers and advisors clearly communicate the interoperability requirements and potential of a product to users before they decide to adopt it. Feeling fully informed and able to weigh up both the drawbacks and benefits of new technologies, users may be more likely to feel confident in their end decision [12]. On a wider scale and in the longer term, manufacturers and regulators need to consider how to put in place requirements and guarantees that new technologies will retain smart functionalities [12], regardless

of the service provider or product in use, and that customers are not locked into a single provider and/or manufacturer because of interoperability issues (risking higher costs and the unsuitability of service to personal circumstance) [133, 135, 139, 140, 141]. The issues experienced by users with the smart meter rollout, whereby meters installed in the early (SMETS1) rollout ceased functioning and became 'dumb' when users switched energy suppliers, serves as a warning that similar problems could be hugely damaging to the societal uptake and acceptance of smart home technologies.

Users

Digital Poverty and Exclusion

Several smart home technologies examined in the review were partly or wholly dependent on access to the Internet and/or users having the skills, confidence, and knowledge to use digital technologies effectively. Technology anxiety, digital exclusion and a lack of digital capabilities can therefore be considered important barriers affecting the adoption of smart home technologies.

With specific regards to Internet access, latest estimates suggest 1.5m households in the UK do not have Internet access and 2m struggle to afford Internet access. Internet access was a prerequisite for several of the smart home projects reviewed in the industry and policy literature [17, 123, 116, 19]. One project, for example, was reliant on the household having an Internet connection to collate and communicate data from smart plugs, electricity meters, and other smart devices to a cloud-based server [17]. Households could not take part in other smart home innovation projects if they did not have an Internet connection to facilitate monitoring, system software updates, and the continual optimisation of smart devices [123, 116]. In addition, the quality of the Internet connection was raised as a barrier in other studies, one of which noted that good Internet/Wi-Fi was a prerequisite for consistent wide area network (WAN) communications between different smart devices in the home [19]. A second study emphasised that external factors would also influence Internet quality, suggesting that during peak evening hours Wi-Fi quality can deteriorate as interference from other connections occurs in high population density residential areas (e.g. from the increased evening use of streaming services after the conclusion of the working day). This study also noted that Wi-Fi quality may be variable in different rooms of the home, leading to smart devices located in certain rooms not communicating or responding optimally to external signals [111].

However, it was noted in some of the reviewed literature that digital barriers to smart home adoption could be tackled as part of the smart home engagement process. For example, processes of engagement around smart technologies could include provision to support a household to access an Internet connection through a social tariff developed by broadband providers, especially in the social housing sector [123]. Another project was exploring ways in which households without home broadband could be enabled to adopt smart home technologies, specifically by exploring how plug-and-play hardware integrating a wireless network, broadband, and a Freebox could do so in future work [17].

With regards to skills, latest estimates suggest that 10m UK households lack the basic digital skills and confidence to engage effectively with digital technologies. Academic literature considered this in terms of technology anxiety. In the context of smart home adoption, this is defined as a mixed sensation of fear that encompasses feelings of anxiety and discomfort while interacting with technology-related functions and interfaces associated with smart homes [15]. Studies noted that technology anxiety negatively influences attitudes concerning smart home technology [8, 11, 15]. This anxiety is likely to be perceived by user groups such as elderly users and individuals with poor technology literacy, who are likely to have a low level of exposure to and experience with smart home technology [22]. These individuals tend to fear that they might not know how to operate the technology given its technical features, which might be perceived as complicated and hard to understand. Such user groups may feel discomfort and nervousness when dealing with advanced technology [23, 31]. They have such technology anxiety due to their perception of the complexity of advanced technology. Also, users may feel technology anxiety stemming from privacy fears and security concerns [40, 45, 49, 39 36]. Users are worried that their private data might leak due to providers possibly sharing their personal data with other parties. In the industry and policy literature,

a similar notion was not typically defined as technology anxiety, but was discussed in terms of users not having the digital capabilities, knowledge, or skills to adequately use, operate, and have confidence in smart home technologies [11, 123, 16]. For the purposes of this section, the term technology anxiety is adopted as a broad indicator of this theme as a whole.

Some industry and policy studies exploring the future of smart energy for older users showed that, as well as ensuring reliable and equitable Internet access, it is critical to provide opportunities for participation and learning as well as encouraging all older users to gain 'digital living skills' – in other words, to offer an opportunity to transform technology anxiety into personal innovativeness [151]. In other words, the development of smart home technologies was viewed as an avenue through which technology anxiety could be addressed by providing education to older users, contributing to the adoption of these technologies as well as broader social policy objectives. This is even more the case because of the balance between automation and empowerment. For example, one project trialling domestic battery storage and solar PV in fuel poor social housing found that half of the households taking part did not feel they had enough knowledge about how the technologies work [123]. However, all households agreed that the technologies needed no active input to work. This suggests a degree of automation would be beneficial in helping digitally excluded households to adopt and use smart home technologies [123]. Other studies suggested that some degree of interaction with smart home devices will probably always be required (e.g. to maintain password security or authorise software updates) [117]. Therefore, it is likely that a minimum level of education and digital skills provision will be necessary to drive the adoption of smart home technologies among user groups experiencing technology anxiety, especially older users and those with low digital literacy.

Finally, studies noted that the ability of the nascent smart home industry to adequately support digitally excluded users with queries will also be important. For example, research focusing on the equally nascent district heating sector has highlighted the importance of suppliers having digital and non-digital means of providing customer service, but has also suggested that non-digital support might be inadequate and not available on a sufficient scale to resolve customer queries quickly [136]. This suggests that if energy service companies begin to provide smart home services as discreet products/services, perhaps through energy- or heat-as-a-service business models [11], they will have to ensure sufficient customer support is available for digitally excluded customers who may have queries after the installation of their devices.

Technological Knowledge, Experience and Engagement

Technological knowledge is an individual's ability and know-how to use technological tools or features, which comes from their experience and engagement with using smart technologies [34]. The academic review indicated a moderate importance of technological knowledge and experience in the adoption of smart home technology.

There was a divergence between the academic and industry and policy literature on the extent to which pre-existing experience with smart homes leads to the continuation or deepening of users' engagement with them. Two academic studies found that individuals who have experience with smart homes achieved satisfaction driven by the benefits (i.e., perceived usefulness) of their adoption [25, 28]. In turn, their experience creates a desire to continue using smart homes [25]. In contrast, the "Smart Home Shopper" study, which investigated smart home purchasing behaviour, showed that 56% of British adults that have bought the latest "must-have" home smart technology have little to no knowledge of how to use such products once purchased [160]. Three out of ten surveyed admitted to regretting at least one or more items purchased. The survey also revealed that nearly a third of adults say they have never read the instructions or manuals when buying a new piece of technology, with 13% of respondents revealing that they could not connect to the devices they had purchased. This research indicates that while people are purchasing smart home technology and services, there is a significant proportion who do not know how to use such products and are therefore unable to realise the benefits. The findings illustrate the importance of understanding adoption in terms of initial and ongoing use, not just at the point of purchase or installation.

For non-users, individuals with a good understanding of smart technologies tend to have a positive attitude towards smart home adoption [59]. In addition, a higher level of individual engagement and experience with smart technologies is likely to maximise users' exposure to and knowledge of smart technologies [26, 27, 32, 48]. Individuals with different levels of knowledge and experience have different perceptions of smart homes adoption [50, 31]. With the appropriate knowledge of smart technologies, individuals can decide whether the technologies are appropriate for their needs. Similarly, with an appropriate level of experience they can decide whether to use it or not [34]. In contrast, studies have also found low awareness of the need for potential future updates to smart technologies (I2). Where users experience unexpected changes or updates to smart devices in their home as a result of updates that they were not informed about, confidence can be affected. In addition, there is also a need to consider the level of awareness and knowledge across the whole household (i.e. beyond the individual level), and the needs related to support and/or training of wider household members. One study found that where a household contained a couple, it was more likely that one person took on the role of understanding, using and controlling the smart technology [I51].

Autonomy with Control

In the context of smart home adoption, the need for autonomy refers to the necessity that smart home technologies function independently without human intervention. It also reflects the requirement to adjust the configurations autonomously according to the surrounding changes to fit users' preferences and practical needs [31].

In the academic literature, the need for autonomy has been found to have a strong influence on adoption. Smart homes' automation systems are expected to replace many tasks that mostly require manual operation [31]. The literature suggests that individuals' need for autonomy is driven by their awareness of energy consumption and preference for energy-efficient home energy management systems. For instance, autonomous smart technology can manage energy efficiently when the house is empty, preventing energy waste [28]. Smart home automation can underpin assisted living, helping vulnerable individuals to maintain a good quality of life [33]. In particular, elderly users have a higher need for autonomy as it brings more convenience and reduces their dependence on others. With an automated home system, their daily life will be assisted by smart technologies that function autonomously, such as a simple heating setting configuration that heats indoor space automatically [39]. For other user segments, their need for autonomy is based on their own preference to automate their home with smart devices like a smart thermostat or a smart water heater [29]. In addition, environmental attitudes play a role in influencing individuals' need for autonomy. When the individuals have a motivation towards energy conservation and want to improve home energy saving, they will be likely to choose autonomous systems that can monitor their energy consumption intelligently [30].

In addition, the industry and policy literature stressed that while the need for autonomy is significant to smart home adoption, users will in many cases still want to feel in control of their systems and feel that they can adjust them manually if desired. Studies emphasised that the ability, at appropriate moments, to exercise control over and personalise the use of smart technology will be an important driver in enabling adoption, such as being able to manage services from multiple devices and easily change settings, passwords and privacy preferences (I11, I66). The design of smart technologies with in-built override functions was also described as important because they create a sense of empowerment for users and provide a reassurance that the system can be adjusted in the future if desired, even if the functions are never used (I11, I39, I66). To take one example, a user may wish to override a smart EV charger, programmed to begin charging whenever electricity is forecasted to be cheapest or rooftop solar generation highest, to charge their EV when it is needed immediately or unexpectedly (I48). Override functions were also described as important for allowing users to opt-out of automated features, such as auto-decision making and auto-optimisation updates. Lastly, the literature stressed that users should be able to have confidence around where the liability for optimisation errors fall, and that should such errors cause detriment or harm to them they will have access to appropriate and effective redress mechanisms [I40, I48, I52].

Overall, the review finds that autonomy will be a central factor driving the adoption of smart home technologies, but that users will require the option to manually adjust their systems if they would like to or if it is necessary for accepting new features or updates. Ultimately, communication will be key to enabling user understanding of, and engagement with, automation, and users will have to be fully informed regarding the levels of automation, optimisation, and decision-making their new technology or service would make and why. This will enable users to understand how smart technologies can meet their own personal priorities, needs, and preferences, and allow them to tailor the level of automation their system operates with accordingly.

Enjoyment and Pleasure

Hedonic feelings refer to the pleasant sensation that smart homes can create through feelings of enjoyment and serenity [22]. The joy generated by engagement with smart home technology creates a pleasant sensation [23], which then encourages householders to keep using it [22]. Smart devices used for home decoration such as automated mood lighting, automated water fountains, and entertainment systems create a pleasant aesthetic experience and an atmosphere of serenity [22]. The functionalities of devices that provide such sensory experiences generate an overall pleasant sensation [22]. Other than that, the functionalities of smart devices with different controlling features that require individuals to learn how to use them are perceived as fun and cool because such exploration is like allowing users to "play" with technology. In addition, the customisable features of the smart home energy management system enable users to configure their smart home settings according to their preference and are perceived as pleasant because they can make the system perform according to their desires.

User Comfort: Thermal Preference, and Sensitivity

Users' comfort in terms of thermal preference and sensitivity refers to the individuals' sensory satisfaction due to experiencing the ideal space temperature that is neither too hot nor too cold [34]. Based on the literature review, the emphasis on user comfort in smart homes indicates a strong influence of this factor on smart home adoption. Individuals have a high expectation that smart home technologies can bring living comfort to their daily lives at home, such as taking care of their thermal needs [33]. The sense of comfort is perceived subjectively. Still, it is usually closely related to the comfort generated from an intelligent heating system in smart homes. For example, in some cases, user thermal comfort is perceived by users when they can stand barefoot on warm tiles, and others may experience such comfort when they come back home to a warm space which was heated based on a defined schedule, without the need to wait or to employ manual control [33]. A smart thermal system integrated with sensing technology is designed to function with automated control settings based on users' consumption patterns to provide maximum thermal comfort [63].

'Likely Adopters' and Different User Groups

Certain user groups may be more or less likely to adopt smart home technologies, sometimes termed 'likely adopters'. From the academic literature side higher household income was found by some academic research to positively influence users' willingness and ability to pay for smart home technologies [29, 30, 38]. More affluent individuals were found to have a positive attitude towards adopting smart home technologies [30]. Academic research also identified higher levels of educational attainment and educational background more generally as a factor influencing engagement with and adoption of smart home technologies. This was described as due to them having pre-existing exposure to and knowledge of the energy efficiency benefits of smart technology [48]. Furthermore, individuals with a higher level of educational attainment may be more likely to express their pro-environmental beliefs and practise energy saving due to their pro-environmental intentions [48]. Finally, personal innovativeness was also identified in the academic literature as an openness to new technology and an attitude to risk-taking that was in many ways in contrast to technology anxiety. Findings suggest that personal innovativeness is of great importance when it comes to smart home adoption [48], and that individuals with higher personal innovativeness have

higher intentions to adopt smart home technology [26, 39]. This indicates that individuals with high levels of personal innovativeness are risk-takers, particularly in smart home adoption; even though they have never used smart homes before, they are open to taking the risk to live in and adapt to a new home concept.

When it came to the industry and policy studies, these also suggested the characteristics of users more likely to adopt smart home technologies. For example, with regard to the Smart Living Agenda in Wales, young people were regarded as most likely to support modernisation and various aspects of the low carbon transition [130]. Other studies found that younger Mums were a demographic likely to adopt smart home services and technologies, as well as consumers with complex needs such as those relating to mobility issues and learning disabilities [161]. Indeed, analysis across a range of demographic groups identified younger people and vulnerable groups as generally more positive about the benefits of smart home technologies [167]. Interestingly, even among those regarded as enthusiasts, or early/likely adopters, one study noted that the use of smart technologies changed over time, with more intensive use in the first four months, followed by a reduction in use and a shift to more simple uses once the capabilities had been realised [166]. This suggests that general use, even among likely adopters or enthusiasts, may shift fairly quickly to what could be considered basic use, and therefore users may miss out on the wider benefits of smart home technologies.

Research also reported that there may be reluctance amongst certain user groups to adopt smart technologies for various reasons. For example, households containing children may display reluctance to install technologies where it is perceived that they will have limited control over what the technology does and who has access to data (reflecting wider cyber security and privacy concerns amongst consumers both with and without children in the home) [110, 111, 124, 166]. Academic research also suggests that households defined as low-income and with lower educational attainment may be less able to use smart home technologies [32]. This raises the possibility, noted in other studies [122], that certain user groups may be excluded from being able to adopt smart home technologies because they cannot afford them or because they do not meet specific needs related to their socio-economic attributes, vulnerabilities, or household composition. The smart technologies sector should therefore consider the use of an enhanced definition of vulnerability, building on that used in Ofgem's vulnerable consumer strategy, as well as providing good practice guidance and recommendations when it comes to meeting the needs of vulnerable consumers in the context of smart devices and services. This would require engagement with third parties, such as third sector and local authority organisations, to understand and identify vulnerability types, as well as training staff to recognise and appropriately respond to consumer vulnerability and provide vulnerability-appropriate communications, advice and support at each stage of the customer journey (including post-installation follow-up) [134].



Support Networks and Communities

Engagement

A core theme across much of the evidence from the industry and policy review centred around the importance of engagement and what factors impact upon consumers' ability to effectively and meaningfully engage with the products, services, markets and policies related to smart homes. In one resource setting out a risk register for critical moments in the consumer experience of demand side response [I55] it was noted that engagement is not solely about consumers' unwillingness to engage, but also their inability to engage. The UK government's Smart Systems and Flexibility Plan (2021) has set out strategies for how government, industry and the regulator can best engage consumers in smart energy services and technologies. The Plan notes that:

"The market must deliver services and products that make it easy and rewarding for consumers to engage with energy and adapt their usage to support decarbonisation through offering information, support and services that provide benefits and value to consumers. No matter how they engage in the market, all consumers should pay fair prices for their energy as we transition to a smart energy system." [I4]

Understanding what constitutes effective engagement, as detailed in the Smart Systems and Flexibility Plan, draws on several factors discussed across the review as a whole thus far. Throughout, fairness is regarded as essential in delivering flexibility and smart energy systems, ensuring that fuel poor, low-income and/or vulnerable users are equally able to access and meaningfully participate in smart energy, including smart energy tariffs. Research has noted how customer inertia and low levels of energy market engagement are largely found among legacy prepayment meter households, who are often more vulnerable and disproportionately more likely to be living with a low income and in fuel poverty [I5].

However, to date there has been limited evidence on how fuel poor, low-income and/or vulnerable users can participate meaningfully in smart energy [I22]. Projects have been critiqued for typically trying to persuade such consumers to trial technologies and services, without attempts to find out what people want and design technology that is appealing and useful [I22]. As the report by Energy Systems Catapult notes: *"most projects do not follow what is often considered best practice innovation processes"* [I22]. The review, focusing specifically on low income and otherwise vulnerable (LIV) consumers, identified 6 risks that could emerge as a smart energy market develops:

1. LIV consumers may not be able to afford to purchase smart products and services
2. LIV consumers may not benefit from smart products and services
3. LIV consumers face greater risks if the product or service fails to work as expected
4. Lack of data access reduces how much LIV consumers benefit
5. Unequal distribution of system costs
6. LIV consumers experience problems that may impede the emergence of a smart energy market

It has been reported that it is essential that different methods of communication with householders be evaluated to better understand the different demographic groups that may need help and support, particularly among those who want to engage but cannot [I12]. Householders are often keen to engage, but that information also needs to be put into a meaningful context first – noting how what-if scenarios focused on behaviour change and energy/cost savings were particularly valuable in achieving this [I66]. In the context of supporting those in the rented sector, part of this involves building relationships with organisations such as housing providers and charities [I3]. Another report argued that there is a need for further research to better understand how to identify and use existing trusted social resources to effectively engage fuel-poor customers when it comes to smart home adoption [I13].

As noted, this can mean framing energy efficiency improvements and retrofitting, or the installation of smart homes, as valuable in terms of energy and costs savings, not in terms of achieving low carbon targets, for example. More practical and pragmatic in nature factors were deemed important for ensuring households are willing and able to adopt smart homes. For households experiencing (or at risk of) fuel poverty, being able to understand financial gains and considerations is critical, as is enhanced control, visibility, and mechanisms for paying for energy (i.e., easier topping up for prepayment meters). As noted elsewhere, effective and accurate installation – getting it right first time – is vital for ensuring users stay engaged in schemes and with the smart energy and/or water services and products installed [113]. The key drivers for engagement and adoption noted in the evidence review centre around saving money and feeling in control.

A key challenge running through all the identified literature on engagement is the importance of advice provision, or the question of who is considered to be the most appropriate source of advice about smart home technologies. This is considered in detail in the Advice, Information and Support section.

Advice, Information and Support

Across the majority of resources included in the review, a need for much more comprehensive advice and support for households was identified, particularly in terms of its potential to help people to be able to engage in the smart home transition and make the correct choices about what smart technologies will be most beneficial for use in their homes. A major factor in enabling households, specifically those considered vulnerable, to adopt smart technologies in the home will depend on the provision of accessible, timely and accurate advice from well-informed, trusted actors.

There were differences in how this was conceptualised, presented, and discussed between the academic and industry and policy strands of the literature. In the academic literature, the focus was primarily on experts and expert recommendations, the suggestions from skilled, trained and knowledgeable individuals (e.g., energy experts or energy providers) regarding the technical aspects of smart home technologies [39]. Given the nature of smart home technologies, which consist of technical features that not everyone has expertise about, research suggests that the emergence of smart home technology has increased people's reliance on experts as they require appropriate support related to smart home technologies [31]. Hence, for non-users, it is important that before they decide to use smart technologies, they get holistic insights and recommendations from experts, such as the technologies' life expectancy and maintenance. When it comes to the adoption of smart technologies, such as smart thermostats, people perceive that the advice from energy providers and experts is more valuable than recommendations from the people around them, such as family and friends [39]. The recommendations from experts contain technical statements that be more specific as in turn useful compared to the more general points of view shared by family and friends. In many European countries, expert recommendations are made available as a service that provides insights about smart technologies, emphasising energy efficiency through web-based platforms [39]. Such platforms enable people to get appropriate advice and insights about smart home technologies to guide their adoption process. The above also applies when it comes to post-adoption support. For smart home users, in the event of system error or faults, the right person for them to reach out to for support and advice will be the experts.

In addition to the above, the way in which product use is described to users is important. With regards to the development of advice and support schemes and services relating to smart home technologies, one resource noted how initiatives involving advice should include householders and consist of simple, clear messages connected to lived experiences and daily activities, routines and habits [166]. Situating and contextualising advice is, therefore, critical to its success, and therefore the effective adoption of smart homes. As set out in some of the industry literature, comprehension can improve with the use of icons and visuals to illustrate elements conveyed in product descriptions, and information and advice should therefore be provided in a variety of formats (i.e., visual, written, in different languages, non-technical, easy), with links to online resources, including instructional videos [142, 145, 146]. The need to ensure that advice and support should focus not only on the use of the smart home systems or technologies, but also the process of installation, and beyond to general



use and terminating use (if desired) has also been noted [I44]. Also, incorporating the opportunity to see the technology in action and talk to others who have lived with it/know about it was regarded as a particularly effective element in advice and support [I46]. Finally, tailoring messaging to local communities and characteristics can also increase the effectiveness of information provision. As such, a key finding across the review was that communicators should look to segment users and tailor messages and delivery methods accordingly [I13, I14, I36, I37, I39, I42, I45, I62].

Industry and policy literature focusing on those defined as fuel poor, low-income, and/or vulnerable demonstrates that trusted intermediaries are often best placed to communicate the benefits and opportunities of smart home technologies to these groups. This is because the findings suggest that simply highlighting the intended benefits of new smart technologies to households in a generalised manner may not encourage uptake amongst vulnerable households (for example, suggesting it will bring financial savings). Where households are fuel poor, for example, and/or experiencing financial vulnerability, they may already be under-consuming energy or engaging in practices to save money [I63]. As such, consideration needs to be given regarding the benefits such technology can bring to vulnerable consumers as well as working with government, third sector organisations and other relevant organisations to understand how technologies can be combined with other support initiatives to enable households to consume adequate amounts of energy appropriate to health and wellbeing needs in an affordable manner.

In particular, research suggested that the experience of frontline workers who support these groups with other issues means that they would be well placed to communicate the benefits and opportunities of smart technologies, as well as potentially supporting them through other challenges (like installation and use) [I1, I5, I12, I23]. This includes a need for local field officers, based in the area and who have good local knowledge and the ability to speak the local languages. However, many such advisors do not currently have the requisite understanding of smart home systems and technologies to be able to offer suitable advice. A barrier to uptake, therefore, is the need for upskilling within the sector [I1, I45]. The review found that there is also scope for manufacturers and retailers to build relationships with organisations likely to be advising vulnerable consumers, such as local authorities, third sector organisations, registered social landlords and housing associations [I3].

Where engagement takes place is also important: there is value in having a presence in community settings, both for providing advice and support about existing smart home technologies, and for communicating opportunities to trial new forms of smart home technologies [I3]. Research focused on the role of advice and support in the alleviation of energy vulnerability and fuel poverty has also noted the importance of targeting such support at opportunistic moments – or moments of change. A similar finding emerged from the review in terms of trigger points that are considered critical, or optimal moments for introducing smart home technologies. Moments representing a change in a customer's life – referred to as trigger points - might include house moves or renovation, for example [I27, I66]. This does not always necessarily relate to the use, with one study noting that a key trigger point in social housing is to work, where possible, on empty homes when fitting new technologies [I45]. Another study highlighted how awareness campaigns could specifically target 'moving home' as a trigger point for focusing messaging relating to the adoption of smart homes, especially when combined with associated offers [I27].

Taken together, this evidence suggests that while expertise is key, there is no simply defined actor or actors that is best placed to singularly provide advice to smart home technology users that will be consistently perceived as trustworthy and expert. Instead, it suggests that all stakeholders involved in the design, development, and installation of smart home technologies have a different role to play in delivering advice and information at different points of the customer journey, and that the most appropriate actor to advise any given user will be dependent on the user's specific needs, preferences, vulnerabilities, and their perception of what precisely constitutes expertise. For fuel poor, low-income, and/or vulnerable users, the evidence suggests that frontline workers who have pre-existing experience will be valuable advisors on smart home technologies, but only if they can be upskilled to provide this advice. More widely, the evidence suggests that energy providers, experts perceived to have no links to the product and weak ties to consumers, and independent websites will be important and trusted sources of information about smart home technologies. However, more research is clearly required to match different user groups with the actors that they will consider most trustworthy and expert.

Tenure Relations

An important theme relating to support networks and advice provision in the reviewed literature was the ways in which tenure relations will shape the adoption of smart home technologies. The literature suggests the adoption of smart home technologies will be shaped differently depending on the housing arrangements/agreements and key actors involved, e.g. landlords and social housing providers. This is because in these sectors the occupant of a home does not have complete agency over the decisions that are made regarding the adoption of different products, services, and technologies for that home. The enablers for smart home technologies in the private and social rented sectors will therefore be dependent on the relationships between landlords and tenants, which offers significant opportunities as well as potential barriers.

With regards to social housing, one study developed “*criteria for a smart thermostat designed for social landlords*” [16], which can be interpreted as drivers that shape the adoption of smart thermostats in social housing. Similarly to other factors discussed in this report, the study identified: upfront costs; the ease with which housing providers could install thermostats at scale in their stock; ease of use for the tenant; level of control offered to the tenant (e.g. the number of heating zones that can be controlled); the quality, granularity, and accessibility of data for the housing provider; the strength of security protocols; and interoperability (i.e. the capability of the thermostat to be compatible with other smart technologies that the housing provider might also wish to roll out in future) [16]. In addition to these factors, a second study identified the integration of different smart technologies through a central “smart box” as a critical factor shaping the adoption of smart, solar, and storage technologies in the social housing sector [18]. Finally it has been noted that social housing tenants living in energy inefficient properties were an effective proxy for identifying fuel poor households, thus enabling the adoption of technologies by tenants who had the most to gain from their energy-saving potential [13].

In addition to the above, two studies indicated that the presence of wider advice and support offered by the housing provider after installation was important to maintaining tenant satisfaction and preventing any potential rejections of the technology in the future [18, 116]. This included support to select an appropriate electricity tariff that could work optimally with their technologies (e.g., a Time of Use tariff), and broader energy-related advice delivered by a tenant liaison officer [18]. Further, one study highlighted the importance of ongoing advice to tenants, especially in housing where tenant churn is high:

“Good engagement is necessary with households provided with clear documentation on how the system works at the recruitment stage and installation. A handover pack with information about the system and its operation should be provided if a new resident moves in. Labels should be left on the battery and by the electricity meter. It is important to avoid the resident mistakenly switching from a time of use tariff to a single rate tariff.” [116]

In summary, the factors shaping the adoption of smart home technologies in the social housing sector are similar to, but not reducible to, broader factors identified in this report, and it is clearly vital to understand the needs of the landlord and tenant alike if adoption in this sector is to be successful.

In the private rental sector, one study examined the factors shaping the adoption and acceptance of smart heating controls in student-occupied houses of multiple occupation (HMOs) [120]. Energy use in student HMOs is often shaped by tenancy relations. For example, the inclusion of energy bills within rent paid to the landlord can encourage overconsumption of energy, but also that in HMOs, where energy bills were the responsibility of the student, underconsumption and energy rationing frequently occurred. The study concluded that three barriers exist to the adoption of smart home technologies in student HMOs: insufficient communications between student-tenants and their landlord, which contributes to an inertia around the installation of heating controls; a lack of behaviour change and awareness campaigns by universities to better educate students and landlords alike about sustainability and energy use inside the home; and a lack of knowledge among students regarding the potential benefits of smart home technologies for controlling and managing their energy consumption. The study recommended further research into these barriers and how to overcome them, as well as changes in communication practices between landlords, student-tenants,

and universities to encourage greater awareness of how to manage and control heating systems in student HMOs.

Finally, it should be noted that studies identified broader policy and regulatory drivers of smart home adoption in the social and private rental sectors, as discussed more generally elsewhere in this report. Specifically, one study noted that initiatives to install smart home technologies in social housing in Scotland was driven in part by the need to comply with the Energy Efficiency Standard for Social Housing (ESSH) [16]. Similar regulations exist across the other nations of the UK for improving the energy efficiency of social and private rental sector housing and quality assuring installations, and although two studies argued that these regulations are often insufficient to drive change and can even be barriers to successful adoption [11, 123], it is possible that such regulations drive the adoption of smart home technologies by landlords as they can contribute directly to improved energy efficiency.



Policy, Industry and Regulation

Government Policy

The importance of government policy and the regulatory landscape in smart home adoption was highlighted in both the academic and industry and policy literature. Evidence suggests that government policy and regulation will play a significant role in shaping citizens' adoption of smart homes [62], but only if strategies include effective government policies and regulation that remove barriers and encourage uptake. Specific policy and regulatory themes were identified in the industry and policy review: a) the use and security of data, b) regulation, complaints, and redress, c) the smart home market and marketing strategies, and d) brands and reputation. These themes are dealt with sequentially in this section.

Data - Use and Security

Several resources pointed out that one barrier to uptake of smart technologies and services relates to data use and perceptions regarding data security. Resources highlighted how customers often feel unable to trust how their personal information and data will be collected, stored or shared, as well as having doubts over the level of control that they themselves will be able to exert over their personal data and privacy. To reassure those with such data-related concerns, customers need to be enabled to provide informed consent, understand how and why their data will be used and in what ways (and with whom it will be shared) as well as being confident in their ability to control and opt out in relation to what data their devices collect and with whom it is shared [133, 135, 139, 167]. Control over one's own data is regarded as essential: people should be able to make choices about how their data is used, and solutions such as centralised data dashboards which would offer greater control over data should be provided [124].

In a study of different demographics of likely adopters, average consumers, and rejectors, the latter two expressed some or strong concerns regarding assurances related to data security and privacy [167]. Minimising the risk of data leakages [140] and breaches [167] and ensuring consumers, particularly those that are vulnerable, feel confident in this is a critical factor in the adoption of smart homes. Flexibility, as well as security, was also noted as important: having access to one's own data and being able to transfer this to a different company or third party was preferred, as well as being able to take technology to a new home [140].

Consideration should be given to how customers may experience smart devices and services. Considering real or potential violations of privacy norms, steps need to be taken to ensure use through the provision of clear, accurate and timely information at all points of the customer journey and by allowing customers to understand and control whether and which aspects of their data is shared and with whom (and to what purpose) [117]. While the review found that the most concerning data-related risks focus on not knowing what happens to data, vulnerability to cyber-attacks, and the risk of collecting too much (and arguably unnecessary) data, there were no striking differences found across the concerns of different demographic groups, e.g., those in different age brackets [167]. This suggests that data security and use is perhaps a key concern across user groups and therefore of significant importance in understanding what acts as an enabler or a barrier in the adoption of smart home technologies and services.

A study by Citizens Advice [167] found that people are actually more willing and comfortable to share a significant amount of data and are conscious that they already do so. Data that people are comfortable sharing includes: preferences, shopping lists, routines that are not linked to security, energy use data, and interactions with smart products. Data considered sensitive – e.g., data linked to finances, health, passwords, information about children, and private conversations – was deemed less comfortable to share. The study reported mixed views on opt-in versus opt-out mechanisms for data sharing, with some respondents stating that no data should be collected by default. To provide reassurance when it comes to data use and security linked with the adoption of smart home systems and products, steps need to be taken to ensure that users: are able to provide informed consent; are given transparency and control; understand what data is being collected and for what purpose; have awareness of how data is stored and protected, who it is shared with and why. However, research

has found that ultimately users find it hard to articulate what data protections they would like to see in place, linked to feeling disempowered and a need to better understand and be aware of consumer rights. [I67]

Regulation, Complaints and Redress

A focus on best understanding the consumer journey to a smart energy future is valuable framing to adopt, particularly in trying to identify and overcome risks. Breaking down this journey across several points in time was highlighted as important framing, with a need to interrogate the decisions, activities, data, and actors involved at different stages [I64]. As highlighted, consumer protections are required at several points, including the point of awareness/selection of new energy services, products or technologies, through to purchase, installation, first use, general use, to switching or upgrading, and perhaps most importantly, at the point at which technology may be removed or a service ended [I64].

Many of the resources reviewed noted the importance of appropriate regulation and legislation underpinning activity around the introduction of smart home systems and technologies [I1, I5, I24, I33, I39, I58]. This also stretched to a need for efforts to increase awareness of consumer and tenant rights, for example that all tenants need to be properly and fully informed of their right to refuse retrofit and/or the installation of smart home technologies [I46]. Another resource noted the role that industry will need to play in providing transparent, comparable and simple information about smart energy and water services and products to enable users to make the right decision for their circumstances, and how this has to be underscored by robust regulation to avoid consumers carrying any risk or related costs where suppliers or installers fail [I39]. There was a general consensus that future regulation should include the setting of standards for communicating information to customers, as well as customer protection [I12, I41]. In addition, manufacturers, designers and retailers should have access to centralised repositories and mechanisms for sharing data and best practices in innovation which are also human centred to avoid duplication of effort and replication of findings as well as inconsistency/inadequacy of implementation [I22, I27, I31, I52, I54]. More widely, a code of conduct for the industry in terms of customer interaction is required [I28]. Beyond general consumer protection and regulation, studies highlighted that the needs and ability to pay of fuel poor, low-income and/or vulnerable users should be taken into consideration at each stage of market development and regulation, from product design and testing to service and contract provision.

Independent advice and redress for when things go wrong was a common area of focus and noted as a critical aspect of the policy and industry landscape to be addressed [I12, I23]. One resource noted how accreditation schemes should include a requirement to provide redress to households if and when installations do not meet the required standards [I1]. Research also highlighted how households, especially vulnerable households, should not be subjected to any pressure with regards to the acceptance and adoption of smart home technologies, such as smart meters, and this needs to include information on rights and redress [I3]. In the UK, there is a key role for government and the regulator in taking steps and communicating to people that action will be taken against scams, that standards will be monitored and enforced upon the industry, and that trusted redress routes will be in place where failings occur [I27]. One resource argued for the need for a single body to be accountable and responsible for the delivery of quality assurance in this sector [I27].

Where redress is required, it should be prompt and effective [I40]. Users should be able to unbundle or withdraw completely from services and systems, access their own data (as discussed) and be able to keep or transfer data or technology when they move home [I40]. In a study of vulnerable older Australian households [I67], it was found that, when things go wrong, consumers expect a mix of support and redress functions that consist of technical fail-safes and interactions with humans. Ultimately, however, consumers believe education on smart technology is needed to avoid problems occurring in the first place [I67].

The Smart Home Technology Market and Marketing

The UK's 2021 Energy White Paper sets out a plan for the energy future of the UK, with specific consideration of the market framework changes that may be required to facilitate the development and uptake of innovative and smart tariffs and products that work for consumers and contribute to net zero [161]. This highlights the importance of the smart home market and the role of government and regulators, as well as industry, in ensuring that the market is appropriately set up to work for all consumers in a fair way.

There were a small number of studies that discussed the importance of the smart home market and specifically marketing functions and approaches. In the context of energy vulnerability, this means ensuring that smart home products and services are marketed fairly and are not misleading to consumers with regards to function or performance (i.e. energy or costs savings). One study focused specifically on the analysis of marketing materials and product reviews for smart home technologies and services [137]. Eleven themes were drawn from the analysis, which examined the potential benefits of smart home products in marketing to consumers. These themes provide a key insight as to the important factors in fair and transparent marketing of smart homes, and included considerations of: control and empowerment; comfort and relaxation; convenience, ease of use and effortlessness; energy and cost saving; security, peace of mind and disaster mitigation; individualisation and personalisation; ease of set up; intelligence and smartness; automation as essential; emerging technologies as a path to future possibilities; and, instances where technology needs more development [137].

Other studies highlighted the importance of considering the ways in which smart products and services would be bundled together and sold as packages to customers. It is important that different combinations of smart tariffs, smart appliances (which are able to shift electricity consumption to different times of the day, for example), and smart services are provided to suit and meet the needs of different user groups, including those defined as fuel poor, low-income, and/or vulnerable. This would ensure that different user groups are not prevented from accessing the best deals or services due to exclusionary product/service/tariff (as well as avoiding the risk that they become de facto locked into the most expensive tariffs and services due to the unsuitability of available smart options to their situation [14, 15, 113]). The suitability/unsuitability of available bundles and packages for different lifestyles, routines and requirements therefore should be communicated clearly and upfront to make it possible for consumers to make an informed decision [14]. Where technologies and/or bundles involve contracts, customers should have the ability to and knowledge/confidence that they can exit a contract before the contract ends, that fees will be waived if service does not meet the promised standards, that unfair contracts will be investigated promptly, that contract comparison tools will be accredited and trustworthy and that there will be clear pathways to advice and redress [124, 131, 164].

Finally, studies emphasised that the market needs to be transparent at each stage of the customer journey regarding software licensing issues relating to technologies purchased and owned by customers. Where usage, loan and repair rights over a product could be disrupted due to software ownership concerns, this needs to be made clear to customers whilst adequate consumer protection and right to redress also needs to be put in place. Regulatory bodies need to ensure that, as the market develops, it is both transparent and accountable in order to protect consumers and build trust [133, 139].

Trusted Brands and Reputation

As well as the importance of working with and adequately equipping and supporting trusted intermediaries, trust in relation to the products and brands was noted in the review as important for adoption. For example, one resource detailing the analysis of a large-scale survey with consumers during Smart Home Week found that there is a preference for smart home technologies from technology giants, such as Google or Samsung, identified as leading tech brands [168]. Interestingly, government-endorsed kitemarks (such as the Trustmark) were found to have no real impact on



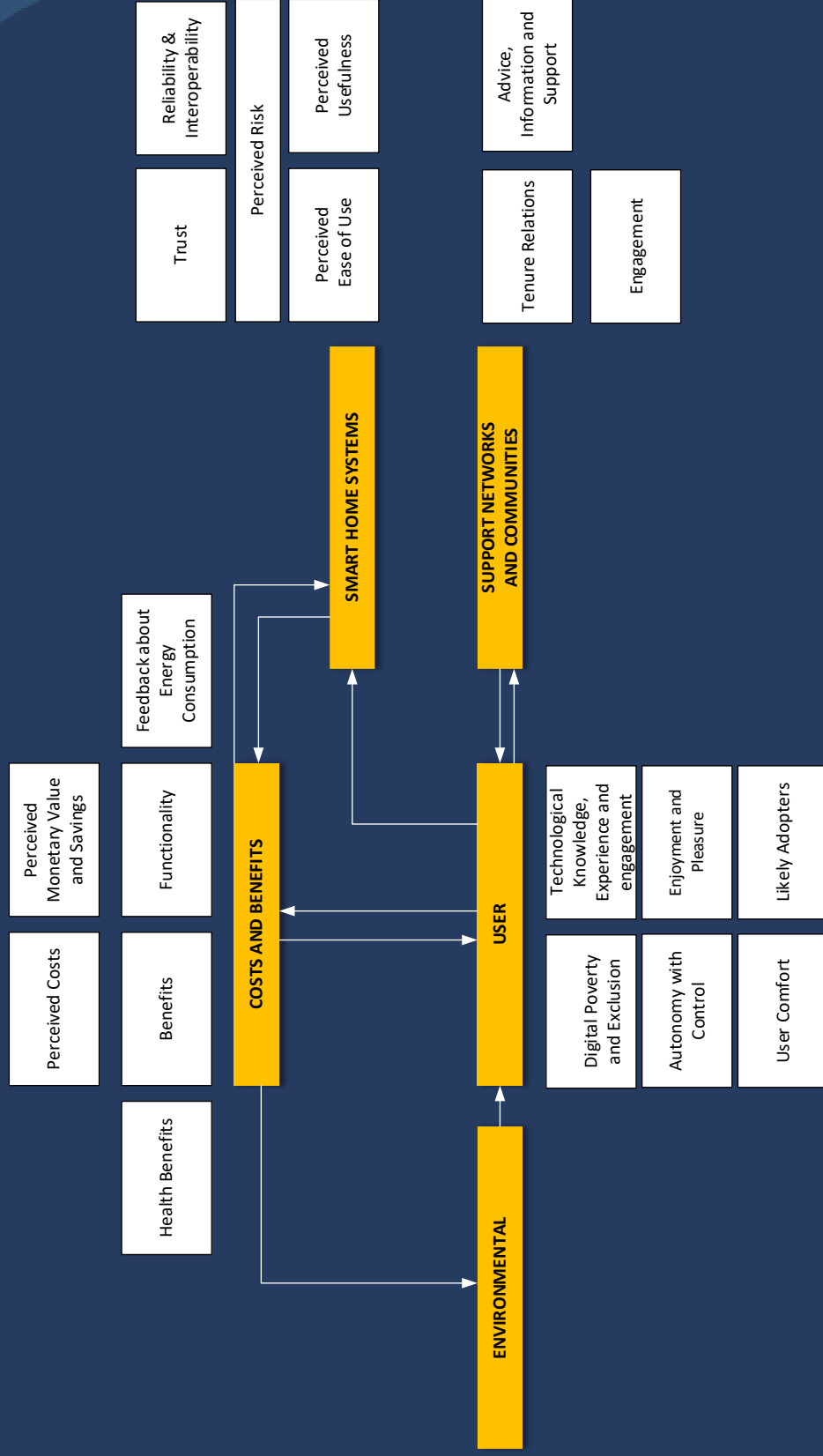
The Adoption Framework

The framework synthesises and maps the factors identified during the review. At a high level the framework includes five main pillars of smart-home technology adoption regarding energy management (yellow boxes). At a more specific level, the framework presents the factors (white boxes) that sit under each pillar. As the literature review also highlighted the importance and complexity of the policy landscape, this is presented in the framework as an overarching pillar (blue box). There are multiple interactions, discussed below, between these pillars, which concomitantly influences the user's evaluation and adoption of smart home technology aimed at energy consumption reduction. Specifically, we have identified the following pillars: 1) cost and benefits; 2) environmental; 3) user; 4) support networks and communities; and 5) smart "home" system.

The Environmental pillar of the framework assumes that there is a series of factors such as pro-environmental beliefs, personally gained knowledge or that from expert recommendations, degree of automation in smart green technologies (i.e. adjustable green defaults) which will influence the understanding and adoption of smart home energy-related technology. The environmental pillar has a substantial effect on the User pillar of the framework, in the sense that the environmental factors can act as drivers or barriers and shape the users'/consumers' views and behaviour. As shown in the framework, the User pillar comprises several psychological factors that will dictate how consumers evaluate, adopt and interact with smart technology. This pillar also signals that specific consideration should be given to vulnerable categories of consumers (e.g. the elderly, the less digitally literate, the disabled) for which smart technology might not be well understood or welcomed initially. Equally, attention should be paid to how user profiles/customer segmentation (beyond standard demographic profiling variables) are developed from the early stages of innovation development through to adoption and implementation.

As next shown in the framework, the User is part of and interacts with (in a two-way process) Networks and Communities, another main pillar. This pillar is critical to supporting the individual user with advice and information, with the implementation of smart energy technology in homes, as well as enhancing the inclusion of vulnerable users and promoting the co-design of useful and meaningful smart home technologies. Another adoption pillar highlighted by the literature relates to the Smart Home Systems. Consumers/users tend to evaluate the Smart Home Systems in terms of perceived usefulness, ease of use, risks and reliability. The higher a system scores on these dimensions, the more likely that a consumer will adopt a certain smart energy technology.

The final pillar presented in the framework is labelled as Costs and Benefits and is one of the most discussed categories both in the academic and industry strands of the literature. This pillar captures consumers' perceived benefits and costs of adopting smart technologies in their homes, the perceived monetary/economic value, as well as the functionality and feedback provided by the technology considered for adoption. As illustrated by the framework, the Costs and Benefits pillar interacts with/influences other main pillars such as the User, Environmental and Smart Home Systems.



POLICY, INDUSTRY AND REGULATION

- Government policy
- Data: Use and Security
- Regulation, Complaints and Redress
- The SHT Market and Marketing
- Trusted Brands and Reputation

	Awareness	Persuasion	Decision	Implementation	Continuation
Costs and Benefits	<p>What does it do?</p> <p>How many devices do I need to create a smart home?</p> <p>How much will it cost me in total?</p> <p>How much will it save me?</p>	<p>What difference will this make to my daily life?</p> <p>Will my house still be warm?</p> <p>Can I trial smart home devices?</p>	<p>Can I afford it?</p> <p>Can it cover all my needs and requirements?</p>	<p>Do I have to install it on my own?</p> <p>Are there any installation costs?</p> <p>Is there going to be a lot of upheaval to install it?</p>	<p>How much does it cost to run?</p> <p>Am I seeing savings on my bills?</p>
Smart Home Systems	<p>Is it a scam?</p> <p>Can I trust the vendors?</p> <p>What kind of devices exist?</p> <p>Can different devices work together?</p> <p>What will happen to my data?</p> <p>Is it better to buy devices from the same vendor or different ones?</p>	<p>Do I know other people who use this?</p> <p>Is it straightforward to use?</p> <p>Can it do everything I need it to do?</p> <p>Will it be as reliable as my current system?</p> <p>Which platform is better for me?</p>	<p>Do I still have overall control of the system?</p> <p>Will I get a return on my investment?</p> <p>Does it do everything my current system does?</p>	<p>Is it difficult to program/ learn to use?</p> <p>Is it interoperable with other appliances in my home?</p> <p>How do I learn how to use the system for maximum gain?</p>	<p>Is it working as it's supposed to?</p> <p>How can I adapt or extend the system?</p>
The User and The Home	<p>Is there something missing or something that could be improved in my home?</p>	<p>Can it be fitted in my home without causing too much disruption?</p> <p>Will it fit with my current routine?</p>	<p>Do members of my household support the idea of implementing a smart home?</p> <p>Does my landlord have to say yes?</p>	<p>Can everyone in my household use it easily?</p>	<p>What happens if I move house?</p> <p>Can I take it with me?</p>
Environmental	<p>How can I contribute to fixing climate change?</p>	<p>Will this really make a difference to my carbon footprint?</p>	<p>Do experts on environmental issues recommend this product?</p>	<p>Will it always be efficient, or only if I use certain settings?</p>	<p>How do I know it's still working effectively?</p>
Support Networks and Communities	<p>Is it recommended by my support networks/ community groups?</p> <p>Are there examples of how things could work in similar cases to mine?</p>	<p>What does my landlord/ housing association (etc.) think of it?</p> <p>Was it co-designed by people with similar needs to my own?</p>	<p>Are those in my community who use smart homes satisfied with them?</p>	<p>Can relevant communities support me if I have a problem with the installation or using the system?</p>	<p>Who do I contact if it stops working?</p> <p>How easy is it to remove everything?</p>
Policy, Industry, and Regulation	<p>How does me having a smarter home help the bigger picture?</p>	<p>Are there Government/ Industry schemes to help me access these technologies?</p>	<p>Are there any subsidies available to me to pay for it?</p>	<p>How can I be sure the installers are trustworthy and will do a proper job?</p> <p>Who do I speak to if they leave the job incomplete?</p>	<p>What happens if something goes wrong? How do I get my issues resolved?</p> <p>How can I make a complaint?</p>

Recommendations

Cost and Benefits

As monetary benefits and/or savings vary significantly dependent on many factors (including property type and customer behaviours), organisations involved in the development, sale, and installation of smart home technologies should ensure they also emphasise additional, non-financial, benefits, in areas such as health, wellbeing, and convenience. These benefits should be provided alongside an honest assessment of the known risks by property type and personal circumstances, specifically those relevant to vulnerable groups, and should seek to combine the technologies with other support initiatives where possible, to maximise the benefits and mitigate any risks. Vendors could provide a consistent impact calculator that can help users assess the financial and environmental savings.

Recommendation 1: Both financial and non-financial benefits of smart technologies should be presented to the customer/user, alongside an honest assessment of the known risks, at all points of the adoption journey.

Smart Home Systems

The functionality of smart home systems should not just be high to encourage adoption, but should be accompanied by appropriate controls and safeguards to allow tailored use dependent on individual needs. Systems should be easy enough for users to make the most of the functionality irrespective of their digital skills/experience. This recognises the various motivations consumers may have when considering smart home technologies, alongside any individual limitations and/or risks.

Recommendation 2: High functionality of smart home systems need to also be accompanied by appropriate controls and safeguards to allow tailored use, dependent on individual needs.

Smart homes may appear more attractive to consumers if they are built with flexibility to enable users to use the technology, and any interoperable devices, according to individual needs and preferences. Particularly where interoperability is required for managing health and/or wellbeing needs, consumers need to have the reassurance that the technologies will not detrimentally impact on the use of their other systems and appliances.

Recommendation 3: Smart home systems should be built with flexibility and interoperability, with added reassurance that health and wellbeing needs will not be detrimentally impacted.

Smart technologies should be designed by meaningful inclusion, designed *with*, not *for*, users. Including different user groups with ranging needs and barriers makes it possible for the resulting product to be accessible and attractive to a wider range of consumers, and provides reassurance that it is more likely to meet complex needs. Where the technologies being designed are health-based controls, these should also be designed with health-care professionals, to ensure that both quality and continuity of care take precedence.

Recommendation 4: Manufacturers of smart home technologies should follow the principle of inclusion by design and ensure that their products are designed with users to address a wide range of needs and barriers.



The User and the Home

Digital barriers, such as lack of Internet access or poor-quality connections, should not be deemed to be ‘final’; these barriers can be overcome with other actions, including linking access schemes such as telecoms social tariffs, or through the use of mobile connections. Organisations involved in the development, sale, and installation of smart home technologies should therefore have a strategy to engage with users experiencing digital exclusion and/or technology anxiety, implementing appropriate mitigating actions to improve accessibility.

Recommendation 5: Organisations should have a strategy to engage with users experiencing digital exclusion and/or technology anxiety, implementing appropriate mitigating actions to improve accessibility.

Environmental

Although the environmental benefits of smart home technologies are often used in marketing to attract “green” consumers, it is recognised that these are not always the primary motivation for a purchase. Without appropriate education and guidance on the most effective application, technologies may not always work in the most efficient manner. The adjustable/dynamic green defaults, therefore, are important to provide continuous reassurance to users that the default settings will work in the most efficient way possible, saving carbon and money on bills, and that the software will encourage users to become more efficient through machine learning, behaviour nudges, and small adjustments to levels of comfort over time.

Recommendation 6: Manufacturers should provide reassurance that the “adjustable green defaults” will work in the most efficient way possible, and that software will encourage users to become more efficient through machine learning, behaviour nudges, and small adjustments to levels of comfort over time.

Support Networks and Communities

Advice and education play a significant role in the successful continuation of smart home technologies. Users, particularly vulnerable users, need to have suitable support networks available to them to help them with the initial stages (post-installation) and the ongoing use of their smart home systems. This support, advice, and education should be able to be accessed via multiple sources. For example, while online resources are useful to many, they may not be suitable for those with low digital or literacy skills. Messaging therefore needs to be clear and simple to understand, and available via multiple mediums. This should include frontline workers, and installers, who should be upskilled to deliver advice to those requiring additional support post-installation.

Recommendation 7: Frontline workers and installers should be trained to give appropriate advice and education to users before, during, and after the installation of smart technologies. This advice should be accessible and tailored to the specific needs, preferences, and vulnerabilities of each user.

Low-income and/or vulnerable groups are often considered “hard to reach” and can be more challenging to engage via traditional engagement methods. Often, engagement is most successful via trusted advice providers, or third-party groups. Given the requirement to fully understand the functionality of smart home technologies, further research to understand the optimal matching of different user groups with the actors they trust most will be extremely beneficial to achieve the maximum value from smart home technologies.

Recommendation 8: Further research should be undertaken to better understand the optimal matching of different user groups to the advice providers that they are most likely to consider trustworthy and expert, and appropriate support needs to be offered to maximise the value of smart home technologies.

Policy, Industry, and Regulation

Effective Government policies and schemes can both raise awareness of smart home technologies, and their benefits, and make these technologies accessible to fuel poor, low-income, and/or vulnerable users, who are likely to benefit substantially from these interventions, but who may be unable to afford the upfront costs without additional support through grants, subsidies, and other schemes.

Recommendation 9: Government policies need to consider the accessibility of smart home technologies for fuel poor, low-income and/or vulnerable users to ensure they are not left behind and can fairly access the benefits these technologies can provide.

Users require full disclosure on how their data will be used and kept secure, alongside reassurance regarding their personal privacy, in line with all applicable data regulations. This should be honest, accessible, comprehensive, and easy to understand, with clear routes for escalation and queries.

Recommendation 10: Data security and privacy statements should adhere to data protection regulation(s) and be provided at all stages of the smart home process in an honest, accessible, comprehensive, and easy to understand manner.

Future regulation should include the setting of standards for communicating information to customers, customer redress, a code of conduct for customer interaction, and the sharing of good practice. With multiple vendors offering a wide range of smart home solutions, there is a risk of miscommunication and mis-selling to gain customers and market share. This cannot be allowed to happen as the market grows, and appropriate regulations can limit this.

Recommendation 11: To mitigate the risks of miscommunication or misselling in a growing market, future regulation need to include standards for communication, customer redress, a code of conduct for interacting with customers, and the mechanism to share good practice.

The smart technologies sector should consider the use of an enhanced definition of vulnerability, building on that used in Ofgem's vulnerable consumer strategy, as well as providing good practice guidance and recommendations when it comes to meeting the needs of vulnerable consumers in the context of smart devices and services.

Recommendation 12: As a participant in the energy industry, the smart technologies sector should adopt an enhanced definition of vulnerability to ensure that no products or services detrimentally impact consumers.

Other Recommendations

The framework outlined in this report provides a starting point for organisations to consider both the barriers and enablers consumers face when considering the adoption of smart home technologies. Further development of this framework is recommended, through testing with a range of stakeholders and users, to ensure the factors identified are accurate, and appropriate solutions are identified. Questions from the point of view of the user have been provided to demonstrate how the framework could be used, but this is only one viewpoint. Further research could expand these questions further, to allow for a different view dependent on the stakeholder type and motivation. For example, a set of questions for manufacturers to consider would ensure that their development process learns from past trials and research, and does not repeat mistakes, but instead learns from best practice.

Recommendation 13: The framework should be further developed through stakeholder and user testing, to ensure that the identified factors are accurate and appropriate solutions are proposed.

