# *Motivations, barriers and risks of smart home adoption: From systematic literature review to conceptual framework*

**Motivations, Barriers and Risks of Smart Home Adoption: From Systematic Literature Review to Conceptual Framework**

**Abstract:** Smart home technology provides a suite of independently and remotely controlled software and hardware that are connected into a network to deliver smart living. Smart homes have immense potential to shape the future living, and the market is maturing, but factors influencing households' adoption of smart home technology services are still an understudied area. The study aims to identify the prominent smart home technology services and generate an understanding of the motivations, barriers, and risks of adoption from a consumer perspective. The paper reviews the literature and builds a conceptual framework of smart home adoption. The findings disclose: (a) Prominent technology services are associated with healthcare, energy efficiency and home security; (b) Primary motivations to adopt smart home technology services include efficient energy management, better home-based healthcare services, potential financial savings and benefits, and enhanced quality of life; (c) Main barriers to the smart home adoption include the distrust and resistance, limited perception of smart home, concerns of financial issues, privacy and security concerns, technology anxiety and negative social influences, and; (d) Main risks include privacy and security threats, energy rebounds and wasteful consumption, difficulty in the domestication of technology and destructiveness in domestic life.

**Keywords:** smart home; home automation; domotics; smart living; Internet-of-Things (IoT); technology adoption

## 1. Introduction and Background

With the rapid development and advancement of digital technologies—concerning the smart city movement, especially in the areas of computer, communication, network and control, new urban technologies have permeated in people's lives and changed their lifestyles [1,2]. In recent years, the term 'smart home' has frequently appeared in major media and has become a well-known term. There are also a number of alternative terms used interchangeably with smart homes, such as electronic homes, digital homes, home automation, domotics, connected home and so on. One of the goals of home technology services is to serve the needs of people, improve their quality of lives, and improve efficiency in their homes—in terms of energy use, surveillance, and the like [3,4].

The concept of smart homes is to utilise residence as a platform, integrating life-related facilities and devices via taking advantage of a range of techniques including wiring, computers, network service, automated control, security systems, and multimedia to build a smart and efficient residential facility [5]. With the adoption of internet-of-things (IoT) technology, smart homes integrate hardware, software systems and cloud computing platforms to build a smart home ecosystem. Finally, through the collection and analysis of user behaviour data, smart homes provide users with personalised life services [4,6]. The goal of smart homes is to provide users with security, convenience, comfort, energy efficiency and entertainment and to improve their quality of life in their residence [7,8].

To date, a broader wave of 'smart living' is sweeping through the world, which is driven by the rapid development of IoT and new technological innovations such as 'artificial intelligence' (AI) [9]. This kind of 'smart living' is highly popular among the younger generation and their increased willingness to adopt smart home technologies promotes the growth of the global smart home industry [10]. According to the 2020 Global Smart Home Forecast report released by the research organisation Strategy Analytics in June 2020, consumers' expenditure on smart home-related hardware, services, and installation would have reached US$89 billion in 2020. Furthermore, by 2021, the related spending on the smart homes will increase to US$120 billion and continue to grow at a 14% CAGR to US$175 billion by 2025. The report forecasts that there will be nearly 390 million homes worldwide, or 19% of all households, installed with at least one type of smart home system by 2025 [11].

In today's smart living era, diversified emerging technologies have been increasingly integrated into architecture-related projects [12]. Benefitting from the advancements of IoT, people's expectations regarding the smart home and its related services are continually expanding, expecting the offered capabilities to change their daily lives. Existing literature showed that the adoption and integration of smart homes technologies have grown exponentially over the last decade in a broad range of sectors, including healthcare, energy management and living environment. The decreasing cost of smart devices and the availability of integration systems made smart homes able to extend in various aspects [13]. For example, Carnemolla [14] indicated that smart technologies and IoT have the potential to support the elderly to age in place. The author conceptualised smart home technology interaction with the built environment via the Environmental Gerontology model and verified the role of technology in supporting 'ageing in place'. Choi et al. [15] presented a platform regarding elderly home-based care, which was formed by the fusion of healthcare services and IoT technology in residence to support ageing in place in the existing rapidly aging society. Lately, Lee & Park [16] developed a framework of smart home services providing biophilic experiences to older residents for the optimal health and well-being, which promotes the sustainable living among the elderly in the context of ageing in place.

In the energy management sectors, Paetz et al. [17] indicated that smart home technology services do have the potential to reduce household energy consumption. The authors conceived of a smart home scenario that combines variable electricity tariffs, smart meters, domestic appliances into the smart home system to improve household energy efficiency and reduce consumption. Subsequently, Ringel et al. [18] verified the expected energy saving can be achieved through smart home energy management technology and found the smart home solution can provide sizable benefits in multiple domains such as resources, economic, social, and environmental. Beyond the above, Dahmen et al. [19] and Pandya et al. [20] focused on the security monitoring and threat detection technology and approaches in smart home to ensure the safety of properties and occupants.

With the growing interest in smart homes, the number of academic publications on the topic has been rapidly increasing over the recent years. In that regard, a systematic literature review is an efficient methodological approach for extracting insights and analysing relationships among existing research on an emerging research topic such as smart homes [21]. Hitherto a number of systematic reviews on smart homes has been published on academic journals. For instance, Marikyan et al. [22] produced a systematic review of 143 academic articles from a user perspective and focused on presenting the definitions and characteristics of smart homes, discussing the types, services, and associated benefits of smart home, outlining the current state of smart home application, and identifying the barriers and challenges to smart home implementation. Other review articles have examined the specific smart home technology services such as ambient assisted living (AAL) [23], energy management technologies [24], AI and IoT in homes [25], elderly care technologies [26, 27], elderly monitoring technologies [28], and intelligent voice assistants (IVAs) [29].

Although the number of publications related to the smart home topic is increasing, the existing research is still limited to the domains of technological advance, application prospects and constraints, and adoption intention of technologies. Additional review studies are needed to clearly capture the new knowledge produced in this growing field of smart home and to fill the remaining research gaps. To deepen the understanding of motivations, barriers, and risks of smart home adoption is the aim of this systematic literature review. Moreover, the present paper develops a conceptual framework outlining specific motivations and barriers that impact users' adoption intention and the risks arising during users' daily usage. This paper also highlights the prominent smart home technology services, which may assist researchers, policymakers, and planners to generate a consolidated understanding on the potential for these technology services to shape the future of cities and societies.

## 2. Research Design

This study undertakes a systematic literature review to address the following research question: 'What are the main smart home adoption motivations, barriers and risks?' Based on the previously conducted systematic literature review work, such as Yigitcanlar et al. [30] and Butler et al. [21], a three-stage procedure has been adopted in this study as the methodology—i.e., Stage 1 (planning), Stage 2 (review), and Stage 3 (reporting).

In the planning stage (Stage 1), the research objective (that is to address the abovementioned research question), keywords, and the criteria of exclusion and inclusion were developed to form the research plan. The research objective was framed to identify the prominent smart home technology services and examine the motivations, barriers and risks for smart home adoption. Therefore, 'smart homes', 'home automation', 'domotics' and 'adoption' were chosen as the search keywords. The selected keywords were searched across article titles, abstracts, and keywords of available publications via an academic search engine that connects to over 390 different bibliographic repositories, including Directory of Open Access Journals, Web of Science, Wiley Online Library, Scopus, ScienceDirect. The inclusion and exclusion criteria were developed (Table 1), which can help effectively select suitable articles and reduce the number of publications.

**Table 1:** Exclusion and inclusion criteria

| **Primary criteria** | | **Secondary criteria** | |
|---|---|---|---|
| **Inclusionary** | **Exclusionary** | **Inclusionary** | **Exclusionary** |
| Academic journal articles | Duplicate records | Smart homes and adoption related | Not smart homes or adoption related |
| Peer-reviewed | Books and chapters | | |
| Full-text available online | Industry reports | Relevance to research objective | Irrelevant to research objective |
| Published in English | Government reports | | |

In the review stage (Stage 2), PRISMA approach was adopted to systematically provide the transparency for data collection. The literature search task was conducted in December 2020. As smart home technology services mostly gained their popularity during the last two decades and the adoption picked up during the last decade, the search task covered the articles published between January 2010 and December 2020—although an initial search with no time limits was conducted to check the suitability of the above-mentioned time period. In the search task, the selected keywords, i.e., 'smart home', 'home automation', 'domotics', and 'adoption', were used to identify articles that contain the adoption aspect of smart home technology services. The query string of ("smart home" OR "home automation" OR "domotics" AND "adoption") was used for searching across article titles, abstracts, and keywords in the databases. Initially, the search returned a total of 1,072 articles based on the primary criteria. After reviewing article titles and abstracts based on the secondary criteria, the number of relevant articles was reduced to 127. To ensure the comprehensiveness and validity of selected articles, a repeated review task was conducted. During this stage, additional articles (n=30) relevant to smart home was re-selected. Lastly, an evaluation of relevance, consistency, and reliability was undertaken for the full text of 157 articles. The evaluation has led to the selection of 72 articles.

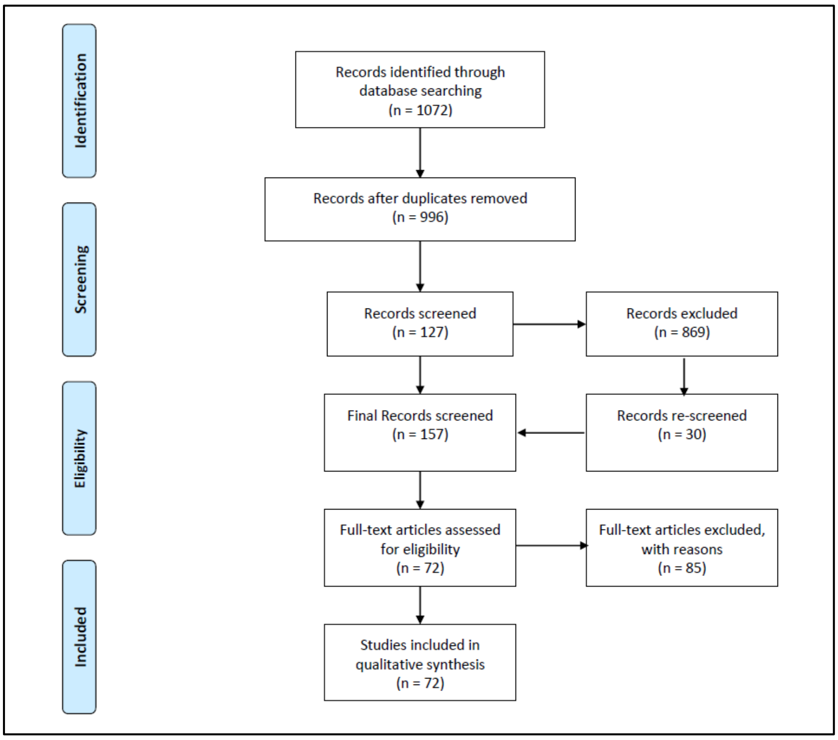


**Figure 1:** Literature selection procedure

In the reporting and dissemination stage (Stage 3), a qualitative analytical approach has been applied to sort the selected articles into specific categories, i.e., pattern matching and explanation building via eye-balling technique. In accordance with the earlier mentioned academic studies using the systematic literature review technique, the eye-balling technique was used to scan for commonalities and disparities of the selected articles, which is sufficiently convincing to draw a conclusion or categorisation [21,30]. Then, the selected 72 articles were reviewed and classified into specific themes via the four-step process. Thereinto, nine articles covering multiple themes are classified under multiple categories. Lastly, through the cross-check with the other review studies and the verification of themes, the selected articles were finally classified under four categories: 'prominent technology services' (n=16), 'motivations for adoption' (n=19), 'barriers to adoption' (n=27), and 'risks of adoption' (n=19). The criteria for categorisation were developed and shown in Table 2. The categories of those selected articles are presented in Appendices A-D.

Finally, the findings of this study may be influenced by the following limitations: (a) Methodology was undertaken based on the qualitative methods without any automated analysis techniques; (b) Selected keywords may not cover all articles relevant to the research objective; (c) Literature selection criteria include online and peer-reviewed academic journal articles; the finding may omit some additional insights from other literature, such as conference papers, books, industry articles, and other forms of grey literature, and; (d) Unconscious bias of authors may influence the finding of this study.

**Table 2:** Categorisation criteria

| **Criteria** |
|---|
| 1. Identify the key issues associated with smart homes via the eye-balling technique in the literature |
| 2. Determine the prominent technology services relevant to smart home in the selected literature |
| 3. Ascertain the motivations to adopt smart home technology services |
| 4. Detect barriers associated with the adoption of smart home technology services |
| 5. Define potential risks of smart home technology services that may appear on the adoption process |
| 6. Arrange the identified motivations, barriers, and risks with similarities to form broader potential categories |
| 7. Narrow down categories and crosscheck consistency and reliability of categories against other published literature |
| 8. Final review of selected and reviewed literature and reconsider the refined categories |
| 9. Validate the selection and classification of categories and finalise the creation of categories |
| 10. Classify the reviewed literature under the determined and most relevant categories |

## 3. Results

### *3.1. General Observations*

Based on the statistical data extracted from the reviewed articles (n=72), the number of publications related to smart home adoption is increasing over time, reflecting the growing interest in this topic among researchers. Specifically, only one article was published in 2012, then two articles were published in 2014 and 2015, 6 in 2016, 10 in 2017, 17 in 2018, 16 in 2019, and 18 in 2020. Europe and Asia are the leading regions with 24 and 22 publications, respectively, reflecting the fact that academic institutions and researchers from these two continents have significant interests in this topic and have conducted user or consumer-based surveys. The reason might be the criticality of smart home technologies for energy sustainability was receiving increasing attention in the energy strategy and academic circles across European countries due to the threat from climate change and the concerns of the uncertainties in energy supply. Moreover, as the issue of rapid aging population appears in some East Asian countries such as in Korea and Japan, the academic communities from these countries increasingly focus on aging societies' solutions achieved by IoT and smart home technologies. With the rise of the IoT, the application of smart home technologies was becoming more and more widespread, and relevant studies have increased observably worldwide. Figure 2 shows the distribution of publications on smart home adoption during the last decade, including the publication year, number, and world region. The increased numbers of relevant publications after 2017 in North America (n=17), Oceania (n=7), and the Middle East (n=3) reflect the arising interest among these regions.

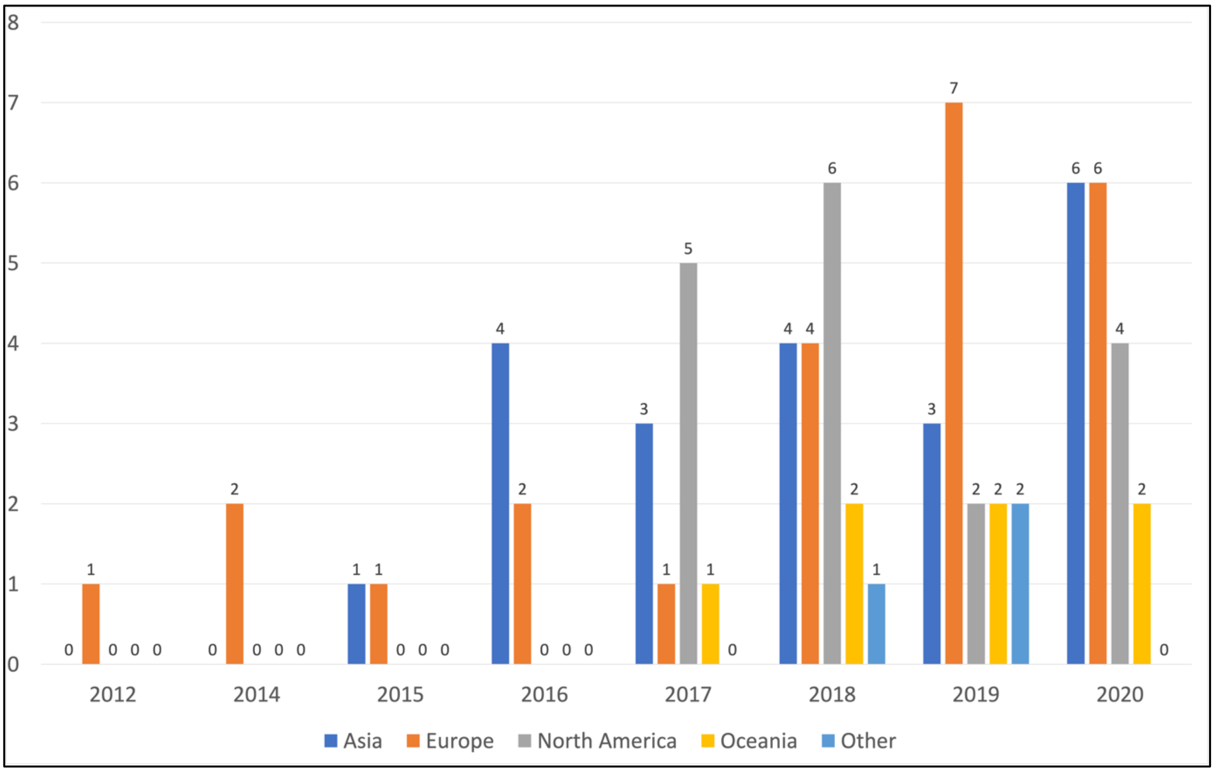


**Figure 2:** Publication distribution by year and region

Given the prominent smart home technology services are associated with domestic services, energy efficiency, and healthcare, three-quarters of the publications (n=54) focus on these three areas, with 30% (n=20) in living environment, 29% (n=19) in the energy management, and 23% (n=15) in healthcare (Figure 3). The categories of research areas were developed based on a previous review study of smart home literature by Marikyan et al. (2019). The selected articles (n=72) were reviewed and classified into each category. The journals that focused on energy and social science with a relatively higher number of publications related to smart home adoption, include Energy Research & Social Science (n=9), Renewable and Sustainable Energy Reviews (n=3), Energies (n=2), and Energy Procedia (n=2). Besides, smart home as a kind of scientific and technological innovation, the journals with the focus on technology and engineering that also have a large number of publications, include Sensors (n=4), International Journal of Human Computer Studies (n=2), Journal of Computer Information Systems (n=2), and Personal and Ubiquitous Computing (n=2). Figure 3 shows the distribution of the smart home adoption articles by research areas.

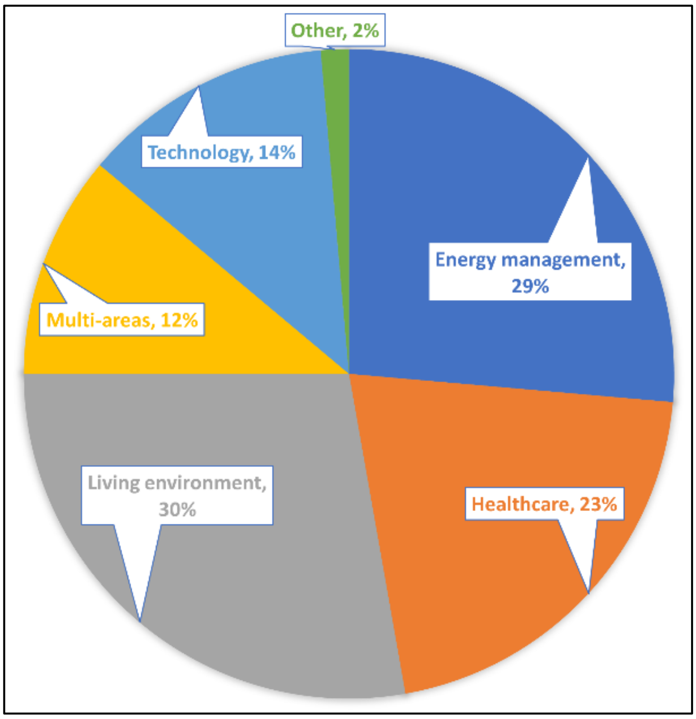


**Figure 3:** Publication distribution by research area

### *3.2. Prominent Smart Home Technology Services*

Based on the reviewed articles (Appendix A), prominent technology services were identified as: (a) Ambient assisted living (AAL) service; (b) Smart home energy management technology service; and (c) Smart home security service. A summary of aims, key functions, and application areas of the prominent smart home technology services is provided in Table 3.

**Table 3:** Summary of prominent technology services

| **Prominent service** | **Area** | **Aim** | **Key functions** | **Literature** |
|---|---|---|---|---|
| Ambient Assisted Living (AAL) service | Healthcare | To promote occupants' well-being inside dwellings by assisting daily activities. | 1) Activity and vital signs monitoring<br>2) Activity and threat detection<br>3) Home-based assistance<br>4) Healthcare services delivery | [14], [15], [16], [26], [28], [31] |
| Smart home energy management technology service (e.g., AI, IoT, IVAs) | Energy management | To improve environmental sustainability by improving energy efficiency. | 1) Energy consumption monitoring<br>2) Energy usage visualization<br>3) Remote control and management<br>4) Providing ancillary services, e.g., demand response, demand-side management, peak shaving and load shifting. | [32], [33], [34], [35], [36] |
| Smart home security service | Living environment | To protect the safety of occupants and houses by threats detection and security interventions. | 1) Activity monitoring<br>2) Threat and intrusion detection<br>3) Real-time alarm and warning<br>4) Safety and security protection | [19], [20], [28], [40], [41], [66] |

The prominent smart home service in the healthcare sector is AAL. This service creates a platform for connecting and interacting among wearable devices, embedded sensors, and domestic appliance, monitoring, and collecting data about users' vital signs, activities, and the surrounding environment [14,15]. Based on these data, the platform can intelligently detect threats or predict possible problems to assist healthcare decisions made or respond to the users' activities and environment via different smart devices [26,31]. The results of an interview conducted in Korea show the respondents expressed high contentment toward this service. The scenario of applying AAL service within residential space could be one of the potential directions for future smart home development [15]. However, existing AAL services still face several challenges in terms of integration and implementation—e.g., the complications of fusing AAL devices with architecture and the limited research on elderly home-based healthcare management [15,31].

Smart home energy management technology service is the prominent application of smart technology in the energy sector. This technology monitors household energy usage via various smart devices and sensors to provide users with the visualisation of real-time and historical information on energy consumption [32,33,34]. The offered management function allows users to directly or remotely control the energy use of household appliances and devices. The associated ancillary services, e.g., demand response, demand-side management, peak shaving and load shifting, assist users and grid operators in optimising and balancing the consumption and supply of energy [35,36]. This technology's potential for energy-saving had been verified by simulation-based case studies in Algeria and Germany. Besides, the study results also found multiple benefits offered by this technology, such as investment benefits and cost savings, increased amenity or convenience, and reductions of $CO_2$ emission [18]. However, a survey conducted in the USA found the non-energy benefits, such as improved quality of the living environment, were driving smart energy management hardware adoption [37]. These non-energy benefits may undermine this technology's intended goal about energy efficiency, i.e., people's desired 'pleasance', provided by the energy-intensive devices or use patterns, may encourage users to consume more energy [38,39].

In the living environment sector, existing research mostly focuses on the security monitoring and threat detection technologies and approaches that protect the safety of properties and occupants, i.e., smart home security service. This service detects and identifies the aware activities via the collected multimedia information such as videos or photos, to forecast potential natural and anthropogenic threats. Once the threat has been determined, this service would alert users in real-time and assist in further interventions [19,20,40]. This service is widely used in the following categories of detection such as intruder, health events, and building system failures [41]. However, the expenses associated with the safety and security benefits may include the loss of privacy and independence [42]. Besides, the cyber threats may be the most severe challenge that smart home security services face, such as maliciously operation of smart home security system to conduct criminal activities or cause physical accidents and financial loss, or even spying or manipulating on human and society [43].

### *3.3. Motivations for Smart Home Adoption*

This section discusses the motivation for adoption associated with smart home technology services, i.e., the motive force pushing or prompting users to adopt. Based on the reviewed articles, the following motivation were identified: (a) Efficient energy management; (b) Better home-based healthcare services; (c) Potential financial savings and benefits, and; (d) Enhanced quality of life. These are elaborated below, and the summary information is presented in Table 4.

**Table 4:** Summary of adoption motivation

| **Adoption motivation** | **Potential benefits** | **Literature** |
|---|---|---|
| Efficient energy management | 1) Provide transparency on daily energy usage<br>2) Maintain or reduce household's energy consumption<br>3) Provide demand flexibility for resources<br>4) Deliver affordable low-carbon energy transition<br>5) Reduce environmental impacts such as saving $CO^2$ emissions | [17], [18], [44], [47], [48], [50], [52], [59], [101] |
| Better home-based healthcare services | 1) Enhance in-home care services to achieve long and healthy lives and prevent loneliness<br>2) Improve the ability of healthcare professional to deliver personalised and timely care<br>3) Prevent serious accidents and serve a critical role in the safety of homes<br>4) Achieve independent living and strengthen quality of life, safety, and prospects for aging-in-place<br>5) Reduce reliance on public-sector service provision | [47], [48], [54], [55], [56], [58], [59], [61], [60] |
| Potential financial savings and benefits | 1) Savings on energy expenses<br>2) Savings on healthcare delivery costs<br>3) A highly beneficial investment by translating energy savings into profits<br>4) A cost-effective solution for public-sector service provision | [17], [18], [47], [48], [59], [61], [62] |

| | | |
|---|---|---|
| Enhanced quality of life | 1) Achieve or enhance a wide variety of controllability to increase convenience for daily tasks and activities<br>2) Provide comfort living environment with safety and security<br>3) Add symbolic value to houses as an item of fashion or style<br>4) Generate pleasance in life via creating ambiance, fun, comfort, atmosphere, elegance, and new aesthetic experiences | [44], [47], [50], [59], [60], [62], [63], [64], [68] |

3.3.1. Efficient Energy Management

The first motivation relates to energy efficiency. The smart home as a key component of smart grids has a strong potential to provide efficient management for householder's daily energy consumption and is the dominant factor in delivering affordable low-carbon energy transition and reducing environmental impacts such as saving $CO_2$ emissions [18,44,45].

The embedded smart devices can provide the functions of visualisation and monitoring for household energy management, which enables users to change their behaviour and achieve energy efficiency without compromising their comfort or convenience [18,46,47,48]. Smart devices provide the transparency of energy consumption by visualisation and monitoring functions, which is the key factor promoting energy conservation in households [32,47,48]. The offered features such as instantaneity and visuality allow users to optimise energy efficiency following their energy use patterns [32]. The smart home technologies undoubtedly increased users' participation in the 'smarter' use of energy resources to enable users to become smart-consumers. The research of consumer behaviour determinants indicates that individual and collective behaviour can be improved via more exposure to relevant information. When intuitive data were presented to the users, it can incentivise them to change behaviour patterns more sustainably [45,49].

Besides, smart home technologies can facilitate demand flexibility programs in energy systems, which "allow continuous seamless interaction between the home and the smart grid, offering the grid ongoing demand flexibility resources for reshaping the demand curve" [50, p.177]. Demand-response (DR) features in the program, which was defined as "a change in electricity consumption pattern of end-users by increasing or decreasing the loads in response to tariff signals and other incentives from the energy supplier", provides energy users with economic incentives to alter their consumption practices and routines in energy control and saving [51, p.153]. DR can help users reduce household energy demand during high-demand or high-price periods (i.e., peak hours), such as allowing users to shift household energy demand to off-peak hours to lower energy costs or receive financial rewards. DR contributes to automation and optimisation of residential energy use, provision of affordable energy, the stability of power grids, and improvement of energy efficiency [46].

Study shows the utilisation of new smart energy technologies can help reach the goal of having secure, affordable, and sustainable energy, and the active participation of users plays the key role in this strategy [6]. In the human-centred perspective, the adoption of smart home technologies in household energy management contributes to collaboratively developing future energy services. Smart home energy management system allows householders to actively participate in domestic energy consumption and management. Based on different reasons or purposes such as energy costs saving and sustainability, users are likely to change their daily energy use patterns to achieve efficiency and sustainable energy use [52].

3.3.2. Better Home-based Healthcare Services

The second motivation relates to healthcare services. With the rising number of the world's elderly population, smart home technologies play an important role in home-based healthcare services [15,53]. Studies show that smart home technologies in home-based healthcare services mainly focused on improving living standards and autonomy for elder or disabled people [54,55,56]. Smart home devices through sensing, anticipating, and responding to users' daily activities to maintain their independence at home in a socially appropriate and timely way [23,56].

The original definition of smart home has been extended in the field of healthcare to "a home or dwelling with a set of networked sensors and devices that extend the functionality of the home by adding intelligence, automation, control, contextual awareness, adaptability and functionality both remotely and locally, in the pursuit of improving the health and well-being of its occupants and assisting in the delivery of healthcare services" [57, p.2]. Older people spend the most majority of time in their residential space. Therefore, embedding healthcare functions and services into a smart home can provide the elderly with the advantages of living in a familiar space, maintaining independence, strengthening the quality of life, and improving the ability of healthcare professional to deliver personalised and timely care [15,53,55,56]. These advantages would maximise seniors' well-being in terms of physical, social, and mental health [15].

Studies show that although older people tend to have a slower learning rate in new technologies than younger people, the various forms of benefits from adopting smart technology often prompt them to hold favourable attitudes towards this innovation, which also has increased their willingness to adopt [31,54,55]. The most significant benefit smart home technologies can provide is continuous, non-invasive, and seamless healthcare services to elder people while staying in their convenient home environment and leading independent and active lives [15,31,54]. The integration of smart home technologies with healthcare services provides a promising and cost-effective way to improve home care for the elderly and the disabled, allowing greater independence, achieving healthy lives, and preventing loneliness [58,59,60].

#### 3.3.3. Potential Financial Savings and Benefits

The third motivation relates to financial savings and benefits. The monetary savings on daily basic needs are the potential benefits brought from the first two motivations. The efficient energy management system achieved by the smart home technologies provides users with the abilities to monitor household energy spending, control household energy consumption, and also switch to better tariffs or cheaper service providers to reduce energy expenses [47,48,52,59]. Home-based healthcare services in a smart home have the capability to promote aging-in-place, which can reduce healthcare delivery costs and save costs on institutional care [59,61]. Studies showed that in the context of having a great socioeconomic burden due to increasing medical expenses in today's aging society, embedding healthcare services into smart homes to achieve aging-in-place may improve cost-effectiveness on societal healthcare costs, especially for public-sector service provision [15,53,58]. Another study verifies that implementing smart homes is a highly beneficial investment, which was achieved by translating the obtained energy savings into highly profitable overall investments [18]. The motivation for adoption would become more positive with an increase in anticipated savings and a decrease in the investment payback period [17]. However, Shank et al. [62] indicated that the advantage of monetary saving can only be offered by specific smart home technologies or services. The strongest driver for smart home adoption should be providing lifestyle benefits, which will be discussed in the next paragraph.

#### 3.3.4. Enhanced Quality of Life

The final motivation relates to the quality of life. Smart home achieves or enhances the controllability of a wide variety of domestic appliances and devices, which provides a better way to manage the demands of daily living and contribute to 'better living' by increasing the convenience of daily tasks and activities with 'simple solutions' [44,47,63]. With the advancements and integration of AI technology and other technological innovations, smart homes can achieve fully independent and automatic operation, which significantly reduces users' workload on managing domestic appliances and daily tasks [60]. Studies show that the most important adoption motivation for most people is the benefits from controllability, convenience, and comfort provided by smart home technologies, and these benefits are valued more than the associated potential risks [37,47,50]. Besides, the smart home can generate pleasance in daily life by creating ambience, fun, comfort, atmosphere, elegance, and new aesthetic experiences [63]. Study shows that people more tend to pursue the look or design of smart products, and how the products create the symbolic value into their house in term of vogue. Respondents said they need to purchase and possess exquisite design or innovation to show they are taking the leading position on the curve of fashion or style [47]. The aesthetic experiences from the appearance of smart home products and the offered ambience of the home can provide users with the pleasance—i.e., "the sensory, effective and satisfying dimensions of everyday life"; the other source of pleasance is the provided symbolic value, which provides users with the ability to 'showcase' or 'show off' their home's features [38, p.6].

### *3.4. Barriers to Smart Home Adoption*

This section discusses the barriers to adoption associated with smart home technology services—i.e., the adverse factors influence users' willingness-to-pay/adopt. Based on the reviewed literature, the following barriers were identified: (a) Distrust and resistance; (b) Limited perception of smart home; (c) Financial considerations; (d) Privacy and security concerns; (e) Technology anxiety, and; (f) Negative social influences. These adverse factors are elaborated below, and the summary information is presented in Table 5.

**Table 5:** Summary of adoption barriers

| Adoption barrier | Suggested response | Literature |
|---|---|---|
| Distrust and resistance | 1) Technical improvement to decrease the risk likelihood, e.g., reliability, controllability, and performance of devices.<br>2) Combat misperceptions about constant surveillance.<br>3) Provide transparency on the collection, processing, and protection of personal data.<br>4) Focus on building trust rather than reducing risk. | [49], [61], [64], [65], [66], [67], [76], [77], [81], [102], [104] |
| Limited perception of smart home | 1) Adopt the participatory development approach.<br>2) Provide personalised education tutorials and technical support.<br>3) Increase consumers' familiarity with smart homes. | [10], [37], [49], [61], [64], [70], [71], [72], [104] |
| Financial considerations | 1) Reduce initial adoption costs to provide users with 'easy entry'.<br>2) Provide attractive business incentives or other preferential policies.<br>3) Consider cost as an important influence factor in smart home popularisation. | [4], [37], [46], [47], [49], [64], [67], [72], [81], [89] [103] |
| Concerns of privacy and security as perceived risks | 1) Technical improvement to prevent the leaking of private information.<br>2) Develop ' Privacy-friendly' techniques.<br>3) Publicise purposed procedures related to private information.<br>4) Legal improvement to reinforce the existing privacy legal framework. | [4], [10], [37], [46], [64], [67], [72], [77], [78], [79], [81], [89], [103], [104] |
| Technology anxiety | 1) Develop technologies focusing on social well-being.<br>2) Provide adequate training programs and real-time technical support to mitigate users' technology anxiety.<br>3) Develop 'easy to use' innovative solutions to improve users' satisfaction level. | [49], [61], [81], [82] |
| Negative social influences | 1) Generate positive word of mouth in multiple ways.<br>2) Advertise smart homes with broader social and well-being benefits. | [4], [46], [47], [58], [64], [72], [74], [79], [82] |

#### 3.4.1. Distrust and Resistance

The first barrier relates to trust issues and resistance, which include users' distrust in smart technologies, services or devices, distrust in IoT, and distrust in associated companies such as manufacturers, and operators (normally refer to utility companies or energy providers). The research found that one of the main barriers to adopt smart home was with its basic component—the smart device itself lacks users' trust. The adoption intention was impacted by reliability, performance, and controllability of the device. Thus, if users perceive the device as trustworthy, their adoption intention would be increased [10,64]. Furthermore, the trust in IoT and the acceptability of IoT were the other barriers to smart home adoption. Based on a survey finding in the UK, respondents had fairly low-level of trust in IoT, particularly regarding the likelihood of physical risks. The older respondents and the less well-educated respondents were the most distrustful of IoT and represented strong resistance. The low level of users' trust in IoT and their resistance to IoT may undermine people's adoption intention for smart homes [65].

The last trust issue is associated with devices manufacturers and operating companies, and normally derived from users' concerns about the potential risks of personal and private data collection and usage, such as leakage of sensitive personal information or wrongful usage of collected information. These kinds of mistrust were amplified by media reports of security and privacy breaches, and gradually became the barrier to the smart home popularisation [4,66,67]. However, another research finding has shown that the fairly high level of trust in operation companies such as utilities or energy providers does not enhance the adoption intention for smart home in the US. This finding suggested that privacy concerns outweigh trust for the US people, which probably because privacy concerns are close to the mainstream values in Western Civilisation, e.g., personal freedom and individualism [46]. Therefore, the concern of privacy and security has been identified as another barrier to smart home adoption and is discussed later.

#### 3.4.2. Limited Perception of Smart Home

The second barrier relates to users' limited perception of the understandings, usefulness, and values of smart home technology services. Shuhaiber & Mashal [64] indicated that people's perception about smart homes has significant influences on their adoption intention. The perceived issues regarding smart home consist of knowledge shortage, knowledge gaps and knowledge barriers [68]. A survey regarding home energy management in the US indicates the low levels of knowledge about smart hardware is one of the key barriers to adoption. Some respondents expressed the market was short of readily available information regarding smart home technologies, which perplexed them in purchasing these smart products [37]. Another research signified the knowledge gaps between technological expertise and user's understanding would destroy the anticipants' usage experiences—e.g., "users were not always clear on the basic functions and features of smart products including interoperability; users were consistently surprised to learn about the possibilities for integrating multiple products"—, which may impact the user's further adoption intention for smart home technology services [68, p.1903]. In addition, the knowledge barriers derived from the complexities of smart technologies have the potential to undermine people's adoption intention. In simple terms, some technological bewilderments may reduce consumers' interests in smart home technologies, which possibly become one of the barriers to the decision to purchase—e.g., deficient knowledge about hubs, platforms, and protocols, indistinct understanding between Wi-Fi, Bluetooth, and ZigBee [68,69].

'Perceived usefulness' (PU) was derived from the 'Technology Acceptance Model' (TAM), which "focuses on the user's subjective possibility of increasing the performance when adopting a technology" [70, p.1076]. TAM is a reliable model of predicting the technology acceptance, which was widely used to measure user's perceptions of technological innovation and their acceptance probability [49,70,71]. Based on the research results, the PU of the technology largely influences the acceptance of smart homes [70]. A survey among students at a large public university in the US suggested that the concern over technology's usefulness is the major factor that increased their resistance to smart products. Besides, the survey found that smart product's perceived values have significant influences on behavioural intention. Consumers will consider smart home technology's investment values during purchases, i.e., the benefits against the monetary value. Because of this, the lack of perceived value has been regarded as the most significant barrier to adopt smart home among potential consumers [10].

#### 3.4.3. Financial Considerations

The third barrier relates to the financial aspect. Most people have a series of financial concerns before their adoption, including the initial purchase cost of the devices or services, the potential cost of installation, maintenance, repair, energy consumption, and the investment feasibility. Studies show that existing smart homes' adoption costs are relatively expensive, including the cost of money and time [4,67,72]. In a workshop regarding smart home adoption in the UK, respondents assumed smart home adoption would involve a long-term investment and be only viable for some homeowners (and also not for most tenants) due to its perceived high costs, including acquisition, installation, operation, management, and maintenance costs [72]. However, cost is the main consideration for consumers in purchasing smart home products. The economic burden caused by higher initial costs could aggrandise consumer resistance to smart homes, which forms barriers to adoption [4]. And the relatively high adoption benchmark also posed a barrier to tenants. The tenants may experience difficulties and problems of taking their smart home devices or services to the next property [68,73].

Furthermore, people's psychology of not wasting resources would have negative influences on household appliances replacement or upgrade. Even if users realise the possible economic benefits from the new smart energy-efficient products, they may remain unwilling to discard their existing functional non-smart or energy-inefficient household appliances [74]. Therefore, besides the potential adoption costs, the smart home's investment feasibility or perceived financial risk constituted another barrier to adopt smart homes. Across the consumers' adoption-decision process, most consumers would assess whether the smart product or service is worth investing or if there are any other cheaper alternatives [4]. Consumers' adoption intention will be decreased when the perceived benefits are lower than the perceived financial costs [71]. Some respondents from the UK's workshop stated the actual benefits or savings would be one of the negative factors that may prevent people from adopting smart homes, the same as they said: "saving 'a few pence' would be meaningless" [73, p.370]. If benefits or savings of smart home devices or services are minimal, other reasonably priced and energy-efficient appliances would be the better choices with significantly cheaper running costs [73].

#### 3.4.4. Concerns of Privacy and Security

The fourth barrier relates to privacy and security. With the increasingly large amount of data being collected and communicated through smart devices and wireless networks, people's concerns related to privacy and cybersecurity have increased and formed a virtual barrier to smart home adoption [4,46,74]. To exchange for benefits such as convenience, comfort or energy efficiency, the smart homes need to vastly expand the range of collection, utilisation, and dissemination of personal information, including very private data such as location, behaviour, and health data. Through IoT, smart home technologies and related services are stretching "the boundaries of the home into cyberspace" [75, p.144]. However, some research findings, unlike the general expectation, provided a completely different research conclusion—i.e., privacy and security risk do not significantly affect smart homes' resistance and do not negatively affect people's adoption intention [76]. These reasons support the above findings: (a) "Security does not play an important role in consumers risk perceptions" [77, p.444]; (b) "Users believe they can control the privacy problem" [4, p.11]; (c) Consumers have low awareness of the potential privacy and security risk and their implications[4,62,78]; (d) "Users have sufficient knowledge to fully understand the risk of sharing personal data" [79, p.11].

Furthermore, another special finding is people's risk perceptions related to privacy and security may be influenced by their cultural backgrounds [46,47,80]. A survey about Home Energy Management System in the US and Japan indicates privacy and cybersecurity were more important in New York. The result shows the privacy and cybersecurity concerns only affected negatively on New York residents' adoption intention, especially the concerns related to utility authorities. This finding might be explained by the US culture—i.e., "the individualistic and more-feminine culture emphasizing personal goals, self-interests, and interpersonal communication; and the low power distance culture making residents less tolerant of the utility authority exerting control over them" [46, p.12]. Nevertheless, Tokyo residents were affected by the highly masculine culture and collectivism in Japan, who might ignore or endure the related risks or consequences carried by the privacy and security issues. Because people from a highly masculine country might focus more on the usefulness and contributions of technology on accomplishing their goals rather than the potential risks. The effect of collectivist culture might let people choose to endure greater difficulty to achieve the larger goals valued by their culture [46].

#### 3.4.5. Technology Anxiety

The fifth barrier relates to technology anxiety. Studies show that technology anxiety is a potential barrier to the smart home adoption, especially to the elderly with lower computer literacy [46,49,67]. The IoT based smart home is a relatively new technology and can provide various related services to improve people's living. However, technological innovation and related complicated services may drive negative presses and feelings on the end user's mind. "To elderly people, the entire changes brought forward by the IoT era in the form of smart homes, are too radical, disruptive and new" [67, p.38545]. Compared with accepting and learning new technologies, older people tend to use the technologies they are personally familiar with and have been used for a long period because they may experience a higher level of uneasiness in using the new technologies due to their reduced cognitive and physical capabilities [81,82]. Existing literature with little focus on how technology anxiety forms a barrier to smart home adoption even has been verified as the adoption barrier to other technologies [46]. But with the increasing penetration of smart technologies in the field of elderly healthcare, the technology anxiety associated with smart technologies will be one of the major adoption challenges, particularly in the global context of aging society.

#### 3.4.6. Negative Social Influences

The final barrier relates to social influence, namely, the social factors influencing consumers' intention to adopt smart home technology services [46,58,64,74,82]. Social influence has been defined as the apperceiving degree of user about the judgment of innovation from the important people in their social circle, which influenced user's adoption intention [64,82]. Studies revealed during the initial stage when users lack relevant use experiences of innovative products, their adoption intention or decision was greatly influenced by the evaluations and opinions from external environments such as social network, the voices of mass media, and government policies [46,58,82]. However, some studies conducted in different countries found there are no strong relationship between the social influences and adoption intention—e.g., Japan, Pakistan, and Malaysia [46,74]. The difference in culture, education level, or residents' opinions about government enforcement (such as incentives or policies, or regulations) might result in these different findings [74].

### *3.5. Risks of Smart Home Adoption*

Based on the reviewed literature (Appendix C), this section discusses the risks of adoption associated with smart home technology services, i.e., the risks resulted during users' daily usage. The following main risks were identified: (a) Privacy and security threats; (b) Energy rebounds and wasteful consumption; (c) Difficulty in the domestication of technology, and; (d) Destructiveness in domestic life. A brief discussion on these risks is elaborated below. The potential consequences of adoption risks and actions to be taken are presented in Table 6.

**Table 6:** Summary of adoption risks

| Adoption risk | Potential consequence | Potential solution | Literature |
|---|---|---|---|
| Privacy and security threats | 1) Leakage of personal information.<br>2) Losing control over the devices.<br>3) Realising criminal activities.<br>4) Causing physical accidents or financial loss.<br>5) Manipulating or spying on society | 1) Provide users with warning and assistance to response or recover from attacks or threats.<br>2) Consider multiple factors impacting the security of smart homes in the product design process.<br>3) Provide users with easy-to-understand advice and share up-to-date information related to cyberspace knowledge. | [42], [43], [47], [60], [83], [84], [105], [106], [107], [108] |
| Energy rebounds and wasteful consumption | 1) Environmental rebound effect.<br>2) Offsetting the initial emissions reduction.<br>3) Raising or sustaining energy-intensive ways of life.<br>4) Increasing wasteful energy consumption.<br>5) Undermining the goals of sustainability. | 1) Contribute to consumers' change of perception.<br>2) Thorough consideration during policymaking and planning process.<br>3) Embed energy-efficient concepts into product design.<br>4) Reconfigure visions of the smart home. | [39], [47], [63], [88], [90], [100] |
| Difficulty in the domestication of technology | 1) Time and effort intensive.<br>2) Frustrating usage experiences.<br>3) Placing new demands and complex problems on users. | The reviewed literature did not suggest any solutions related to the domestication of smart home technology. | [47], [69], [79], [88] |
| Destructiveness in domestic life | 1) Unsettling existing roles and relationships among householders.<br>2) Losing privacy, autonomy and independence.<br>3) Monopolising the control power to create or exacerbate the power imbalances in the family.<br>4) Proliferating of "non-essential luxuries" in domestic life. | There is a lack of in-depth analysis and socially informed solutions about smart home technologies' influences on the social dimension, such as social interactions, security, and well-being. | [42], [43], [79], [88], [89], [93] |

#### 3.5.1. Privacy and Security Threats

The first risk relates to privacy and security. The smart home environment is created and constituted by multiple types of cyber-physical devices and systems. It extends the existing internet network by connecting daily domestic items such as housing technology, household appliances and devices, and consumer electronics [43,83]. The interconnected technologies provide the functions of monitoring, access, and control to serve users' needs and more vulnerability to threats in cyberspace [43,84].

Compared with the physical security offered by smart security devices, such as smart locks or alarms, most users paid less attention to their digital security during daily use. The provided security functions may make users feel safe in terms of physical security, i.e., domestic items within the house cannot be easily stolen. They can check the working condition easily by sight or touch. Most of the time, users may ignore or be unaware that all devices are interconnected (cascading effect). Once one of the devices loses or lacks sufficient digital security, a potential entry point may be provided by the system unconsciously, which allows any 'potential threats' to access users' home network and 'steal' information held in other smart home systems [84,85]. As a result, the security of these devices may not necessarily be guaranteed in the digital dimension [85]. Even if the sufficient digital security of the device itself can be ensured, manufacturers, operators (e.g., utility companies, energy providers), or relevant internet companies (notably Google or Facebook) also have the potential to manipulate users allowing the unconventional access or share any information, even the sensitive and private data that users are unwilling to share. Whatever methods have collected the sourced data (e.g., hacked from an insecure system or device or manipulated to share more data than intended), the results are the same. The collected parties can repurpose this information and treat it as a profitable instrument, such as building a targeted advertising database or resell it to third parties. In such cases, users lost control of their personal information or even became unaware that their personal information was leaking out [85,86].

Furthermore, cyber-attacks or cyberspace violations (e.g., maliciously interfere or control the normal functions or services) may make an unsafe living environment, including physical and digital, that affects occupants' well-being. These kinds of malicious acts can have immediate or possible long-term consequences on the occupant's life, such as financial loss, physical harm, and long-lasting emotional impacts [60,84]. "In such a case, the smart home will become a liability for a resident rather than an asset" [41, p.93].

#### 3.5.2. Energy Rebounds and Wasteful Consumption

The second risk relates to energy rebounds and wasteful consumption. Studies show smart home, as a key component of smart grids, potentially plays a significant role and contributes to the future energy transition [39,45,75]. However, the increased energy efficiency offered by smart homes may bring about the rebound effect, which refers to "an increase in demand following the introduction of more efficient technology" [39, p.2]. Some kinds of increased demands may be unrelated to saving energy or becoming more sustainable [87], even would cause wasteful consumption to prioritise or pursue some energy-intensive visions of smart home such as comfort, luxury, convenience, or pleasance [38,47,88]. The intended environmental benefits may be undermined by the goal of smart home on promoting lifestyle vision, which even reinforces unsustainable energy consumption [38,47]. The emerging evidence suggests that the new forms of energy demand created by some energy-consuming smart technologies were working against a culture of energy demand reduction [47,88,89]. Furthermore, some studies indicate the smart home technologies certainly provide the possibility for improved household energy management but little evidence of substantial contribution in generating substantial energy savings [69,88,90]. Therefore, the potential benefits of smart home technologies on energy efficiency to a great extent depend on their design and users' usage modes [89].

#### 3.5.3. Difficulty in the Domestication of Technology

The third risk relates to the difficulty in the domestication of technology. The 'adapting' or 'domesticating' smart home technologies is identified as a demanding and time-consuming task as it requires a substantial amount of learning and work from the users [88,90,91]. Domesticating smart home devices into their lifestyles is perceived as not being easy or intuitive for most users. The reasons may be users have little interest in the relevant technical knowledge, unwilling or unable to spend the needed time to familiarise a full set of functionalities offered [47,88]. Studies show the majority of households had experienced domestication or management problems during their daily use of smart home technologies [69,88]. When any forms of 'adapting' or 'domesticating' break down, users may become frustrated and abandon using these technologies [47,69,90]. On some occasions, users would use a 'minimising effort' strategy to accommodate the new technologies into their homes, i.e., abandon the available advanced functions, only using the basic functions or services of the smart home as similar as using their previous systems [69,90].

Even though users can successfully domesticate some smart technologies, this was far from smooth. Smart home technologies not only integrate additional equipment such as monitors, sensors and control interfaces into the existing residential environment but also introduce "a new layer of control functionality onto existing domestic appliances and devices" to achieve interaction with each other [88, p.136]. However, the different types of communication standards and proprietary protocols were favoured by different smart device manufacturers or were upgraded in different generations (e.g., protocols like Zigbee, Z-Wave, X10, Insteon). Those communication standards and protocols have different architectures and cannot achieve interoperability with each other [92]. In fact, users commonly brought smart home technologies into the home incrementally in a 'piecemeal' way, due to their or household changes of preferences, demands, or needs (e.g., different marital status, alteration of family structure) [72]. In this case, smart devices from different manufacturers or generations may be perceived as incompatible with other elements of the existing smart ecosystem [47]. The interoperability between different smart devices places new demands and relatively complex technical issues on users, which may bring more challenges to further domestication.

3.5.4. Destructiveness in Domestic Life

The final risk relates to disruptiveness in domestic life. Scholars theorised that smart home technologies are disruptive technologies for domestic life [67,88]. Not every family member universally holds the control ability of technologies. By adopting smart home technologies in a home, the home's control power would shift to "the hands of the most tech engaged and savvy household members", which may create or exacerbate existing family power imbalances and disrupt existing relationships among family members. Emerging studies show the female has a wider skills gap with new technologies that may lead to a gender imbalance in the household or even more disturbing outcomes: "smart home devices may exacerbate domestic violence towards women" [93, pp.180-181].

Besides, different aspects of the domestic environment were re-domesticated into the new 'smarter' residence by smart home technologies, providing householders with potential new paths to control or do the domestic tasks [88]. However, these potential new paths may destabilise existing roles and relationships between householders and domestic technologies. With the increasing dependency on smart technologies, the householders would also be embedded into the 'smarter' home, i.e., a larger whole, a larger smart ecosystem. "This could create conditions where people serve the system, rather than having the system serve them", which was known as the "paradox" of the smart home [47, p.11]. When users fail in domestication, they would quickly lose their control of smart technologies. Because most users do not fully understand how these technologies work. When smart technologies go wrong or fail, users need to seek external assistance or support to address their needs [47,94]. A representative survey among UK homeowners found that smart home technologies contribute to increasing users' control over the domestic environment. Nevertheless, these benefits come at the price of "reduced autonomy and independence of the home from the encompassing sociotechnical systems" and proliferate such as laziness and other 'non-essential luxuries' in domestic life [89, p.76].

## 4. Discussion and Conclusion

### *4.1. Key Findings*

This research aims to identify the motivations, barriers, and risks influencing smart home adoption intention from a consumer's perspective and to propose the potential responses and solutions that may improve users' acceptance of the smart home. The key findings of the systematic literature review are summarised and presented in Tables 3-6.

Smart homes' primary goal is to embed various kinds of IoT-based smart technologies into the built environment to provide users with security, convenience, comfort, energy efficiency and entertainment and to improve their quality of life in their residence. The prominent technology services associated with smart homes include: (a) Ambient assisted living service; (b) Smart home energy management technology service, and; (c) Smart home security service (Table 3). The multiple potential benefits brought from the above technology services formed the motive force pushing or prompting users to adopt smart homes including efficient energy management, better home-based healthcare services, potential financial savings and benefits, and enhanced quality of life. Especially during the recent (COVID-19) pandemic, people anew focused on the relationship between domestic activities and smart home technologies and realised the importance of smart home technologies to household healthcare, domestic energy management, and social well-being. Von Humboldt et al. [95] explored the roles of the interventions achieved by smart home technologies during a pandemic, such as reducing the costs of public health resources and improving the health and quality of domestic life. Chen et al. [96] and Zanocco et al. [97] explored the influences of the COVID-19 pandemic and associated restrictions on domestic energy use patterns. They indicated that the significant variation of domestic energy use patterns during the pandemic has positive effects on smart energy management technologies' adoption intention. The crisis of the pandemic and related restrictions is substantially changing and influencing people’s daily practices and routines. It provides a new direction for future smart home research, i.e., exploring the influences of enormous social crisis and human behaviour patterns changes on the users’ adoption intention (Table 4).

The main barriers to adopt smart home technology services include: (a) Distrust and resistance; (b) Limited perception of smart home; (c) Financial considerations; (d) Privacy and security concerns as perceived risks; (e) Technology anxiety, and; (f) Negative social influences (Table 5). One of the critical factors determining the success of smart home technology and its related services is the user’s adoption and incorporating these in domestic life, i.e., end users’ acceptance [98,99]. Therefore, the smart home industry and stakeholders including the private and public sectors should commit to dissolving existing adoption barriers, increasing users’ acceptance, and providing smart homes with a healthy and sustainable implementation environment.

Some suggestions are, firstly, the industry should consider improving the reliability, controllability, and performance of smart devices to decrease users’ concerns regarding the likelihood of potential risks. In terms of personal data collection, processing, and protection, manufacturers and operators should provide users with sufficient transparency to gain consumers’ trust. Secondly, the industry and operators should increase consumers’ familiarity with smart homes, i.e., raise the understanding of this technology and associated services, their potential value, and how smart homes might change people's lives. One of the efficient ways is to involve consumers within the technology engineering process to understand their real needs and communicate the prospects and potential benefits of smart homes (from home to grid to city) clearly to the consumers. Thirdly, the industry should focus on costs control such as spreading the costs over the whole lifecycle of product or service to provide users with an 'easy entry' in the initial stage. Operators and governments may provide attractive business incentives or other promoting policies to help the industry reduce the costs and lower the financial threshold for consumers to adopt smart homes. Fourthly, the industry should reduce or avoid the risks of data misused and leaked technically and develop smart home techniques in a privacy-friendly way. The government should reinforce the privacy-related legal framework to regulate industry and operators' activities in production and implementation. Fifthly, the industry should develop technologies that can address older people's needs such as facilitating new social and community connection to increase the scale of their social circle. The industry and operators should provide users with personalised educational tutorials and technical supports based on different demographics and social-psychological factors, which would allow users to easily use these technology services and mitigate their technology anxiety. Finally, the industry should generate positive word of mouth in different forms and prepare relevant countermeasures to solve the existing or potential negative feedbacks. In addition to the well-known technological benefits, the industry can advertise the smart home with broader social and well-being benefits, such as contributing to $CO_2$ emissions reduction and benefits related to a healthier living environment.

The smart home as an intelligent innovation, its nature of impersonality and unpredictability would inevitably cause certain risks in users’ daily use [70]. The adoption risks identified include: (a)

Privacy and security threats; (b) Energy rebounds and wasteful consumption; (c) Difficulty in the domestication of technology, and; (d) Destructiveness in domestic life (see Table 6). The potential consequences associated with these risks are physical accident and financial loss, offsetting the initial emissions reduction, unsettled domestic relationship, and decline in the household autonomy and independence, which may provide users with an uncertain, constrained, worrying and anxious experience and influence consumers' initial acceptance and adoption [70]. Hence, the smart home industry and stakeholders including the private and public sectors should be committed to overcoming these risks and achieving the desired outcomes in the further implementation process.

In terms of cyberspace knowledge, the government can provide people with easy-to-understand advice and share up-to-date information to increase people's security awareness, which commits to advancing and protecting shared interests in cyberspace. Secondly, the government and industry should contribute to consumers' change of perception, i.e., redefine 'smartness' as energy efficiency, and promote understandings of "smart appliances can translate to more energy efficient homes" [100, p.79]. The industry could embed the easily achievable and energy-efficient concepts into smart device design and reflect them in eco-design guidelines. During the energy policymaking and planning process, the government should consider the possibilities of different outcomes or consequences related to smart home adoption including optimistic, ambiguous and risky, and prepare relevant countermeasures aiming at achieving the desired sustainable outcomes. The government and industry should collectively consider how to reconfigure the energy-intensive visions of smart home to new energy efficiency, environmental, and sustainable visions. Finally, there is a lack of in-depth analysis and socially informed solutions about smart home technologies' influences on the social dimension, such as social interactions, security, and well-being. Further research is needed to explore the roles of resulting social influences on the smart home adoption process.

### *4.2. Towards a Conceptual Framework*

Based on the systematic literature review, this section developed a conceptual framework outlining the essential findings and their interrelationships, aiming to assist future research, development and implementation of smart home technologies and associated services. The conceptual framework indicates that a successful outcome of smart home adoption depends on users' perception of its motivations, barriers, and risks (Figure 4). Whilst the potential benefits of using existing prominent smart home services form the motive force pushing or prompting users to adopt, some adverse factors that influence users' willingness-to-pay/adopt constitute the barriers to adoption. The potential risks resulting from users' daily usage may also influence users to alter their first/initial adoption intention/decision.

While many motivations, barriers, and risks of smart home adoption have been identified, users' final adoption intention may also be influenced by some unique local factors such as culture, beliefs, demography, geography, or stakeholder's characteristics. As Washizu et al. [45] and Chen et al. [46] mentioned, different local characteristics had significant differences in influencing local residents' adoption intention. For example, fewer factors influence Japan's adoption intention than in the US, which may be because smart home technologies have potential to achieve the greatest energy savings in Japan, which has higher population densities and smaller living spaces per capita. In the US, privacy and cybersecurity concerns affected adoption intention negatively due to the local cultural characteristic of individualism and feminism. In contrast, these concerns have no influences on adoption intention in Japan. Therefore, the potential responses and solutions should be considered and developed based on different regions' unique characteristics to ensure these actions can solve the unique adoption issues with different local characteristics.

After industry's improvements, government incentives, or users' behavioural change, the rejecters may change their initial refusal attitude. Besides, the resulting social influences from the smart home technologies are still unclear and it is an understudied research area on the social dimension. Future research should focus on the effects of smart home technologies on social interactions, security, and well-being, and explore the roles of resulting social influences in the smart home adoption process and develop socially informed solutions.

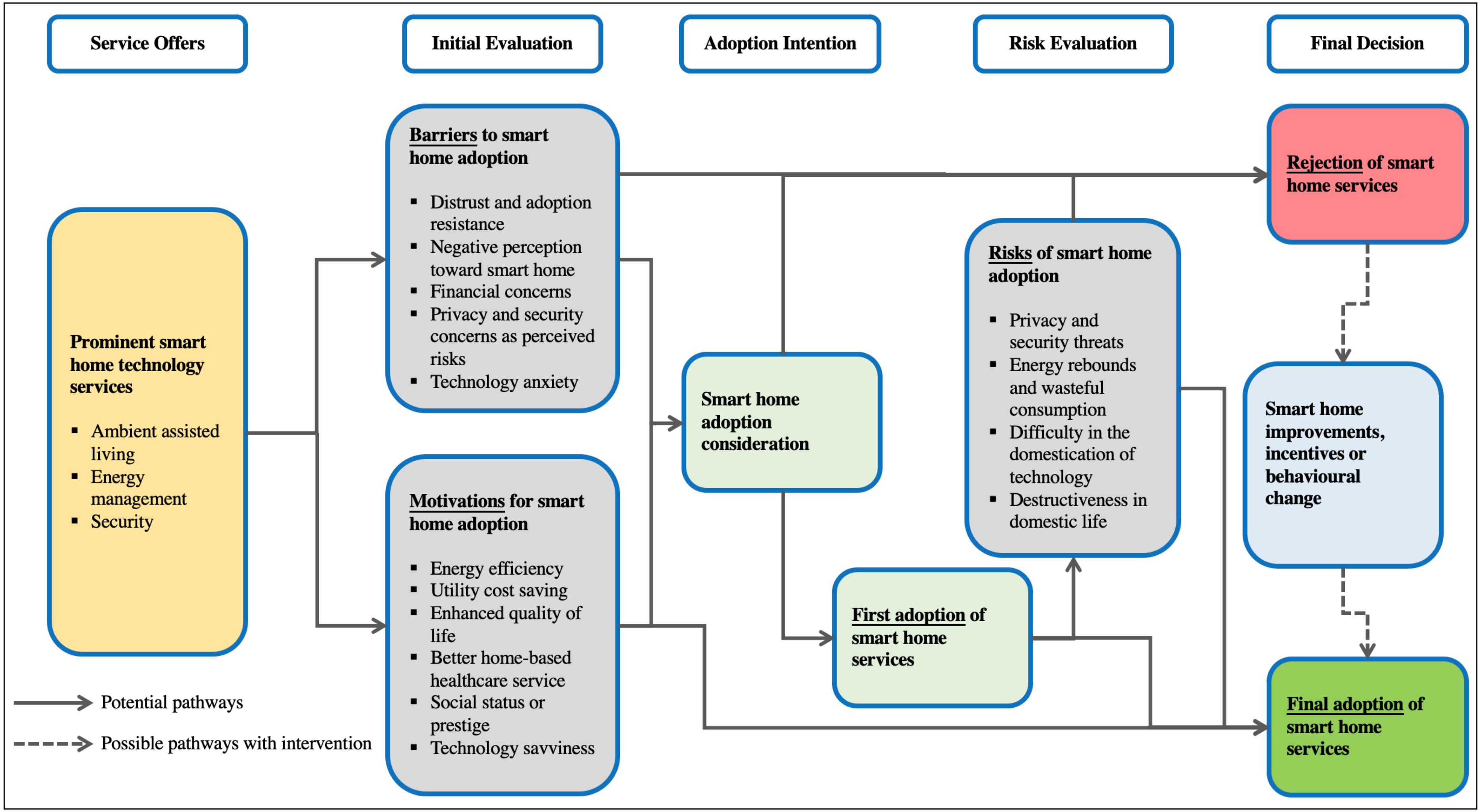


**Figure 4:** Conceptual framework for smart home adoption

### *4.3. Research Agenda*

The paper identifies the prominent smart home technology services and the brought motive force pushing or prompting people to adopt. Besides, smart home adoption's potential barriers and risks are summarised, and a brief discussion has been provided on possible responses and solutions. The conceptual framework has been developed and outlined the interrelationships between these influencing factors, which will assist future research, development, and healthy adoption of smart home technologies and associated services. Although the smart home as a scientific and technological innovation has been springing up in the last few years, the topic of its adoption is relatively new in the field, and there are still significant research gaps that need to be filled up. This section developed the following research agenda based on the paper's findings aiming to offer some prospective insights for further research.

Firstly, the unique local factors of different regions play a critical role in changing the adoption intention of smart homes, such as the difference of culture, beliefs, demography, geography, or stakeholder's characteristics. Conducting more user- or consumer-based surveys locally would help academic communities or local governments better understand how these factors influence potential adopters' acceptance and intention toward the smart home. The initial research scale could be carried out under a broader background, such as the difference between East and West. Subsequently, a more in-depth analysis focusing on targeted factors, such as local demography and stakeholder's characteristics, would help achieve the desired outcomes of better, healthy, or sustainable smart home implementation in the purposed areas or regions.

Secondly, smart home research from a social perspective is still not widely undertaken, such as its influences on social interactions, security, and well-being. There is a need to explore the caused social effects and potential consequences, which may potentially influence further smart home adoption and future implementation. Thirdly, the daily practices and routines of people would result in a significant change in the post-pandemic era, such as energy consumption pattern, healthcare services delivery mode, and people’s lifestyle. Exploring the influences of enormous social crisis and human behaviour patterns changes on the users' smart home adoption intention would be one of the new research directions in the future. Finally, the smart home’s potential in shaping our cities and societies’ future is still not mentioned in the existing literature. With the advance of IoT and other scientific and technological innovations, technologies are changing our urban environment. Further research should explore the connection between the smart home and the city, and the smart home's role in the transition to the smart city, identifying the missing link between smart homes and smart cities.

## Appendices

**Appendix A:** Prominent smart home technology services

| No | Author | Journal | Title | Year | Region | Area | Technology/service | Function |
|---|---|---|---|---|---|---|---|---|
| 1 | Badar & Anvari-Moghaddam | Advances in Building Energy Research | Smart home energy management system–a review. | 2020 | India | Energy management | 1) Smart home energy management systems | 1) Monitor the household energy usage and collect relevant data.<br>2) Energy usage data processing and analysing.<br>3) Energy usage pattern forecasting or estimation (if needed), e.g., load consumption, renewable energy sources (RES) determination.<br>4) Optimize and execute energy consumption by utilizing demand response (DR) techniques. |
| 2 | Lee & Park | Sustainability | A framework of smart-home service for elderly's biophilic experience | 2020 | Korea | Healthcare | 1) Biophilic experience based smart home services | 1) Light control to provide various light environments.<br>2) Environmental control to provide peasant air and thermal.<br>3) Provide easily managed and cared environment of animals and plants.<br>4) Allowing users to see external environment of the building in real time to give a sense of protection and understanding of nature.<br>5) Provide biophilic experience and having experiences with nature through immersion technologies, i.e., simulated VR and AR environments.<br>6) Simulate an environment with natural change over time. |
| 3 | Maswadi et al. | IEEE Access | Systematic Literature Review of Smart Home Monitoring Technologies Based on IoT for the Elderly. | 2020 | Malaysia | Healthcare<br><br>Living environment | 1) Monitoring technology systems | 1) Monitor users' physiological parameters.<br>2) Monitor system operation situation.<br>3) Detect and respond to emergency events.<br>4) Safety and security monitoring and assistance.<br>5) Social interaction monitoring and assistance<br>6) Assistance in cognitive and sensory aspects. |
| 4 | Choi et al. | Journal of Asian Architecture and Building Engineering | Future changes to smart home based on AAL healthcare service | 2019 | Korea | Healthcare | 1) Ambient assisted living (AAL) services | 1) Automatically provide health information.<br>2) Monitor health status.<br>3) Assist user to improve nutrition and exercise level.<br>4) Assistance in learning healthy habits.<br>5) Assistance in adjusting chronic inadequate habits and posture。<br>6) Provide healthcare service providers of accurate information. |
| 5 | Sapci & Sapci | JMIR Aging | Innovative assisted living tools, remote monitoring technologies, artificial intelligence-driven solutions, and robotic systems for aging societies: systematic review. | 2019 | USA | Healthcare | 1) Monitoring technologies<br>2) Intelligent algorithm | 1) Monitor users' health status and activities to detect accident-prone events in advance.<br>2) Predict possible issues based on collected data and produce possible suggestions assisting healthcare decisions making.<br>3) Sense users' surrounding environment and respond to their activities. |
| 6 | Carnemolla | Visualization in Engineering | Ageing in place and the internet of things: How smart | 2018 | Australia | Healthcare | 1) Home-based care service | 1) Monitor health status.<br>2) Detect emergencies.<br>3) Notify the healthcare professional with users' health status changes |

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| | | | home technologies, the built environment and caregiving intersect | | | | | 4) Automate daily tasks and home maintenance.<br>5) Support the elderly's independence and safety in daily life.<br>6) Communicate and connect with broader caregiving or social networks.<br>7) Provide daily supports regarding navigation and transport. |
| 7 | Pandya et al. | Applied System Innovation | Smart home anti-theft system: A novel approach for near real-time monitoring and smart home security for wellness protocol. | 2018 | China | Living environment | 1) Smart home anti-theft system | 1) Provide warnings or alarms to users regarding the unauthorized access of their property.<br>2) Real-time home security protection. |
| 8 | Chen et al. | Mobile Networks and Applications | Smart home 2.0: Innovative smart home system powered by botanical IoT and emotion detection. | 2017 | China | Living environment | 1) Botanical IoT and emotion detection technology | 1) Provide wireless control and access to achieve real-time interaction between user and domestic appliances.<br>2) Enhance the interactions of intelligence and affective with the user. |
| 9 | Dahmen et al. | Journal of Reliable Intelligent Environments | Smart secure homes: a survey of smart home technologies that sense, assess, and respond to security threats | 2017 | USA | Living environment | 1) Smart secure home | 1) Intruder detection.<br>2) Health event detection.<br>3) Building system failure detection. |
| 10 | Dahmen et al. | Sensors | Activity learning as a foundation for security monitoring in smart homes. | 2017 | USA | Living environment | 2) Security monitoring and treat detection | 1) Identify and reason security threats in real time. |
| 11 | Fan et al. | Energy Procedia | Energy visualization for smart home. | 2017 | China | Energy managemen t | 1) Energy visualization technology | 1) Real-time monitoring and management of household electricity consumption via the internet or smart devices application. |
| 12 | Ford et al. | Building and Environment | Categories and functionality of smart home technology for energy management. | 2017 | USA | Energy managemen t | 1) Smart home energy management technology | 1) Load monitor achieves real-time monitoring of energy or power.<br>2) In-home display provides real-time monitoring and information about historic events regarding energy or power.<br>3) Smart thermostat provides visualization on the setpoint of HVAC and real-time monitoring of status.4) Smart light provides status of light.<br>5) Smart plug/switch provide feedback on power use.<br>6) Smart appliances provide appliance status and notifications about certain events. |
| 13 | Majumder et al. | Sensors | Smart homes for elderly healthcare—Recent advances and research challenges. | 2017 | Canada | Healthcare | 1) Smart monitoring systems | 1) Automatic emergency calling system.<br>2) Automatic events detecting function regarding users' activity.<br>3) Vital signs monitoring systems.<br>4) Reminding systems.<br>5) Automated health assessment. |

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| 14 | Liu et al. | Energy Procedia | Review of smart home energy management systems | 2016 | China | Energy managemen t | 1) Smart home energy management system | 1) Monitor, control, and optimize the flow and use of energy.<br>2) Provide ancillary services includes demand response, demand-side management, peak shaving and load shifting. |
| 15 | Zhou et al. | Renewable and Sustainable Energy Reviews | Smart home energy management systems: Concept, configurations, and scheduling strategies. | 2016 | China | Energy managemen t | 1) Smart home energy management system | 1) Provide visualization and real-time feedback on operational modes, energy status, and energy consumption of domestic appliances.<br>2) Store historical data regarding domestic appliances' energy consumption, spot price, and demand response analysis from the grid.<br>3) Allow users to monitor and control of energy usage patterns of domestic appliances.<br>4) Enhance the optimization and efficiency of energy consumption via the smart management system.<br>5) Generate alarm if any abnormality detected and sent warnings to the centre system including relevant information of failure. |
| 16 | Zhang et al. | Neurocomputi ng | ISEE Smart Home (ISH): Smart video analysis for home security. | 2015 | China | Living environment | 1) Smart video analysis | 1) Baby abnormal activity detection.<br>2) Abnormal behaviour detection of old (sick) people.<br>3) Illegal intrusion detection.<br>4) Security protection of the unattended house |

**Appendix B:** Motivations for smart homes adoption

| No | Author | Journal | Title | Year | Region | Area | Motivation | Findings |
|---|---|---|---|---|---|---|---|---|
| 1 | Arthanat et al. | Journal of Enabling Technologies | Determinants of information communication and smart home automation technology adoption for aging-in-place. | 2020 | USA | Healthcare | 1) Promote home safety, health monitoring and independence of the elderly to age-in-place. | 1) Once the elderly realises the benefits provided by smart homes, such as physical activity, independence, and function, they will readily accept this innovation. |
| 2 | Cockbill et al. | Energy Research & Social Science | Householders as Designers? Generating Future Energy Services with United Kingdom Home Occupiers | 2020 | UK | Energy management | 1) Provide energy information<br>2) Enable control of energy<br>3) Have the potential to change future energy services<br>4) Provide services that 'Go Beyond' energy | 1) Provide information, suggestions, or reminders to householders, which regarding energy usage, users' behaviours, and energy supplier and tariff.<br>2) Extend controllability over appliances to provide potential new ways of energy management.<br>3) Promote resource efficiency and alternative way of doing to change the preconditions for energy use.<br>4) Identify potential safety and security threats and provide warnings or alerts. |
| 3 | Shank et al. | International Journal of Human–Computer Interaction | Knowledge, Perceived Benefits, Adoption, and Use of Smart Home Products | 2020 | USA | Living environment | 1) Monetary saving<br>2) Ease of use and lifestyle benefits<br>3) Generate pleasance via using and controlling, i.e., having fun | 1) Monetary saving only provided by specific smart home technologies or services.<br>2) Potential benefits outweigh risks such as privacy and security risks, users generally trust product manufacturers can provide sufficient protections regarding security threats even these protections cannot be verified. |
| 4 | Sovacool & Furszyfer | Renewable and Sustainable Energy Reviews | Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies | 2020 | UK | Energy management<br><br>Living environment<br><br>Healthcare | 1) Improve energy services management or reduced energy consumption.<br>2) Improve household's convenience and controllability.<br>3) Financial benefits.<br>4) Aesthetic benefits.<br>5) Health benefits.<br>6) Entertainment benefits.<br>7) Protected safety and security of the home | 1) Reduce energy demand and provide better demand management.<br>2) Simplify household works and reduce users' mental load on tasks.<br>3) Provide clearness on energy spending and save money.<br>4) Add symbolic value to a house and allow owners to show their leading position on the curve of fashion or style.<br>5) Provide better in-home healthcare and assistance services to enable people to live at home for a long and with a healthier living environment.<br>6) Provide better ways of entertainment such as listening to music, watching movies, or online streaming.<br>7) Prevent serious accidents from happening and serve a critical role in the safety and security of the home. |
| 5 | Zaidan & Zaidan | Artificial Intelligence Review | A review on intelligent process for smart home applications | 2020 | Malaysia | Energy management<br><br>Healthcare | 1) Efficient use of electricity.<br>2) Safety guarantee in terms of electricity consumption.<br>3) Better health care services.<br>4) Cost saving. | 1) Provide efficient power management by the transparency of energy usage to allow users utilise energy efficiently.<br>2) Provide a safety electricity guarantee through load maintaining and restriction.<br>3) Enhance in-home care for older or disabled people. |

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| | | | based on IoT: coherent taxonomy, motivation, open challenges, and recommendations. | | | Living environment | | 4) Allow users to fulfil domestic energy needs at affordable costs. |
| 6 | Arthanat et al. | OTJR Occupation, Participation and Health | Profiles and predictors of smart home technology adoption by older adults | 2019 | USA | Healthcare | 1) Promote aging-in-place to save costs on institutional care | 1) Promote older adult's independence and strength their quality and safety of life. |
| 7 | Lutolli & Vrhovec | Elektrotehniski Vestnik | Adoption of smarthome devices: Blinded by benefits, ignoring the dangers? | 2019 | Slovenia | Technology | 1) Improve devices' controllability to reduce user's workload on daily tasks.<br>2) Support the independent life of the elderly and disabled people. | 1) The integration of artificial intelligence can support fully independent and automatic operation of smart homes, which reduces users' workload on managing and daily tasks.<br>2) Different kinds of smart home devices can provide users with the advantages of comfort, security, energy efficiency, etc.<br>3) Enhance the level of healthcare services and provide better quality of life. |
| 8 | Ringel et al. | Energies | Multiple benefits through smart home energy management solutions—A simulation-based case study of a single-family-house in Algeria and Germany. | 2019 | Germany | Energy management | 1) Energy saving.<br>2) Economic benefits.<br>3) Environmental benefits. | 1) Achieve energy savings in the low-cost installation scenario.<br>2) A highly beneficial investment, which through translate the energy savings into highly profitable overall investments.<br>3) Not only offers the environmental benefits such as saving CO2 emissions but also engage individual into welfare of environment. |
| 9 | Schill et al. | Ecological Economics | Consumers' intentions to purchase smart home objects: Do environmental issues matter? | 2019 | France | Sustainability | 1) Environmental beliefs. | 1) Consumers' environmental concern has a positive and significant effect on their intention to purchase "eco-friendly smart home objects" (ESHO). "The more consumers care for the natural environment, the more they will be willing to purchase ESHO". |
| 10 | Shuhaiber & Mashal | Technology in Society | Understanding users' acceptance of smart homes. | 2019 | Jordan | Living environment | 1) Generate enjoyment via working in smart homes. | 1) Perceived enjoyment can elevate users' attitude towards smart home and increase their adoption intention. |

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| 11 | Basatneh et al. | Journal of Diabetes Science and Technology | Health sensors, smart home devices, and the internet of medical things: an opportunity for dramatic improvement in care for the lower extremity complications of diabetes. | 2018 | USA | Healthcare | 1) Better health care delivery and outcomes | 1) Smart home devices as a part of Internet of medical things (IoMT) have contribute to opening "new avenues and opportunities in health care from remote monitoring to smart sensors and medical device integration". It has the potential to empower patients to maintain their independence at home and improve the ability of healthcare professional to deliver personalized and timely care. |
| 12 | Parag & Butbul | Energy Research & Social Science | Flexiwatts and seamless technology: Public perceptions of demand flexibility through smart home technology. | 2018 | Israel | Energy management<br><br>Living environment | 1) Demand flexibility of energy<br>2) Benefits of comfort and convenience | 1) Provide demand flexibility of resources including flexible generation and flexible transmission.<br>2) Finding shows prospective adopters were willing to accept the risks associated with the technologies to pursue the benefits of comfort and convenience. |
| 13 | Sanguinetti et al. | Energy Research & Social Science | Understanding the path to smart home adoption: Segmenting and describing consumers across the innovation-decision process | 2018 | USA | Living environment | 1) Improved quality of the living environment, e.g., convenience, comfort, enjoyment, security, and health. | 1) The non-energy benefits, i.e., promoting lifestyle vision, are driving home energy management smart hardware adoption, rather than environmental benefits. |
| 14 | Alaa et al. | Journal of Network and Computer Applications | A review of smart home applications based on Internet of Things. | 2017 | Malaysia | Energy management<br>Living Environment<br>Healthcare | 1) Benefits of energy conservation<br>2) Benefits of healthcare<br>3) Reduce the cost of basic needs<br>4) Entertainment and comfort | 1) Assist user wirelessly control and manage domestic appliances and energy consumption efficiently to increase the convenience and efficiency of daily activities and maintain energy usage for monetary savings and reduce expenses.<br>2) Enhance the in-home care services and provide assistance for the elderly or the disabled to achieve long and healthy lives and prevent loneliness.<br>3) Save householder's money on daily basic needs, such as healthcare delivery costs and energy costs.<br>4) Provide comfort, safety and security living environment to users. |
| 15 | Strengers & Nicholls | Energy Research & Social Science | Convenience and energy | 2017 | Australia | Living environment | 1) Achieving convenient lifestyle to generate pleasance | 1) Smart home can generate pleasance in people's life by enrolling in convenience or other simple solutions, which |

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| | | | consumption in the smart home of the future: Industry visions from Australia and beyond. | | | | | includes creating ambiance, fun, comfort, atmosphere, elegance, and new aesthetic experiences. |
| 16 | Peek et al. | Gerontology | Older adults' reasons for using technology while aging in place. | 2016 | Netherlands | Healthcare | 1) Achieve independent living. | 1) Smart home technologies contribute to achieving elderly users' independent living, such as provide assistance on daily tasks, social communication, and maintaining physically active. |
| 17 | Wong & Leung | Facilities | Modelling factors influencing the adoption of smart-home technologies. | 2016 | Hong Kong | Healthcare | 1) Maintain elderly's independence and to live safely at home | 1) Provide a more cost-effective and less-dependent solution for public-sector service provision. |
| 18 | Wilson et al. | Personal and Ubiquitous Computing | Smart homes and their users: a systematic analysis and key challenges. | 2015 | UK | Energy management<br><br>Living environment | 1) Better manage the demands of daily living<br>2) Reduce energy demand in households | 1) Help people to achieve or enhance household tasks and activities, which will contribute to "better living".<br>2) Achieve the goal of energy demand reduction and has the potential to play key roles in the transition to affordable low-carbon energy. |
| 19 | Paetz et al. | Journal of Consumer Policy | Smart homes as a means to sustainable energy consumption: A study of consumer perceptions. | 2012 | Germany | Energy management | 1) Monetary saving.<br>2) Environmental friendliness.<br>3) High levels of flexibility.<br>4) Transparency about electricity consumption and costs.<br>5) Enthusiasm for new technologies. | 1) Finding shows monetary savings were the most important motivation. |

**Appendix C:** Barriers to smart homes adoption

| No | Author | Journal | Title | Year | Region | Area | Barrier | Solution |
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| 1 | Chen et al. | Energy Research & Social Science | When east meets west: Understanding residents' home energy management system adoption intention and willingness to pay in Japan and the United States | 2020b | USA | Energy management | 1) High adoption cost.<br>2) Cybersecurity and privacy threats.<br>3) Cultures and social-psychological factors.<br>4) Lack of unified communication and interoperability standards. | 1) Develop easy to use products and provide simple education tutorial based on different demographics and social-psychological factors.<br>2) Introduce innovation with multiple benefits, such as financial (cost-saving), environmental (emissions reduction), social and well-being (healthier lifestyle).<br>3) Develop technical improvements to deal with privacy and security concerns.<br>4) Develop integration strategies to solve the compatibility between innovation and 'non-smart' home (existing or older homes). |
| 2 | Ghorayeb et al. | International Journal of Human-Computer Studies | Older adults' perspectives of smart home technology: Are we developing the technology that older people want? | 2020 | UK | Healthcare | 1) Social responsibility and connectedness desire.<br>2) The concerns of personal information anonymity. | 1) Develop technologies aiming to facilitate new social and community connection to increase the scale of the social circle.<br>2) Provide the data sharing selection function to users. |
| 3 | Grunewald & Reisch | Energy Research & Social Science | The trust gap: social perceptions of privacy data for energy services in the United Kingdom. | 2020 | UK | Energy management | 1) Low levels of trust in the key organisations such as utilities, energy providers, and smart home companies. | |
| 4 | Hong et al. | Telecommunications Policy | What will be the possible barriers to consumers' adoption of smart home services? | 2020 | Korea | Living environment | 1) High initial adoption cost and high potential maintenance costs.<br>2) Personal information leakage.<br>3) Negative psychological concerns, e.g., affect occupants' self-image or lifestyle. | 1) Provide affordable products and services.<br>2) Reinforce users' trust and confidence via advertising.<br>3) Raise consumers' familiarity with the smart home.<br>4) Develop technical improvements to prevent personal information leakage.<br>5) Reinforce existing legal framework regarding privacy. |
| 5 | Sovacool & Furszyfer | Renewable and Sustainable Energy Reviews | Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies | 2020 | UK | Living environment | 1) Lack of homeownership.<br>2) Cultural differences. | |
| 6 | Talukder et al. | Technological Forecasting and Social Change | Predicting antecedents of wearable healthcare technology acceptance by | 2020 | China | Healthcare | 1) Social influences such as evaluations and opinions from external environments.<br>2) Technology anxiety<br>3) The resistance to innovation and changes. | 1) Generate positive publicity via different forms and prepare counterplans for negative voices.<br>2) Provide good training and easy-use products and services. |

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| | | | elderly: A combined SEM-Neural Network approach. | | | | | |
| 7 | Hubert et al. | European Journal of Marketing | The influence of acceptance and adoption drivers on smart home usage | 2019 | Germany | Technology | 1) Perceived usefulness (PU) and perceived ease of use (PEOU) of technology.<br>2) The compatibility between technologies and lifestyles. | 1) Improve the compatibility of smart home and users' lifestyles<br>2) Avoid causing major changes in users' daily living environment and mode of life. |
| 8 | Ji & Chan | Energies | Critical factors influencing the adoption of smart home energy technology in china: A Guangdong province case study | 2019 | China | Energy management | 1) Consumers' attitude towards technical performance.<br>2) Social influences from external environments such as government policies, the voices of mass media, and social network.<br>3) Social norm such as the moral dimension of an individual's internal values. | 1) Enhance technical performance and user experience. |
| 9 | Mashal & Shuhaiber | Kybernetes | What makes Jordanian residents buy smart home devices? A factorial investigation using PLS-SEM | 2019 | Jordan | Living environment | 1) Concerns about reliability.<br>2) Social influence.<br>3) Exorbitant or unaffordable cost.<br>4) People’s awareness or understanding. | 1) Establish the consumer's trust. |
| 10 | Mulcahy et al. | Journal of Marketing Management | Are households ready to engage with smart home technology? | 2019 | Australia | Living environment | 1) Trust significantly impact consumer’s adoption intention. | 1) Customise strategies based on consumers’ technology readiness to minimise feelings of discomfort and insecurity.<br>2) Marketing messaging focus on building trust rather than reducing risk. |
| 11 | Nikou | Telematics and Informatics | Factors driving the adoption of smart home technology: An empirical assessment | 2019 | Finland | Living environment | 1) Perceived usefulness and perceived ease of use.<br>2) People’s awareness or understanding. | |
| 12 | Pal et al. | IEEE Access | Embracing the smart-home revolution in Asia by the elderly: An end-user negative perception modeling | 2019 | Thailand | Living environment | 1) Distrust of IoT devices and sensors.<br>2) Limited interoperability between different devices and lack of technical standardization.<br>3) Huge upfront investment or later adoption costs.<br>4) Data privacy and leakage of sensitive personal information. | 1) Reduce adoption costs.<br>2) Create a favourable environment, e.g., tax concession, preferential policy.<br>3) Adopt a ‘privacy by design’ approach.<br>4) Conduct awareness campaigns regarding data transparency and improved privacy measures. |
| 13 | Shuhaiber & Mashal | Technology in Society | Understanding users’ acceptance of smart homes. | 2019 | Jordan | Living environment | 1) Perceived security and privacy risks.<br>2) Distrust due to perceived risks. | 1) Establish users’ trust in smart homes.<br>2) Popularise relevant knowledge to increase users’ awareness about smart homes. |

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| | | | | | | | | 3) Provide interactive functions to improve users' enjoyment on smart home. |
| 14 | Washizu et al. | Sustainability | Willingness to pay for home energy management systems: A survey in New York and Tokyo | 2019 | Japan | Energy management | 1) People's awareness regarding usefulness and convenience.<br>2) Technology anxiety.<br>3) Low levels of trust in utility.<br>4) Exorbitant adoption cost. | |
| 15 | Aldossari & Sidorova | Journal of Computer Information Systems | Consumer acceptance of Internet of Things (IoT): Smart home context | 2018 | USA | Living environment | 1) People's awareness regarding the usefulness.<br>2) Lack of perceived values.<br>3) Security risks. | 1) Involve consumers in the product engineering process to meet their expectation.<br>2) Technical improvements regarding security.<br>3) Provide transparency on personal data handling and protection. |
| 16 | Arthanat et al. | OTJR Occupation, Participation and Health | Profiles and predictors of smart home technology adoption by older adults | 2018 | USA | Healthcare | 1) The types of smart devices or services influences adoption intention.<br>2) Demographic characteristics influences adoption intention. | 1) Provide awareness of benefit and usefulness.<br>2) Reduce technology anxiety. |
| 17 | Cannizzaro et al. | PLoS ONE | Trust in the smart home: Findings from a nationally representative survey in the UK | 2018 | UK | Living environment | 1) Low levels of trust in IoT.<br>2) Resistance to IoT. | 1) Develop security standards and adopt them in the product design process.<br>2) Provide transparency on personal data handling.<br>3) Improve product reliability.<br>4) Provide users with information and knowledge regarding security and privacy threats and incidents.<br>5) Resonate with consumers' need, expectations, and concerns. |
| 18 | Pal et al. | IEEE Access | Analyzing the elderly users' adoption of smart-home services. | 2018 | Thailand | Healthcare | 1) Users' affordability, i.e., high initial set-up costs.<br>2) Security and privacy concerns. | 1) Develop 'easy to use' innovative solutions to improve satisfaction level.<br>2) Consider cost as an important factor in smart home popularisation.<br>3) Consider health and social aspects first rather than hedonic values during designing smart homes for the elderly.<br>4) Pay more attention to data privacy and anonymity. |
| 19 | Pal et al. | IEEE Access | Internet-of-things and smart homes for elderly healthcare: An end user perspective. | 2018 | Thailand | Healthcare | 1) Low levels of trust in service providers, i.e., regarding privacy and security of data collection.<br>2) Concerns of data anonymity.<br>3) Technology anxiety.<br>4) High adoption costs. | 1) Provide personalized and real-time technical support.<br>2) Reduce the cost of products or services. |
| 20 | Sanguinetti et al. | Energy Research & Social Science | Understanding the path to smart home adoption: Segmenting and describing consumers across | 2018 | USA | Energy management | 1) Un-readily information.<br>2) Sceptical devices performance.<br>3) Technological difficulty.<br>4) Concerns of investment feasibility.<br>5) Manoeuvrability issues. | |

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| | | | the innovation-decision process | | | | 6) Security and privacy concerns, i.e., unauthorized use of personal information. | |
| 21 | Sanguinetti et al. | Energy Efficiency | What's energy management got to do with it? exploring the role of energy management in the smart home adoption process | 2018 | USA | Energy management | 1) Low knowledge levels of smart home.<br>2) Un-perceive benefits.<br>3) Concerns of products and services, e.g., performance, costs, data privacy and security. | 1) Provide users with accessible information.<br>2) Bundle smart home with more popular products or services to increase the perceived values. |
| 22 | Wang et al. | Journal of Computer Information Systems | I want it anyway: consumer perceptions of smart home devices. | 2018 | USA | Living environment | 1) Privacy concern, user concerned they lost control over personal information.<br>2) Performance concern.<br>3) Time consuming concern, user do have an awareness of installation, setting up, and successful operation would take much time. | 1) Establish relevant privacy policies to inform users transparently how will the collected information be used.<br>2) Improve the performance and conciseness of devices to reduce the disruption to daily routines and time of installation and operation. |
| 23 | Yang et al. | Journal of Sensors | IoT smart home adoption: The importance of proper level automation | 2018 | Korea | Technology | 1) Perceived controllability, interconnectedness, reliability affect user's adoption intention. | 1) Assure the functional diversity of smart products and configure related services.<br>2) Invest basic infrastructures to provide the user with a better usage experience.<br>3) Develop technical improvements and set up internal policies to prevent information leakage to increase perceived reliability. |
| 24 | Chen et al. | Energy Research & Social Science | Between the technology acceptance model and sustainable energy technology acceptance model: Investigating smart meter acceptance in the United States. | 2017 | USA | Energy management | 1) Perceived privacy risk.<br>2) The trust to utilities or energy providers significantly acceptance and adoption intentions. | 1) Provide transparency on data handling process.<br>2) Prevent unauthorized data use and provide warnings to consumer.<br>3) Retain users' control and dispel misperceptions about real-time surveillance. |
| 25 | Wilson et al. | Energy Policy | Benefits and risks of smart home technologies | 2017 | UK | Living environment | 1) Concerns of adoption cost, include upfront cost and follow-up cost of usage and maintain.<br>2) Concerns of data privacy and security.<br>3) Lack confidence in devices reliability.<br>4) The interoperability of different technologies or devices from different manufacturers. | 1) Build quality control framework.<br>2) Build up the policies to support smart home technologies that are enabling health, quality of life or other social benefits.<br>3) Involved stakeholders in product engineering process to develop a shared vision. |
| 26 | Wong & Leung | Facilities | Modelling factors influencing the adoption of smart- | 2016 | Hongkong | Healthcare | 1) Social influences, older user's adoption intention or decision was greatly influenced by "government support". | |

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| | | | home technologies. | | | | | |
| 27 | Balta-Ozkan et al. | Energy Research & Social Science | European smart home market development: Public views on technical and economic aspects across the United Kingdom, Germany and Italy. | 2014 | UK | Living environment<br><br>Energy management<br><br>Technology | 1) Privacy and data security concern.<br>2) Lack of technological knowledge and resulted failures.<br>3) The concern of suitability in existing or older building.<br>4) High adoption and maintenance costs. | 1) Communicate the benefits to consumers.<br>2) Develop 'privacy-friendly' techniques.<br>3) Legal improvements to change users' perceptions about unsuitability of innovation for older buildings.<br>4) "Perceptions on the suitability of smart home technology and services mainly for homeowners indicate policy leadership should make sure 'people are not disadvantaged' and that no further divisions are created in society".<br>5) Spread the costs over whole lifecycle of smart homes. |

**Appendix D:** Risks of smart homes adoption

| No | Author | Journal | Title | Year | Region | Area | Risk | Consequence | Solution |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ghorayeb et al. | International Journal of Human-Computer Studies | Older adults' perspectives of smart home technology: Are we developing the technology that older people want? | 2020 | UK | Healthcare | 1) Difficulties in using technologies.<br>2) Reduce daily activities and increase loneliness.<br>3) Increase dependence and decrease autonomy. | 1) Potential influence on socialising.<br>2) Create burden to other family members.<br>3) Technology replaces human to increase older people's loneliness. | 1) Develop unobtrusive technologies.<br>2) Provide older people with an easy understanding of technical knowledge about technology.<br>3) Allow older people to customize and control technology.<br>4) Develop technologies focusing on social well-being. |
| 2 | Nicholls et al. | Nature Energy | Social impacts and control in the smart home. | 2020 | Australia | Living environment | 1) Threats of social manipulation and control<br>2) Diminished family interactions<br>3) Threats of techno-fix or techno-fail | 1) Create or exacerbate existing family power and gender imbalances.<br>2) Leakage of private information.<br>3) Loss of control power.<br>2) Introduce safety and privacy threats into the home from the outside. | Further research "should investigate diverse outcomes — including how smart technologies with energy saving capabilities impact overall home energy use, the positive and negative impacts on social interactions, security and wellbeing, and how a trajectory towards more device-intensive lives will impact financial security in households trying to keep up with new trends and 'necessities' within and beyond the energy sphere". |
| 3 | Oliveira et al. | Personal and Ubiquitous Computing | Smart home technology: Comparing householder expectations at the point of installation with experiences 1 year later | 2020 | UK | Living environment | 1) Some smart technologies were unreliable.<br>2) Understanding and managing smart home is time and effort consuming work.<br>3) Smart home technologies may not fit the way that every consumer manages their households. | 1) Some devices may easily fail in daily use and may have internet glitches and other physical and technical problems.<br>2) Users may experience difficulties in the technology of domestication and that dedicated time and effort was required.<br>3) Existing devices or systems lacks predictable routines to fit within users' expected lifestyle. | |
| 4 | Sovacool & Furszyfer | Renewable and Sustainable Energy Reviews | Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies | 2020 | UK | Technology | 1) Threats to consumer protection and data security<br>2) Technical reliability and obsolescence issues<br>3) Usability and 'domesticate' issues | 1) The collected users' information such as houses, affiliated technologies, user demographics and consumption patterns can be stolen, hacked, | |

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| | | | | | | | 4) Interoperability and resilience risks<br>5) Energy rebounds and wasteful consumption<br>6) Loss of personal control and autonomy | or misused that creates severe risks.<br>2) The complex and interconnected systems could create dependencies between each device that can erode the reliability of the whole system.<br>3) Domesticating technologies into their lifestyles is time and effort consuming work.<br>4) The interoperability issues and incumbency of smart home would cause challenges for users' daily use.<br>5) The expected positive effect on sustainability may be destroyed by the desired vision.<br>6) "Smart home technologies could lead to loss of personal control and autonomy, with households becoming more dependent on smart technology. This could create conditions where people serve the system, rather than having the system serve them." | |
| 5 | Strengers et al. | International Journal of Human Computer Studies | Pursuing pleasance: Interrogating energy-intensive visions for the smart home | 2020 | Australia | Energy management | 1) The lifestyle vision promoted by smart home technologies may undermine the intended goal of energy efficiency. | 1) The value propositions of smart home may be unable to support the assumption of improving sustainability. | 1) Reimagine other desirable ways of life to reduce energy demands via cultural probes and other participatory methodologies. |
| 6 | Walzberg et al. | Renewable and Sustainable Energy Reviews | Should we fear the rebound effect in smart homes? | 2020 | Canada | Energy management | 1) Rebound effect of energy.<br>2) "Technological advancement alone cannot lead to sustainable | 1) Environmental rebound effect. The initial emission reduction may offset by more polluting products. | |

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| | | | | | | | consumption patterns”.<br>3) Unforeseen indirect social or economic effect | 2) The introduced new consumption models may lead to other types of unforeseen indirect social or economic effect. | |
| 7 | Zimmermann et al. | I-Com | Assessing users' privacy and security concerns of smart home technologies | 2020 | Germany | Technology | 1) Loss of control.<br>2) Increased dependency from technology.<br>3) Cyber-attacks on smart home devices and data storge. | 1) The inability of control or handle smart devices may increase users' external dependency.<br>2) Can be used to achieve criminal activities that causing physical accidents and financial loss | 1) Implement fallback mechanisms and design error management approaches for technical malfunctions. Improve transparency, usability, and controllability of devices to clearly provide guidelines and guaranty to enable users to manually control devices simply.<br>2) The system should be designed under relevant security standards and adopt practices preventing attacks. Once under attacks, the system should provide warning and assistance to users in cope with and recovering from threats. |
| 8 | Chadborn et al. | Healthcare | Citizens’ juries: When older adults deliberate on the benefits and risks of smart health and smart homes. | 2019 | UK | Healthcare | 1) Loss of independence while safety monitoring<br>2) Risk of data-sharing and privacy | 1) Users or other inhabitants may lose their privacy and independence may while activating assistive technologies or safety monitoring function at home.<br>2) Ethical and privacy issues related to information sharing, such as medical information sharing with health professionals or social workers. “Will the individual know and have control over who has access to personal data?” | |
| 9 | Lutolli & Vrhovec | Elektrotehniski Vestnik | Adoption of smarthome devices: Blinded by benefits, ignoring the dangers? | 2019 | Slovenia | Technology | 1) Theft and misuse of sensitive data<br>2) Eavesdropping and interception.<br>3) Connection issues due to natural disasters and accidents. | 1) Cause material damage, personal injury or even death.<br>2) Cause smart home to fail to operate unexpectedly or occur errors.<br>3) Accidental data loss, such as critical or pivotal recorded information. | 1) Industry should put a strong focus on how to provide the identical degree of privacy and security on 'smart' homes, which same as 'non-smart homes. |

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| 10 | Nicholls & Strengers | Energy Research & Social Science | Robotic vacuum cleaners save energy? Raising cleanliness conventions and energy demand in Australian households with smart home technologies. | 2019 | Australia | Energy management | 1) Destruction of the prospective energy reduction's goal and threaten household wellbeing. | 1) Cannot achieve a straightforward or guaranteed outcome of carbon emissions and/or peak demand reduction.<br>2) The broader lifestyle visions could significantly influence household consumption and would likely to undermine energy reductions. | 1) Redefine consumer perceptions of 'smartness'.<br>2) Consider the optimistic technical possibilities and the ambiguities and risks concerning the adoption of the smart home.<br>3) Embed the easily attainable and energy efficient ideas into the smart device design.<br>4) Reconfigure visions of the smart home. |
| 11 | Park et al. | Sensors | Security risk measurement for information leakage in IoT-based smart homes from a situational awareness perspective. | 2019 | USA | Technology | 1) Risk of information leakage | 1) Data collected by the smart devices may lead to leakage of personal information under malicious attacks. In this case, attackers could monitor the user's life or unauthorizedly use their information, which causes economic, social, and political damages. | |
| 12 | Ali & Awad | Sensors | Cyber and physical security vulnerability assessment for IoT-based smart homes. | 2018 | Sweden | Technology | 1) Smart homes based on IoT are highly vulnerable to cyber-attacks. | 1) "If the entire smart home system or a smart device is compromised, the adversary will be able to invade the privacy of smart home inhabitants, steal personal or sensitive information, control the smart home system, and even monitor residents inside the smart home environment". | 1) Apply reliable user authentication methods to supply devices with stronger security capabilities.<br>2) Improve the existing legal framework related to personal information security.<br>3) Consider multiple factors impacting the security of smart homes in the product designing process. |
| 13 | Hargreaves et al. | Building Research and Information | Learning to live in a smart home | 2018 | UK | Living environment | 1) Disruption in technical and social dimensions.<br>2) Users are required to adapt and familiarize technologies.<br>3) Time and effort consuming on | 1) Disrupt existing domestic technologies and unsettle existing roles and relationships in the family.<br>2) Require considerable work to domesticate technologies and require new skills to deal with the interaction | |

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| | | | | | | | learning to use technologies.<br>4) Generate multifarious forms of energy intensification. | between devices provided by new technologies.<br>3) Create or encourage new forms of energy demand. | |
| 14 | Heartfield et al. | Computers and Security | A taxonomy of cyber-physical threats and impact in the smart home | 2018 | UK | Technology | 1) Cyber-physical threats | 1) Financial loss, personal and private information leakage, loss of control over devices. | 1) Classify cyber threats and attack vectors.<br>2) Evaluate threats and impacts.<br>3) 3) In allusion to different characteristics of these attacks to build technical defences to address such threats. |
| 15 | Herrero et al. | Current Opinion in Environmental Sustainability | Smart home technologies in everyday life: do they address key energy challenges in households? | 2018 | Australia | Energy management<br><br>Living environment | 1) Promote energy-intensive ways of life<br>2) Exacerbate vulnerabilities and inequities related to energy in the family.<br>3) Exacerbate domestic energy poverty. | 1) Increase energy consumption and undermine the goals of domestic energy savings.<br>2) Uneven distribution of benefits over different households, which depend on the smart device ownerships or reliable internet services.<br>3) Enable and justify energy policy shifts towards more cost-reflective tariffs that exacerbating energy poverty. | |
| 16 | Wilson et al. | Energy Policy | Benefits and risks of smart home technologies | 2017 | UK | Living environment | 1) Increase dependence on technologies and electricity networks.<br>2) Proliferate non-essential luxuries, e.g., laziness in domestic life. | 1) "The benefits of increased control over the domestic environment come at the expense of reduced autonomy and independence of the home from encompassing sociotechnical systems." | |
| 17 | Jacobsson et al. | Future Generation Computer Systems | A risk analysis of a smart home automation system | 2016 | Sweden | Technology | 1) Cause undesirable consequences to user privacy. | 1) Form decision support for criminal activities. | 1) Integrate security and privacy protection measures into system design. |
| 18 | Xu et al. | IEEE Communications Magazine | Toward software | 2016 | China | Technology | 1) Existing management | 1) Security and privacy threats, such as maliciously controlling | |

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| | | | defined smart home | | | | strategies unable to meet users' demand.<br>2) Security and privacy threats. | devices or stealing privacy information, would lead to huge economic loss. | |
| 19 | Komninos et al. | IEEE Communications Surveys and Tutorials | Survey in smart grid and smart home security: Issues, challenges, and countermeasures | 2014 | UK | Energy management | 1) Privacy and security threats | 1) “Various interactions amongst smart home entities could become targets for a cyber or physical attack by an adversary or even by a mischievous customer”. | 1) “Establishing new metrics for the evaluation of the cyber security mechanisms and solutions suggested.”<br>2) “Establishing a legal framework specific to privacy and security issues.”<br>3) “Establishing new techniques for facing jamming attacks.” |

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