From cookstoves to smart homes: Examining the social dynamics of household energy behaviour

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By

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“Technological change defines the horizon of our material world as it shapes the limiting conditions of what is possible and what is barely imaginable. It erodes assumptions about the nature of our reality, the "pattern" in which we dwell, and lays open new choices”.

Shoshana Zuboff

Declaration of own work

I declare that this thesis

"From cookstoves to smart homes: Examining the social dynamics of household energy behaviour" is entirely my own work and that where any material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

Signature:

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Abstract:

This PhD examines the social dynamics of household energy behaviour through a mixed methods approach. First, through an extensive literature review analysis from 2013 to 2017, it overviews the current knowledge to identify what behaviour change techniques are the most successful for the uptake and maintained use of improved cookstoves. This research also addresses a set of policy recommendations and assesses academic gaps in the literature. Second, based on an original dataset involving expert interviews, site visits to retailers, and a comprehensive review of the literature, this PhD examines the promises and perils of smart home technologies. Drawing on original data collected in the United Kingdom, it later examines current definitions of smart homes and provides 267 specific options commercially available from 113 companies to provide a new classification of smart technology, structured into 13 categories. Then, this PhD situates these technology categories alongside six levels of smartness, from basic or traditional homes to fully automated and sentient homes. Under this benchmark, it discusses 13 distinct benefits and 17 risks and barriers for smart homes to introduce seven policy recommendations and 15 emerging business models. Third, through a rigorous mixed methods research design, comprised of a nationally representative survey in the United Kingdom (n=1,032) and focus groups in London, Manchester, and Surrey (n=18 respondents) this thesis identifies the gendered nature of smart homes across five different dimensions (1) knowledge, awareness, and adoption patterns; (2) housekeeping and daily domestic life; (3) environmental sustainability; (4) trust and risk tolerance; and (5) emotions and feelings. Additionally, this research explores the extent that smart home technologies can act as potential enablers of domestic abuse and as enablers of conflict within households. It concludes with policy implications as well as how these findings point the way towards future research.

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Table 1: List of acronyms with their corresponding meaning presented in alphabetical order

Acronym	Meaning
AI	Artificial intelligence
ANT	Actor Network Theory
BC	Behaviour Change
BCT	Behaviour Change Technique
BEIS	Department for Business, Energy & Industrial Strategy
COP	Conference of the Parties
CRM	Community Readiness Model
DNO	Distribution Network Operator
ICS	Improved Cookstove
ICT	Information and Communication Technology
IEA	International Energy Agency
IT	Information Technology
IoT	Internet of Things
LCICG	The Low Carbon Innovation Coordination Group
LPWAN	Low-power Wide-Area Network
LTS	Large Technical Systems.
MLP	Multi-Level Perspective
NICE	The National Institute for Health and Care Excellence
NHS	National Health Service
OECD	Organization for Economic Co-operation and Development
QoL	Quality of Life
RD&D	Research Design and Development
RDIT	Rogers Diffusion of Innovation Theory
SCOT	The Social Construction of Technology
SEI	Stockholm Environment Institute
SHT	Smart Home Technology

SGTF	Smart Grids Task Force
SLFC	Short-Lived Climate Forcers
SUM	Stove-Use Monitors
TIS	Technological Innovation Systems
UNFCCC	United Nations Framework Convention on Climate Change
CO_2	Carbon Dioxide
Greenhouse gas	GHG
IMP	Interface Message Processor
ITU	The International Telecommunication Union

Chapter 1 Introduction

If we have any chance of limiting climate change to 1.5 degrees, we will need a degree of technological innovation and behaviour change (IPCC, 2018b). Hence, it is of utter importance to switch from risky and carbon intensive technologies to innovative and more sustainable lifestyles (IPCC, 2018a). In these circumstances, The Paris Agreement adopted by consensus on the 12th of December 2015 at the 21st Conference of the Parties (CoP21) of the United Nations Framework Convention on Climate Change (UNFCCC), aims to limit the rise of global temperatures to 1.5 degrees centigrade above pre-industrial levels (Bell *et al.*, 2016). The intention, as stated in Article 2, is to "*strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty* (United Nations, 2015)". In this sense, the role of renewables energies with the integration of emerging technologies, is argued to play a fundamental role in cutting and controlling CO_2 emissions. (International Energy Agency, 2017).

Given that the buildings' sector represents around 28% of total energy-related CO_2 emissions (International Energy Agency, 2019), this research aims to have a broader understanding of households' dynamics regarding energy use and consumption from two very different household energy systems, one mundane/low-tech (cookstoves) and one high-tech (smart homes). In this sense, this research approaches the subject through a dichotomous perspective.

The first looks at the household dynamics related to the adoption of improved cookstoves (ICS) in Sub-Sharan Africa. This research line was undertaken to cover the global reach of the Paris Agreements and at the same time, since tackling this issue, could help in addressing at least four Sustainable Development Goals (1- No poverty, 3- Good health and wellbeing, 5- Gender equality and 13- Climate Action) (Stuart and Woodroffe, 2016). Regarding combating climate change, given that around 41% of households globally, that is, over 2.8 billion people rely on solid fuels (coal and biomass) to satisfy their cooking and heating needs (World Health Organization, 2015), replacing traditional wood and coal-burning cookstoves with cleaner technology could cut nearly a tenth of a degree from global temperature and save more than 10 million lives by 2050 (Lacey *et al.*, 2017). Given that little research has been conducted to understand what drives initial purchase of ICS and in particular, the continued use of advance cooking technologies remains limited. This PhD thesis, in collaboration with Stockholm Environment Institute (SEI), conducted a comprehensive review of the academic literature (2013-2017) with the aim to identify the most successful interventions of behaviour change techniques in the adoption of improved cookstoves. In addition, this research also looked at the most common barriers cited in the literature related to this issue.

The second approach, studies the role that smart home technologies might have on energy consumption and carbon emissions, since some consider (Grubler *et al.*, 2018; Eric Hittinger and Jaramillo, 2019) the development of information and innovation, (ICTs, sensors, processors, wireless communications and control functionality in energy-using technologies and daily routines etc), as a key element for a feasible supply-side decarbonisation within a 1.5°C emission budget. Conversely, others (Vidal, 2017b), fear that increasing data and the 'internet of things' (IoT) could greatly increase global electricity usage. The International Energy Agency (IEA) (2017) although acknowledging that these technologies could improve energy efficiency, aver that some could also induce rebound effects that increase overall energy use, particularly, for those outside of the energy sector, such as e-commerce and e-services, since these enhance convenience, which could ultimately lead to encouraging greater consumers use of these services.

Moreover, this research works from the premise that, at least in the UK, there is a need to modernise the current energy system in order to facilitate a low-carbon energy transition. In this sense, smart homes play a key role, since it is through this mean that the interactive relationship between grid operators, utilities and users is built. In turn, energy users are enabled to respond to signals from energy providers to minimise energy usage when the grid is under stress from high demand, integrate renewable sources more easily into the energy system and even, use smart home technologies to allow users to shift their power use to times when power is available at lower cost (U.S Department of Energy, 2019).

This research, however, goes beyond exploring the role of smart home technologies in the energy arena. Since several recent papers have called for developing a better picture of who smart homes users are (Wilson, Hargreaves and Hauxwell-Baldwin, 2015; Gram-Hanssen and Darby, 2018; Hargreaves, Wilson and Hauxwell-Baldwin, 2018) this research, thus, conducted three focus groups and rolled-out a national survey across the UK to fill this important gap.

Furthermore, throughout this research, the role of gender is considered. Not only because what happens inside homes, is often culturally determined by gender (Cieraad, 2006) which makes homes, one of the most gendered spaces (Tjørring *et al.*, 2018), but also, since multilateral environmental agreements which underpin the Paris Agreement, outline the relevance of women in achieving a low-carbon economy. For instance, the Rio Declaration on Environment and Development states: "*women have a vital role in environmental management and development. Their full participation is therefore essential to achieve sustainability* (UN, 1992)*".* This research, hence, focus on exploring the sustainability-gender nexus and studies what the role of women is in household dynamics regarding

the adoption and perceptions of technologies, namely improved cookstoves and smart home technologies.

1.1. Theoretical framework

Although the overall PhD does not have a singular theoretical framework, the researcher found that this study holds strong theoretical connections. Thus, for the author's best interests, he selected sociotechnical systems as theoretical framework to approach most of the contents of this PhD. However, the researcher would also like to make clear, that the various chapters have their own deeper theoretical underpinning (e.g. on conflict, BCT models, levels of smartness).

Given the broad scope of this PhD, both geographically –it includes UK, Europe and Sub-Saharan Africa—and socially, as it entails social science and humanities fields, including historical and philosophical approaches, sticking only to a technical criteria such as empirical adequacy or logical consistency, would fall short of giving a coherent explanation on the cause and effect of the findings. Instead, this research is explained by a broad variety of categories such as cultural perspectives (e.g. users, firms, social structure and states), natural environment, global position, institutions, cognitive categories, among others to find the interconnections of the technical, social and natural world around us (Hess and Sovacool, 2020). This approach is taken with the mere intention of not limiting science, technology and society solely to technical factors. But instead, showing the reader that most technological aspects have been, in fact, socially shaped.

In this sense and to help in furthering our understanding of the promise and challenges of smart home technologies and improved cookstoves, this PhD thesis perceives the technology and the infrastructure behind them as a sociotechnical system. This means, that throughout this research it is explored the technical aspects of both and are investigated other variables such as cultural perspectives and values, natural environments, institutions and cognitive dimensions. Moreover, and given that this research places strong emphasis on domestic energy consumption, it is mandatory to understand that the generation, transmission and distribution of electricity takes place within a broader technological system that escapes the engineering realm (Sovacool, Axsen and Kempton, 2017).

Working from the premise that a sociotechnical system shows that technologies need to be understood in their social context and that the diverse values expressed by technology architects, managers and consumers shape technological change, figures 1 and 2 aim to illustrate the previous point.



Figure 1: A sociotechnical system for smart home technologies. Adapted from Sovacool et al., (2017) with permission

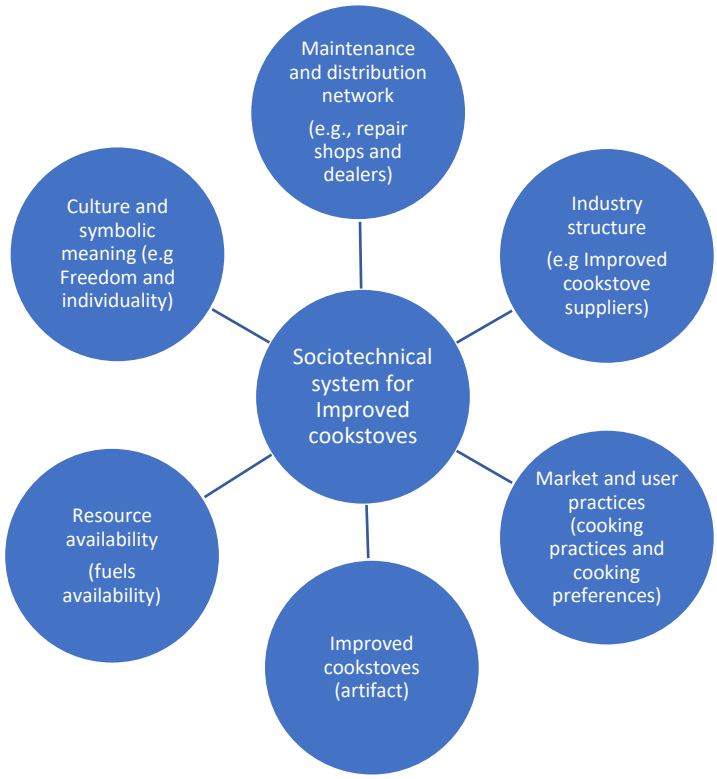


Figure 2: A sociotechnical system for smart home technologies. Adapted from (Sovacool, Axsen and Kempton, 2017) **with permission.**

Now that the author has introduced an overview of the theoretical framework this PhD encompasses, the section below presents the thesis structure, which ought to be viewed from the perspective that each chapter has their own deeper theoretical framework.

1.2 Thesis structure

This PhD thesis is divided in 10 chapters. The first 3 chapters entail the Introduction, aims and objectives and methodology. Later, Chapter 4, focuses on behavioural change techniques that influence the adoption and maintained use of improved cookstoves. In this sense, the researcher first presents a literature review analysis with the intention of having a broader understanding of rural household's dynamics. To keep the focus on technology adoption and household energy behaviour, chapter 4, thus, investigates perceptions, use and barriers of improved cookstoves in rural communities. Moving forward, chapters 5-6 mostly centre its focus on smart home technologies and what their role in the energy system is. In this sense, each of these chapters first present a literature review to better situate the results obtained from expert interviews and visits to retailer stores. Based on this data collection, Chapter 5 explores definitions, business and

applications of smart home technologies and Chapter 6, provides a list of benefits, risks and barriers and a makes policy recommendations to accelerate the uptake of smart home technologies. Chapters 7-9, study users' perspectives and gendered dimensions of smart home technologies based on a national survey instrument and three focus groups. Moreover, based on this dataset, chapters 7-8 illustrates, for instance, highlights the means by which smart home technologies could enable domestic violence and facilitate conflict within households. These chapters (7,8 and 9) compare users' perspectives to those found in the literature. Finally, Chapter 10, provides a comprehensive discussion, a set of policy recommendations and implications, conclusions and an agenda for further research on household dynamics and technology adoption.

Chapters 1 Introduction

This chapter sets context for the issues explored in this thesis, in addition, notes and explains why a sociotechnical systems framework was used to approach most of the contents of this PhD. The chapter ends by the author providing a brief summary of each chapter developed in this PhD thesis.

Chapter 2 aims and objectives,

This chapter entails the rationale, aims and objectives of the thesis, along with the question the researcher addresses throughout this thesis. Moreover, it provides the background of the investigation, provides the significance of its work and lays the foundation for the research undertaken. The chapter finalises with the list of publications resulting from this PhD

Chapter 3 Methodology

The methodology section is found in chapter 3. This chapter highlights the methods that were applied for data collection, these being: literature reviews for each chapter, expert interviews, a survey instrument and three focus groups.

Chapter 4. Improved cookstoves and behaviour change techniques: a literature review

This chapter was built based on a review of the academic literature (2013-2017) regarding the adoption and maintained use of improved cookstoves. In this sense, chapter 4, through a comprehensive literature review approach, presents emerging themes, such as the role of economic incentives and subsidies in the uptake of improved cookstoves and the importance for policy makers to value cultural drivers and gender hierarchies when designing improved cookstoves programmes. This chapter then indicates gaps in the academic literature and finally, in an attempt to further advance knowledge, the author presents eight policy recommendations to promote the adoption and continued use of improved cookstoves.

Chapter 5 Critically reviewing smart home technologies business model's and applications,

This chapter explores within the context of Europe and the UK, markets for smart home technologies and platforms. In addition, the author makes contribution to the literature by providing its own definition of what smart home technologies are as well as their main applications. This chapter later analyses fifteen distinct business models for smart home technologies, ranging from energy services and household data monitoring to health care and assisted living, security and safety, and new advertising channels (among others). It finalises with a discussion and policy implications

Chapter 6 Smart home technologies in Europe: A critical review of benefits, risks and policies

based on the expert interviews' findings, this research offers a new classification involving 13 categories of smart technology covering 267 specific options commercially available from 113 companies. It situates these different technology classes alongside six degrees or levels of smartness, from the basic or traditional home to the fully automated and sentient home (Benjamin K. Sovacool and Furszyfer Del Rio, 2020) same categorization is explored throughout the rest of the thesis. Then, this research moves forward and presents 13 benefits that smart the home offers as well as 17 risks and barriers for their adoption. Finally, seven policy recommendations are provided for their deployment and development.

Chapters 7 Exploring the gendered dynamics of smart home technology preferences in the United Kingdom

Chapter 7 explores how people perceive the opportunities and drawbacks of smart homes and smart home technologies via the lens of gender. Furthermore, it is studied what factors shape differing perceptions across gender and smart home technologies' implications for future sustainability as well as technological design. This is approached by a rigorous mixed methods research design including a nationally representative survey in the United Kingdom as well as focus groups across the UK.

Chapter 8 Inhibiting or inciting domestic violence? Control, surveillance and domestic abuse in the smart home of the future

Through a rigorous mixed methods research design the including a nationally representative survey and three focus groups across the UK, the author explores a still unattended area, that related with how smart home tecnologies can act as potential enablers of domestic abuse and/or violence. However, the author not only looks at smart home technologies through these lenses but also, explores the use of smart home technologies as possible deterrents and mechanisms to reduce and address domestic violence and provide victim protection and recovery.

Chapter 9 smart but unfriendly: Smart home connected products as a source of conflict within households

Chapter 9 looks at how these technologies enable conflict within homes and with neighbours. In this sense, the six emerging themes that this research explores are conflict with (1) housemates, (2) couples and partners, (3) children and parents, (4) landlords and tenants, (5) hosts and guests and (6) neighbours.

Chapter 10 Discussion and conclusion

Lastly, Chapter 10 provides an extensive discussion based on this research's findings, along with policy recommendations and implications. Moreover, in this space, the author of this PhD presents what lessons smart homes offer cookstoves and what lessons cookstoves offer smart homes. Then, this work proceeds to provide overall conclusions of this PhD, where the research findings are summarised and highlights topics for further research and analysis. This section also reminds the reader that research around household dynamics, either looking at energy use or technology adoption, is rather a complex topic since it can be approached from various disciplines and angles

Chapter 2. Aims and Objectives

2.1 Summary and introduction

In this chapter, the author first presents the aim of this PhD thesis, which in its shortest version could be summarised as an attempt to enhance the understanding around household dynamics regarding the adoption and use of smart home technologies and improved cookstoves. Then, in this same section, the author presents the questions this research addresses. Before introducing the significance of the work, section 2.3 describes the objectives of this thesis, which consist in advancing the literature on smart home technologies and improved cookstoves, particularly looking at the benefits, drawbacks, risks and users' perceptions of these technologies. Finally, in this chapter, the author presents the publications resulting from this PhD.

2.2 Aim

This PhD thesis possess two main aims:

- To enhance the understanding around household dynamics regarding the adoption and use of smart home technologies and improved cookstoves and;
- Situate how these technologies disrupt users' everyday routines and what their impact on the environment is.

As part of these two main aims, this PhD also encompasses the virtue to advance the understanding of which behaviour change techniques are most successful regarding the adoption of improved cookstoves. In this sense, this PhD thesis first asks a key question, which later can be broken down into a set of sub questions:

- In what ways do behaviour and behavioural interventions shape cookstove adoption?

This can be broken down into at least three interconnected sub-questions:

- How do rewards (e.g. financial incentives and subsidies) influence in the adoption of improved cookstoves
- Do demographic factors shape decision making regarding the adoption of these technologies?
- How does social support impacts on users' perspectives of improved cookstoves?

Another field that unpins from the aims of this PhD, is that regarding a further understanding of what factors shapes perceptions and attitudes towards smart home technologies and what their role in the energy system and in the sustainability dimension is or could be. In this sense, this PhD seeks to answers the following question and sub-questions:

- What are the benefits, barriers, and polices for making smart home technologies more sustainable?

This overarching theme question is also broken down into the following sub-questions:

- How does one define smart home technologies (SHTs)? What are they?
- What technologies or options for SHTs are available in the UK?
- What are their biggest benefits?
- What are their biggest barriers?
- What business models have the most promise?
- Are smart home technologies gendered?
- In what ways do smart home technologies promote domestic violence and abuse?
- How do smart home technologies create conflicts within households?

Indeed, the author assumes that by answering the previous sets of questions, the literature around household dynamics, energy behaviours and technology adoption must be advanced. Now that the author has introduced the aims of this research, it moves forward to present the objectives below.

2.3 Objectives

The main objective of this thesis is presented below and later this is broken down into a set of sub objectives:

- Contribute to advancing the literature on smart home technologies and improved cookstoves, particularly looking at the benefits, drawbacks, risks and users' perceptions of these technologies

This can be broken down into at least seven sub-objectives

- Obtain an understanding of what shapes the adoption of improved cookstoves and what the role of behaviour change techniques is in this process.

- Identify what smart home technologies are available in the market and if these have different levels of smartness.
- Rethink the promise of smart home technologies as means to enhance control and leisure.
- Guide future innovation patterns, technology deployment, and policy activity relating to smart homes.
- Contest the sustainability of smart home technologies.
- Identify elements that shape differing perceptions across gender regarding the adoption of improved cookstoves and smart home technologies
- Overall, advance the knowledge regarding social dynamics of household energy behaviour in the global north and south

2.4 Significance of the work

This research provides a novel approach to addressing the adoption of improved cookstoves through behaviour change techniques and interventions. In doing so, this research identifies common barriers cited in the academic literature. Moreover, the significance of the thesis also rests on the foundation that it critically assesses the concepts, benefits, risks and policies of smart home technologies. In addition, it reviews their different applications and potential business models in the UK and Europe. Whilst doing so, the study challenges how sustainable these technologies are. Finally, this PhD thesis addresses the academic gap and identifies who the users of smart home technologies are through the lens of gender.

In this regard, this thesis makes original contributions to knowledge in relation to:

- This research presents which behavioural change techniques are the most successful regarding the adoption of improved cookstoves.
- Revealing if smart home technologies make, or might make, energy services more affordable and help in meeting urgent carbon mitigation priorities.
- Presents the gendered nature of smart homes across five different dimensions: (1) knowledge, awareness, and adoption patterns; (2) housekeeping and daily domestic life; (3) environmental sustainability; (4) trust and risk tolerance; and (5) emotions and feelings.
- Identifies the duality of smart home technologies as possible means to enhance domestic violence and conflict within households, but also, as deterrents and mechanisms to reduce and address this issue.
- Presents the market availability of smart home technologies in the UK and Europe, as well as, different levels of smartness.

- This research not only criticises but also advances the literature in the fields of smart home technologies and improved cookstoves.

The significance of this work, moreover, relies in the relevance of the themes here explored. For instance, the need to switch from traditional to improved cookstoves depends on the fact that this practice represents a serious global issue since the use of fuelwood for cooking and to satisfy other household energy needs leads to grave environmental and health issues (World Bank, 2014; World Health Organization, 2015). Whilst the first leads to deforestation and climate change (OECD/IEA, 2014) , the second, is among the main causes of respiratory infections in the global south (World Health Organization, 2009), resulting in more than 3.8 million deaths annually. In this sense, current analyses suggest that without a substantial change in policy, the total number of users will remain largely unchanged by 2030. That is, around 40% of the global population will still be affected by this issue. In this sense, a new method to approach traditional cookstoves users is needed. On the other hand, smart homes have a variety of potential benefits – some of which, are unproven expectations. The literature often group such benefits into four categories: 1. health-related, 2. environmental, 3. financial, and 4. psychological (i.e., wellbeing and social inclusion). Moreover, literature revising risks and barriers to their adoption often consists of technical investigations focusing on control and security. In addition, research indicates that when the adoption and use of smart home technologies and improved cookstoves is approached, homes are usually studied as a neutral, sterile and bland place, rather than a complex space of relationships.

This research, hence, advances the literature in all these areas. For instance, looking at smart home technologies, it identifies more benefits and barriers than those currently found in relevant literature. In addition, by conducting focus groups and rolling out a survey at the national level, this research draws attention on who the users of smart home technologies are. Furthermore, what is presented in this research can be implemented to guide industry, manufacturers, policy makers and could even help in creating and enhancing legal frameworks to generate safeguards to protect users' data and personal information. Such policies could be related to data ownership, privacy and to victims of cyber abuse. Regarding improved cookstoves, this research could work as a guide to create a framework for implementers of cook stove programmes. The work could also provide governments with best practices to approach potential users and identify some easy-to-implement main drivers for adoption.

Drawn from these research areas, this PhD thesis thereby contains the following elements:

- An update of the literature available in the field of improved cookstoves as well as behavioural change techniques to boost drivers for their adoption.

- The development of a broad and innovative methodology that includes three methods of original data collection.
- An in-depth analysis to fill academic gaps regarding users' perceptions of smart home technologies and available literature in this field.
- A set of policy recommendations addressing both themes.

2.5 Publications

- **Furszyfer Del Rio, DD**, BK Sovacool, N Bergman and KE Makuch. "Critically Reviewing Smart Home Technology Applications and Business Models in Europe," E*nergy Policy*, 144. doi: https://doi.org/10.1016/j.enpol.2020.111631
- Sovacool, B.K. and **Furszyfer Del Rio, D. D.** (2020) 'Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies', *Renewable and Sustainable Energy Reviews*, 120. doi: 10.1016/j.rser.2019.109663.
- Sovacool, BK and **DD Furszyfer Del Rio**. "Contesting the sustainability of smart home technologies," revised and resubmitted to *Nature Sustainability*
- **Furszyfer Del Rio, DD,** F Lambe, J Roe, N Matin, KE Makuch and M Osborne. "Do we need better behaved cooks? Reviewing behavioural change strategies for improving the sustainability and effectiveness of cookstove programs", Submitted to *Energy Research and Social Science.* (addressing minor revision at the time this PhD was submitted)
- **Furszyfer Del Rio, DD**, BK Sovacool and M Martiskainen "Controllable, frightening, or fun? Exploring the gendered dynamics of smart home technology preferences in the United Kingdom" Submitted to *Journal of Cleaner Production*
- **Furszyfer Del Rio, DD**, BK Sovacool and M Martiskainen "Inhibiting or inciting digital violence? Control, surveillance, and domestic abuse in the smart home of the future", submitted to *Science Technology and Human Values*
- **Furszyfer Del Rio, DD**, "Smart but unfriendly: Home connected products as enablers of conflict", submitted to *Technology and Society*

Chapter 3. Methodology

3.1 Summary and introduction

This chapter starts by providing a list of definitions of commonly used terms; however, the author not only provides the definition found in the literature but also a definition on its own. Later, the author lists the methods employed during this research, not before introducing the research strategy of this PhD. Once these themes are presented, the methods employed throughout this thesis are in-depth explored.

3.2 Definitions of terms frequently used in this thesis

A variety of terms and expressions commonly used in the dimensions of behaviour change and smart technologies are referred throughout this thesis. In many cases, there is not one commonly accepted definition of such term. However, the definitions offered in table 2, below, presents the concept definitions applied in this research.

Table 2 Definitions of terms frequently used in this thesis presented in alphabetical order

Term	***Literature definition***	***Researcher's definition***
Behaviour change	For Bunn and Sagan (2017) behaviour change encompasses a programmatic goal and must include approaches to improve compliance with business processes and policies through targeted outreach.	This research defines behaviour change as any efforts put in place to change people's personal habits and attitudes to prevent diseases and facilitate the use and long-term uptake of technologies.
Behaviour change technique	The smallest identifiable components that in themselves have the potential to change behaviour (Michie, 2015)	Working from Goodwin's et al., (2014) definition, this thesis conceives behaviour change technique as the active component within a clean cooking intervention that helps producing changes in attitudes, habits and behaviours to achieve improvement to human health and /or environmental impact

Behavioural change intervention	Michie et al., (2011) define behaviour change interventions as "*coordinated sets of activities designed to change specified behaviour patterns*"	The author of this PhD uses this same definition throughout this thesis.
Cyber abuse/technology abuse	The UCL team working on Gender and IoT (2019) define cyber abuse as any way in which technologies can be exploited to harass or control individuals. These include unwanted (sexual) attention, image-based violence, emotional manipulation, or coercive offences.	This research recognises this definition but adds other aspects to make the concept broader and suggests: Involuntary monitoring and surveillance practices, electronically enabled trafficking and doxing as part of the technology abuse definition.
Data protection	Privacy international defines data protection as the law/instrument designed to protect users' personal data (2018a).	Tis PhD research envisions data protection as the instrument that protect individuals' personal information and that must promote consumers' empowerment to enhance data control and protect them from abuses
Domestic violence	The UK government defines domestic violence as *"any incident or pattern of incidents of controlling, coercive or threatening behaviour, violence or abuse between those aged 16 or over who are or have been intimate partners or family members regardless of gender or sexuality* (Home Office, 2013a)"	This PhD thesis agrees with the definition provided by the Home Office UK government.
Gender	UN Women defines gender as "A social and cultural construct, which distinguishes differences in the attributes of men and women, girls	This PhD thesis agrees with the accurate definition provided by UN Women.

	and boys, and accordingly refers to the roles and responsibilities of men and women. Gender-based roles and other attributes, therefore, change over time and vary with and within different cultural contexts (UN Women, 2020)".	
Improved cookstoves	Barnes et al (1994) reports to the World Bank that improved cookstoves are defined as one that not only meets scientific and safety standards, but also these need to have high combustion quality, technical efficiency, minimal smoke emission, ergonomics and structural stability.	This PhD thesis conceives Improved cookstoves as technologies that through better combustion processes improves human's health, accelerates cooking processes and avoids further environmental degradation
Internet of Things	The Internet of Things consists of technologies and services that connect through cloud computing services, social networks and smart home technologies (Niemantsverdriet, van Essen and Eggen, 2017) .	This PhD thesis considers the internet of things as technologies that enable communication between electronic devices and sensors through the internet.
Personal data	The Information Commissioner's Office provides an accurate definition of what personal data is: *any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to*	In this PhD thesis the author agrees with the definition provided by Information Commissioner's Office.

	one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person (Information Commisioner's Office, 2019)".	
Profiling	The Information Commissioner's Office based on the GDPR guidelines define profiling as "any form of automated processing of personal data consisting of the use of personal data to evaluate certain personal aspects relating to a natural person, in particular to analyse or predict aspects concerning that natural person's performance at work, economic situation, health, personal preferences, interests, reliability, behaviour, location or movements (Information Commissioner's Centre, 2018).	This PhD recognizes and uses the ICO definition on what profiling is throughout the study.
Smart home	In its work, Hargreaves and colleagues (2018) define what smart homes should entail. For them, the essence of a smart home are ICTs distributed throughout rooms, devices and systems relaying information to users and feeding back user or automated commands to better manage the domestic environment.	This PhD agrees with the definition of what smart homes are provided by Hargreaves et al (2018). However, this research adds that the interaction with devices in a smart home could go beyond the domestic environment into the system or even at a community level.
Smart home technologies	De Silva et al (2012) defines smart home technologies as	This PhD based on 31 expert interviews and a revision of the

	home-like environment that possesses ambient intelligence and automatic control, which allow to respond to the behaviour of residents and provide them with various facilities and feedback.	literature defines smart home technologies as: connected devices that can communicate with each other and react to internal or external signals to enhance the energy services delivered to consumers whilst generating benefits to the system, where the system could be local, national or international. These technologies must possess the ability to interpret available data through a learning algorithm that can predict behaviours and recognize those that are unusual to call for users' attention. These devices ought to automatically program themselves and act on predefined routes to provide the services that the user requires. Technologies could be controlled either by users or delegate it to the system and could be controlled in-site or remotely, so users can have access to the services delivered by the home
Smart grid	According to the United States Department of Energy, in comparison to a traditional grid, a smart grid allows a two-way communication between energy users and the utility company. Where the sensing along the transmission lines is what it makes the grid smart. "*A smart grid is often*	This PhD refers to smart grid as a network that allows consumers to communicate with energy suppliers in order to enhance certain services, such as energy demand. In turn, this ought to save energy and cut costs.

	composed of controls, computers and other equipment working along with the electrical grid to respond digitally to changes in users' energy demand" (U.S. Department of Energy, 2010).	
Stacking	The Stockholm Environment Institute define the practice of stacking as when households use different combinations of old and new technology at the same time to satisfy their energy, cooking and heating needs. (Jürisoo, Lambe and Osborne, 2018)	This same definition is used throughout the PhD.
Technology domestication	In its simplest form, domestication places technology in the users' everyday life. The concept covers practical, temporal, spatial and highlights how this is mixed with the cultural as an expression of lifestyles and values (Pantzar, 1997)..	In this PhD research, technology domestication refers to the process of when technologies become integrated into daily routines, lifestyles and enter into people's lives.

3.3 Research strategy

Three key approaches are taken in the development of this PhD thesis:

1. The development of a qualitative innovative methodology that allows an evaluation of the drivers for adoption, barriers and perceived risks of improved cookstoves and smart home technologies.
2. The application of the methodology to the research areas presented in this PhD
3. A comprehensive comparative analysis contesting the findings from the literature and data collected from qualitative methods.

An extensive literature review was conducted at the beginning of each section. This, with the intention to cover key areas in the fields of smart home technologies and improved cookstoves and in order to highlight and fill research gaps. Moreover, the outcomes of revising the literature are

further used to inform the reader about policies already implemented in the fields of smart home technologies and maintained use of improved cookstoves.

3.4 **Summary table on methods matched to chapter**

Given that each chapter of this PhD resulted in writing an academic paper, the following table presents a brief summary matching each chapter with the methodology employed.

Table 3 Summary table on methods matched to chapter

Core chapter/outputs	Methods to support the research
Chapter 4. Behaviour change techniques and adoption of improved cookstoves.	Literature review analysis from 2013-2017, limited to academic peer-reviewed papers
Chapter 5. Exploring benefits, barriers, risks and policy recommendations in the smart homes dimension	31 expert interviews + 37 site visits to retail stores. + an extensive review of academic literature
Chapter 6. Exploring applications and business models of smart home technologies	31 expert interviews + 37 site visits to retail stores + extensive review of academic literature
Chapter 7. Exploring the gendered dynamics of smart home technology preferences in the United Kingdom	A national representative survey (n=1032) + 3 focus groups across the UK (London, Surrey and Manchester) + review of the academic literature available
Chapter 8 A national representative survey (n=1032), 3 focus groups across the UK (London, Surrey and Manchester). This was complemented with a review of the academic literature available	A national representative survey (n=1032) + 3 focus groups across the UK (London, Surrey and Manchester) + review of the academic literature available
Chapter 9. Smart but unfriendly: smart home connected product as a source of conflict within households	A national representative survey (n=1032) + 3 focus groups across the UK (London, Surrey and Manchester) + review of the academic literature available

3.5 Literature Review

A literature review is presented at the beginning of each chapter since this research agrees with (Petticrew, M., 2006; Sorrell, 2007; Sovacool *et al.*, 2017; Sovacool, Axsen and Sorrell, 2018) that such approach, enhances evidence for policy analysis by minimizing bias, provides a comprehensive and replicable summary of the state of knowledge, aids in recognizing policy trends, improves transparency and ought to help in identifying research gaps. For this PhD thesis, the review of existing literature helped the researcher identifying the weaknesses in existing research designs. The literature review has identified not only gaps in the literature but also in the application and use of technologies, the gaps identified are listed below:

- Behavioural change techniques for the adoption and maintained use of improved cookstoves
- Gender trends in the adoption of improved cookstoves in rural communities
- Users' perceptions of smart home technologies
- The sustainability of IoT devices
- Lack of regulation regarding energy use and data processing in the smart home technologies arena
- The role of gender in the use and adoption of smart home technologies
- How smart home technologies could facilitate or deter domestic violence, cyber abuse and facilitate conflict within households

The literature review sections not only focused on peer-reviewed academic papers but also entailed identification and evaluation of grey literature, including policy briefings and reports from international organizations, such as the World Bank, the International Monetary Fund and International Energy Agency. The literature in both research areas mostly stressed the technical aspects of improved cookstoves and smart home technologies as well as benefits, highlighting saving time and improving users' convenience, comfort and even lifestyles. Given that much of the studies in the tech dimension focused on the Western world, it would have been unfair not to take into consideration those less developed. However, this is not only reason why the author has decided to consider improved cookstoves for its analysis, in its view, the author perceived such technologies with a level zero of smartness. In this sense, this notion of levels of smartness, is considered throughout this thesis and may help in further the understanding on how technologies may influence in social dynamics and household energy behaviour.

In sum, the researcher based on the literature reviews conducted, concludes with the following thoughts. In the improved cookstoves area of study, on the one hand, academics and practitioners

have not identified a silver bullet to help in accelerating the adoption of such technologies. On the other hand, the analysis of smart home technologies left the researcher with many questions open, as studies contradict each other; there is no clear evidence as to whether these technologies address sustainability or increase CO_2 emissions and waste. These results help illustrate the complexity of household dynamics and the lack of domestic and technical knowledge in both, rural and urban contexts.

3.5 Literature review methodology for chapter 4: Behavioural change techniques for the adoption of Improved Cookstoves

In this chapter, a systematic and extensive search was conducted for peer-reviewed academic papers on improved cookstoves published between 2013 and 2017. To have a more comprehensive approach, and as the use of traditional cookstoves is not limited to a specific region, the researcher did not focus on one particular location. However, most of the studies found were in Sub-Sharan Africa with other scattered studies in Asia, South of Europe and Latin America.

The inclusion criteria took into consideration the following elements: 1) date, the study must have been conducted within the timeframe (2013-2017); 2) the studies must have been published in English; and; 3) the studies must have considered a behavioural change intervention (rewards and threat, shaping knowledge, changing the physical environment, social support, goals, planning and monitoring, regulation, and comparisons, identity and belief). Regarding methods, the researcher considered randomised controlled trails (RCT), longitudinal, qualitative and quantitative studies to fit within the criteria.

The researcher replicated methods from Goodwin et al, (2014), which in turn, had been generated from earlier systematic reviews within the cookstove sector. However, unlike Goodwin et al, (2014), due to time limitations, the researcher and the research team (The Stockholm Environment Institute) only considered peer-reviewed academic papers; omitting studies from grey literature. Below, in subsection 3.6, the author presents search syntax applied by Goodwin and colleagues (2014) same that the researchers used for this chapter.

In this sense, some of the themes explored that emerged from this literature review that were beyond behavioural change techniques were: gender trends and cultural drivers. These are briefly discussed in the results section.

3.6 Search terms applied for chapter 4

The search terms reflected the fuels, stoves and household management practices in relation to the sector, and a wide range of BCT terms ranging from very broad (i.e. behaviour change and intervention) to very specific (i.e. habit, trigger and messenger) derived from a wide range of academic disciplines (e.g. health psychology and behavioural economics). In this sense and based on methods by Goodwin et al., (2014) the search terms applied were the following:

(stove OR cookstove) OR (cook AND fuel) OR (cook AND technol*) OR (chulha* OR chulla* OR chula*) OR plancha* OR (clean* fuel*) OR pellet* OR briquette* OR fuel* OR LPG OR LP gas OR ("petroleum gas") OR biogas OR bio-gas OR bio-digester OR ethanol OR (smoke hood*) OR chimn* OR flue* OR ventilat*) AND (behav* AND chang*) OR educat* OR communicat* OR market* OR promot* OR inform* OR awareness OR (increase production) OR (expand distribution) OR (increase demand) OR purchas* OR (improve practice) OR (decreas* exposure) OR (chang* perceptions) OR financ* OR norm* OR incentiv* OR behav* economic* OR nudge* OR ("value exchange") OR reward OR habit OR replac* OR train* OR default* OR trigger* OR ("choice architecture") OR reinforc* OR conditioning OR messenger*.*

3.7 Limitations found in the methodology for Chapter 4

- Time limitations to include grey literature. More so, since grey literature often offers valuable insights from specific case studies. Such as studies conducted by the World Health Organization or the Clean Cooking Alliance, who is the leading organization in mobilizing investments and delivering affordable, appropriate, high-quality clean cooking products.
- Time and resource availability only allowed the researcher to conduct desk-based research rather than collecting first-hand data through interviews and focus groups.

3.8 Literature review for chapters 5-9

These chapters, in comparison to the previous, were not as rigorous in terms of selected timeframes and review of the literature, since in its revision, the author integrated the analysis of grey literature sources, such as, but not limited to policy briefing and institutional reports. In addition, and although the focus of chapters 6 and 7 centres in the UK and the EU, when entering the search terms, the author of this PhD included studies from outside the research scope. Finally, for these chapters, the inclusion criteria was broader, since the studies considered are traced back to the XIX Century. Furthermore, during the revision of the literature the researcher considered studies written in Spanish and French and integrated an analysis that went beyond the technicalities of smart homes, but also considered themes around sociology, law, philosophy, gender studies and politics.

In this sense, chapters 5-9 of this PhD had their own literature review analysis, where the themes explored by chapter could be divided in the following subjects:

- Chapter 6: current market and future projections, prospective business models for smart homes and definitions and applications.
- Chapter 7: smart home energy systems in the UK and Europe and users' perceived benefits and drawbacks.
- Chapter 8: critiques, current state and further developments of smart home technologies.
- Chapter 9: the digital revolution, the rise of surveillance, gender bias in the digital economy and cyber abuse.
- Chapter 10: The meaning of home, conflict typologies, human computer interaction and conflict and conflict resolution.

3.9 Search terms applied

To supplement the researcher's qualitative data (methods mentioned below) and better situate this PhD within the body of growing research, the researcher entered the following search terms whilst conducting the literature:

"smart homes," "smart home technologies," "smart home services," "smart buildings," "automated homes", "cyber abuse", "smart transitions" and "gender smart home technologies". The resulting corpus of studies is cited throughout this article to help situate our findings within the literature.

3.10 Methodology: Expert Interviews

Part of this methodology is taken from the work by Sovacool and Furszyfer (2020) and Furszyfer et al., (2020) where researcher and co-supervisor conducted semi structured interviews from November 2018 to February 2019. The author of the PhD thesis conducted 25 interviews and participated in another one remotely via telephone. The remaining five, were conducted by the co-supervisor.

The method employed was expert interviews, as this approach allows for an in-depth exploration of pertinent processes including but not limited to policies and political issues (Dexter, 1969; Beamer, 2011). In turn, this offers a richer but cost-effective means to generate unique data to analyse the complexities of markets, policies and politics (Galvin, 2015). A further justification to this approach is found in the works (Goldblatt, Hartmann and Dürrenberger, 2005; Dapeng and Weiwei, 2009; Earl and Fell, 2019; Noel *et al.*, 2020) their work illustrates that qualitative research interviews have been extensively used for peer-reviewed academic papers and the broader energy social science

community as an established method of collecting data (Sovacool, Axsen and Sorrell, 2018). Moreover, rather than providing numbers, percentages or magnitude of relevant factors, the qualitative data analysis collected in this research, helps in providing context and insights about the current options of smart home technologies available in the UK and Europe. Qualitative expert interviews were employed to fit the dual aims of this study, namely 1. To gain a more comprehensive view about what smart home technologies are and which are the main benefits, barriers and risks to overcome and 2. To assess promising business models for these technologies in the UK and Europe.

Researcher and co-supervisor conducted 31 semi-structured qualitative expert interviews from November 2018 to February 2019. Experts were approach via email and were cordially invited to participate in the study. In this sense, this research agrees with Otto-Banaszak et al., (2011) that experts are persons responsible for the development and implementation of solutions, strategies and/or policies. Experts, thus, have privileged access to information and possess a high level of aggregated and specific knowledge that is otherwise difficult to access. This is the reason why this research approached experts in the first place; to gain first-hand knowledge in the smart home technologies arena. The sampling strategy for this study was purposive, meaning that the researcher applies their own judgement so as to identify the most suitable stakeholders, with adequate knowledge, in a specific subject or area (Patton, 1990). For this thesis, a purposive approach was employed, given the level of technical expertise required by participants in order to be able to contribute in the interviews. In this sense, experts were identified through their participation in academic literature, policy briefings as well as looking at the boards of companies. Others, for instance R22, R27 and R29 were approached via 'cascading', that is, one participant recommended the researcher to approach them. Experts were from six different types of institutions:

1. Government, including national ministries such as the Department for Business, Energy & Industrial Strategy (BEIS), Behavioural Insights Team and Ofgem as well as local government from Bristol City Council;
2. Academic institutions such as the University of East Anglia, Oxford University, Loughborough, Imperial College London University of Sussex and Nottingham University;
3. Private sector firms including energy suppliers such as Engie, Npower and Airex as well as software and technology companies such as Amazon and Microsoft;
4. Civil society and independent research institutes such as Citizens Advice, the Green Alliance, Energy Systems Catapult, the Association of Decentralized Energy and Price Waterhouse Coopers;

5. Industry and trade groups such as Smart Energy GB and the Alliance for Decentralized Energy;
6. Intergovernmental organizations such as the European Commission and the International Energy Agency (IEA)

This study focused broadly on the commercial availability and viability of smart home technologies within Europe as well as the main benefits and barriers these technologies offer not only to consumers but also the energy system. The bulk of our interviews were undertaken in the UK, not only because the UK is reflective of the European market (Berg Insight, 2018) but also, since a representative number of European services and technologies are available here (BEIS, 2017a; Berg Insight, 2018). The research interviews generally lasted between thirty and ninety minutes, and participants were asked the following questions:

- How does one define smart home technologies (SHTs)? What are they?
- What technologies or options for SHTs are available here in the UK?
- What are their biggest benefits?
- What are their biggest barriers?
- What business models have the most promise?
- What policies are needed to accelerate their adoption?

All interviews were treated as anonymous to encourage candour and protect respondents, and each was given a respondent number (e.g., R2 for respondent 2). Most interviews were recorded so that transcriptions and statements could be checked for accuracy. After collection of the interview data, each interview was subsequently fully transcribed, and then coded. The coding scheme this research conducted to identify, benefits, barriers, policy recommendations, market and business model applications was exhaustive and inductive, meaning every response was coded and then we analysed the full sample inductively. Table 4 below presents a summary of the experts interviewed

Table 4 Expert interviews organized by respondent number, institution and category

Respondent number	Date	Institution	Sector	Location
R1	28/11/2018	City Council Bristol	Government	Phone

R2	29/11/2018	University of East Anglia	Academic	Phone
R3	03/12/2018	European Commission DG Connect	Political-International Organization	Phone
R4	05/12/2018	Engie	Energy Supplier	Skype
R5	06/12/2018	Imperial College London/Amazon	Industry	Imperial College London
R6	06/12/2018	Oxford University ECI	Academic	Oxford University
R7	06/12/2018	Airex	Developer/supplier	Airex's office
R8	07/12/2018	Louborough University	Academic	Loughborough University
R9	07/12/2018	Louborough University	Academic	Loughborough University
R10	11/12/2018	Microsoft Azure Team	Industry	Skype
R11	12/12/2018	PWC	Consultancy	PWC 's offices
R12	12/12/2018	University of East Anglia	Academic	Telephone/Skype
R13	14/12/2018	Citizen's Advice	Civil Society	Citizen's advice office
R14	10/01/2019	Catapult	Civil Society	Phone
R15	11/01/2019	BEIS	Government	Phone
R16	11/01/2019	IEA	International Organization	Skype/Phone
R17	11/01/2019	IEA	International Organization	Skype/phone
R18	14/01/2019	Behavioural Insights Team	social purpose company	Behavioural Insights Team office
R19	16/01/2019	BEIS	Government	Phone
R20	16/01/2019	Green Alliance	charity	Green Alliance's office

R21	17/01/2019	Imperial College London	Academic/Industry	Imperial College London
R22	18/01/2019	Oxford University ECI	Academic	Oxford University
R23	21/01/2019	Citizen's Advice	Civil Society	Citizen's advice office
R24	22/01/2019	Nottingham University	Academic	Skype
R25	23/01/2019	ADE	Civil Society	ADE's office
R26	24/01/2019	Imperial College London	Academic	Imperial College London
R27	28/01/2019	Imperial College London	Academic	Imperial College London
R28	29/01/2019	Imperial College London	Academic	Imperial College London
R29	04/02/2019	Npower	Energy Supplier	Telephone
R30	11/02/2019	Sussex University	Academic	Sussex University
R31	1902/2019	Smart Energy GB	Marketing company	Smart Energy GB office

3.11 Site visits to retail stores

In addition to interviews, the researcher in collaboration with the co-supervisor conducted structured site visits to retailers that had available smart home technologies for sale on the market. The visits comprised prominent retailers including:

- Direct suppliers of smart home technology such as the Apple Store, Samsung Store, O2 Store, and Vodaphone Shop;
- Do-It-Yourself (DIY) and home improvement stores such as IKEA, Homebase and B&Q;
- General department stores or furniture shops with major smart home technologies on offer, such as Peter Jones, John Lewis, and the Conran Shop;
- Home electronics and household appliance retail stores such as Curry's PC World and the Carphone Warehouse (Sovacool and Furszyfer Del Rio, 2020a).

In this sense, we conducted separate visits to 37 retailers in January and February 2019 across eight Boroughs in the Greater London Area (Barnet, Brent, Camden, Croydon, Kensington and Chelsea, Hammersmith and Fulham, Newham, and Westminster) as well as Bristol, Brighton and Hove, and Manchester (see Figure 3). Each store visit, lasted between around 45 minutes each, and provided the researcher and the research team with numerous advantages over merely looking at store catalogues or online websites (Sovacool and Furszyfer Del Rio, 2020a). This approach allowed the research team to conduct additional short interviews and discussions with staff at the store, see what was commercially available and in stock (see Figure 3), and also, to see how items were displayed, were most promoted, advertised and in some cases discounted (Sovacool and Furszyfer Del Rio, 2020a).

Figure 3 Location of 37 structured site visits to retail home improvement, electronics, and household appliance shops in the UK, January and February 2019



Source: retrieved from Sovacool and Furszyfer (2020) with permission

Figure 4: Smart home technology on display at Westfield White City, London, 2019



Source: retrieved from Sovacool and Furszyfer (2020) with permission

3.12 Survey instrument

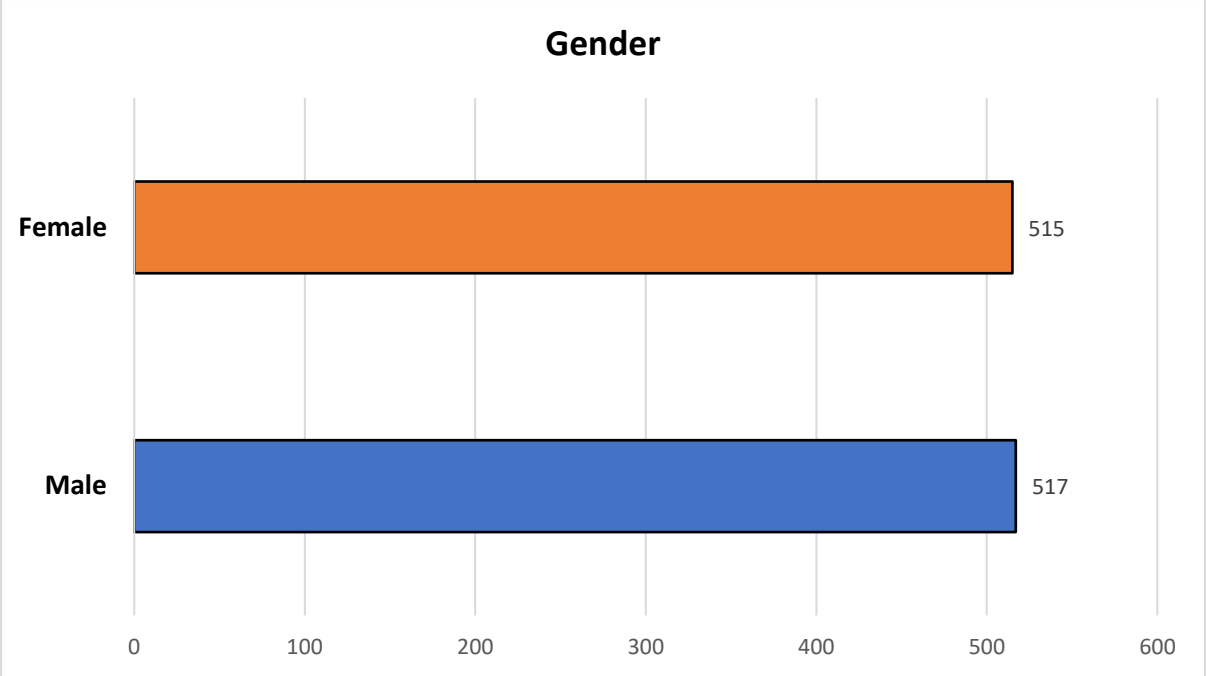
For this PhD thesis, a survey was implemented since the researcher's perspective aligns to the one presented by Babbie when he states that: "*The survey is a systematic method for gathering information from (a sample of) entities for the purpose of constructing quantitative descriptors of the attributes of the larger population of which the entities are members* (Babbie, 1989)." Indeed, for this section, the aim was not to observe social interactions or communications between participants but rather, identify the characteristics of the individual members that participated in the study (e.g. age, income, preferences etc.).

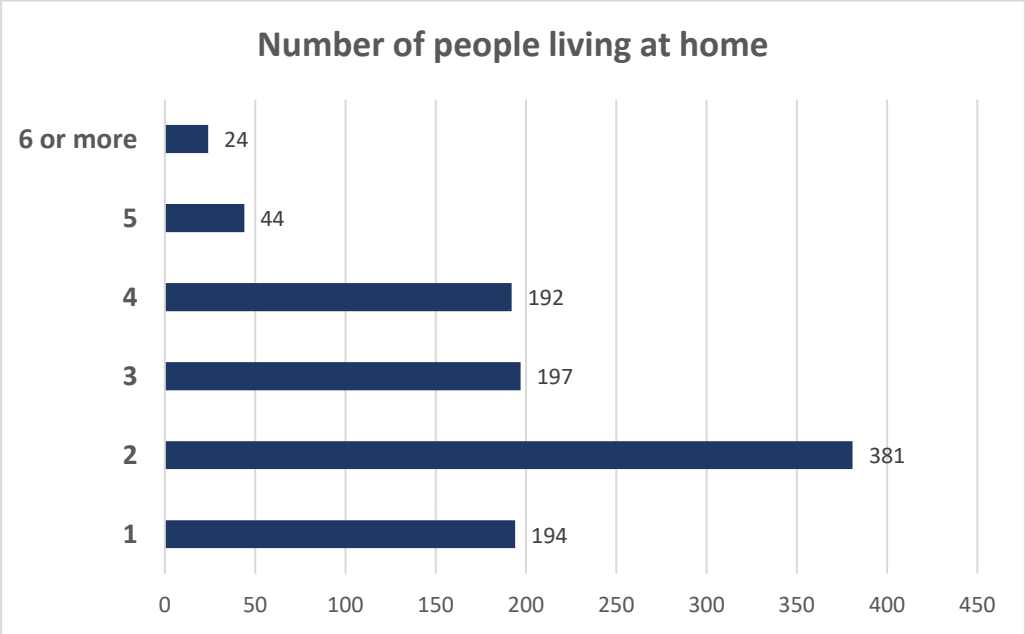
The survey instrument, offered in this thesis in Appendix I, built off earlier work examining user perceptions of smart homes conducted by Hargreaves et al. (2017) and Wilson et al. (2015). Although the instrument is based on previous work, it was built in its totality by the PhD student, co-supervisor and Dr Mari Martiskainen. As a team, through a series of Skype calls and meeting in

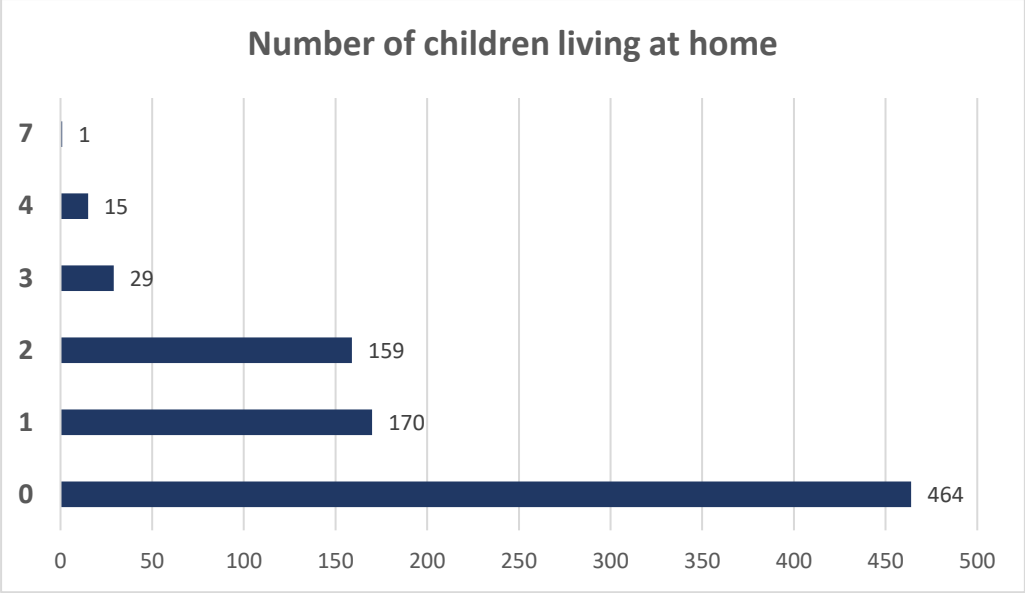
Sussex and London this survey instrument was constructed. The survey was designed to take 10-15 minutes to complete, and it consisted of twenty questions across four sections. The first section explored the socioeconomic and demographic attributes of respondents (people living in the household, age and income). The second section investigated adoption patterns and knowledge of smart home technologies. Participants were asked, for example: do you own or use any smart home technologies? The third section examined preferences in relation to the technology as well as trust and perceived risks. In this section participants answered themes such as: Thinking about smart home technologies generally, for there to be personal trust in smart home technologies, it is important that they…" The fourth had open-ended questions asking respondents to share experiences about smart homes as well as their willingness to be contacted for future research. Most questions used a 5-point Likert Scale (1 = strongly disagree, 5 = strongly agree), with the survey implemented online by a market research company, Dynata, using a respondent panel representative of the UK household population (homeowners and those who rent). Dynata scripted an online version of the survey instrument using their proprietary software. Once checked by the research team, Dynata sent unique person-specific links to the survey to individuals in their respondent panel who have agreed previously to take part in survey research in exchange for incentives. The sampling frame consisted of householders, in the UK, who had to be over the age of at least 18 years old.

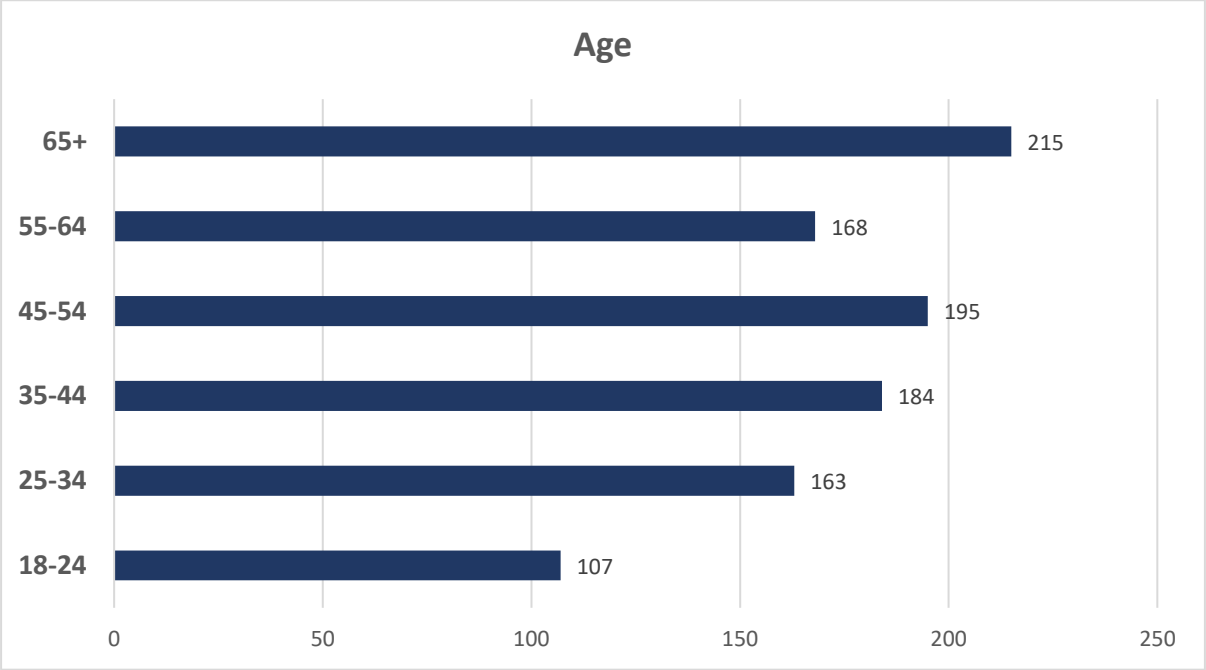
A total of 166 respondents were screened out based on quality checks. These quality checks included 'flat-liners,' straight-line responses on blocks of questions; 'rushers,' those who gave incomplete, contradictory or unrealistic responses (e.g., the respondent who claimed to have 99 children); and 'speeders,' those who had unrealistically fast survey completion times. The final sample comprised 1,032 respondents. To help the reader have a greater appreciation of the data collection Figure 5 shows some of the demographic details of our final sample.

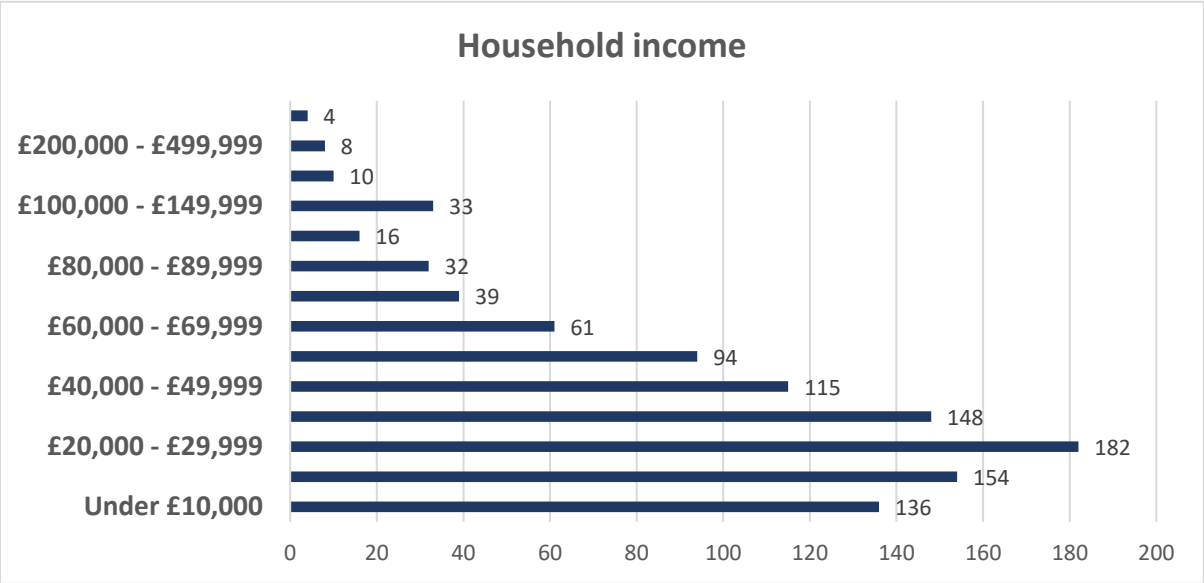
Figure 5: Demographic details of smart home technology survey respondents in the UK (n=1032)

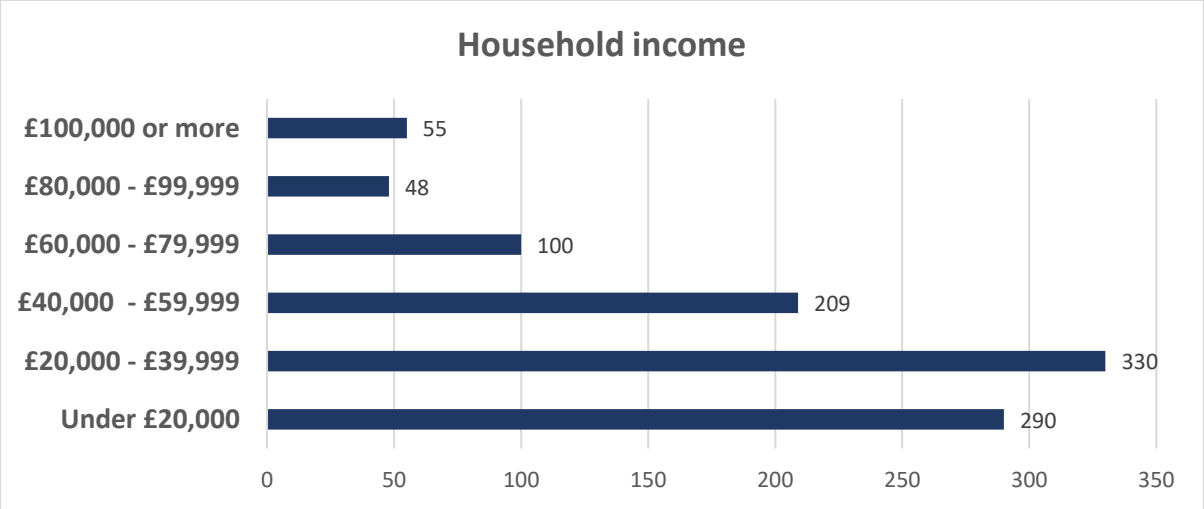

Gender
Female
515
Male
517
0
100
200
300
400
500
600

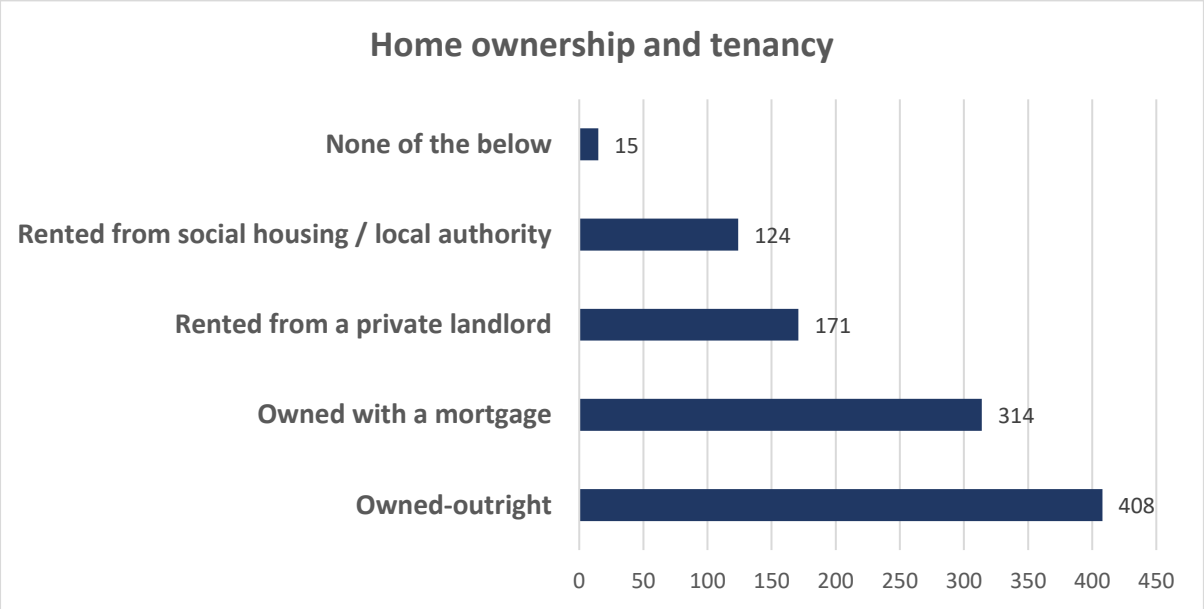

Number of people living at home
6 or more
24
5
44
4
192
3
197
2
381
1
194
0
50
100
150
200
250
300
350
400
450


Number of children living at home
7
1
4
15
3
29
2
159
1
170
0
464
0
50
100
150
200
250
300
350
400
450
500


Age
65+
215
55-64
168
45-54
195
35-44
184
25-34
163
18-24
107
0
50
100
150
200
250


Household income
£200,000 - £499,999
£100,000 - £149,999
£80,000 - £89,999
£60,000 - £69,999
£40,000 - £49,999
£20,000 - £29,999
Under £10,000
4
8
10
33
16
32
39
61
94
115
148
182
154
136
0
20
40
60
80
100
120
140
160
180
200


Household income
£100,000 or more
£80,000 - £99,999
£60,000 - £79,999
£40,000 - £59,999
£20,000 - £39,999
Under £20,000
55
48
100
209
330
290
0
50
100
150
200
250
300
350


Home ownership and tenancy
None of the below
Rented from social housing / local authority
Rented from a private landlord
Owned with a mortgage
Owned-outright
15
124
171
314
408
0
50
100
150
200
250
300
350
400
450

Source: Sovacool, Martiskainen, Furszyfer

3.13 Focus Groups

To triangulate the findings from the survey, the author of this PhD thesis, co-supervisor and Dr Mari Martiskainen also conducted three focus groups in the last quarter of 2019 across London (n=7), Greater Manchester (n=4), and Surrey (n=7). This included two urban locations (London and Surrey) and one rural (Manchester). Focus groups were used in order to gain a depth of understanding of smart homes. Particularly, focus groups were implemented with the aim to get from participants through a moderated interaction the following: complex personal experiences, beliefs, perceptions and attitudes (O.Nyumba *et al.*, 2018). Certainly, as Yin notices (2018) this research method provided the author with insightful interpersonal behaviour and motives from participants.

The focus groups were organized and managed by a separate market research company, YouGov. Each focus groups lasted between two and three hours. Each of them, involved a mix of different demographic respondents with the details summarized in Table 5. As in the survey, participants identified as either male or female and no other genders. The focus groups followed a similar structure to the survey, examining general knowledge of smart home technologies, experience and usage patterns, perceived benefits and disadvantages, trust, and values. Even though they were recorded and fully transcribed by YouGov, the author of this thesis observed all of the focus groups and took personal notes for this research purpose.

For the focus group data was analysed inductively. At first, the researcher read transcripts from all focus groups, identifying emerging common themes across the three groups. In addition, the author triangulated these findings with responses to the survey instrument. These were then grouped in the following core themes: (1) knowledge, awareness and adoption; (2) housekeeping and daily domestic life; (3) environmental sustainability; (4) trust and risk tolerance; and (5) emotions and feelings. Results from these are fully found in chapters 7, 8 and 9. To ensure anonymity, focus group participants are referred to in the results as follows: London male (FGLM), London female (FGLF); Manchester male (FGMM), Manchester female (FGMF); Surrey male (FGSM) and Surrey female (FGSF). The survey respondents are reported as male / female and respondent number (e.g. MXX, F)

Table 5 Demographic Attributes of Focus Groups in London, Manchester, and Surrey (n=18)

a. Focus Group 1 London (Urban)

Age	Gender	Ethnicity	Social Grade	Gross household income	Smart devices owned	Current property
18	Female	White and Black African	B	£60,000 to £69,999 per year	1	Rented from private landlord
21	Female	Chinese	C1	£10,000 to £14,999 per year	1	Rented from private landlord
24	Female	White and Asian	C1	£100,000 to £149,999 per year	1	Rented from private landlord
54	Female	English / Welsh / Scottish / Northern Irish / British	E	Prefer not to answer	3	Buying leasehold/freehold on a mortgage
56	Male	Any other ethnic group	D	£20,000 to £24,999 per year	4	Buying leasehold/freehold on a mortgage
62	Male	English / Welsh / Scottish / Northern Irish / British	C1	£10,000 to £14,999 per year	1	It belongs to a Housing Association
73	Male	English / Welsh / Scottish / Northern Irish / British	A	£50,000 to £59,999 per year	3	Own the leasehold/freehold outright

b. Focus Group 2 Greater Manchester (Rural)

Age	Gender	Ethnicity	Social Grade	Gross household income	Smart devices owned	Current property

66	Male	English / Welsh / Scottish / Northern Irish / British	C1	£10,000 to £14,999 per year	1	Own the leasehold/freehold outright
65	Male	English / Welsh / Scottish / Northern Irish / British	B	£35,000 to £39,999 per year	4	Own the leasehold/freehold outright
73	Male	English / Welsh / Scottish / Northern Irish / British	C2	£45,000 to £49,999 per year	2	Own the leasehold/freehold outright
59	Female	English / Welsh / Scottish / Northern Irish / British	B	Prefer not to answer	2	Own the leasehold/freehold outright

c. Focus Group 3 Surrey (Rural)

Age	Gender	Ethnicity	Social Grade	Gross household income	Smart devices owned	Current property
21	Male	English / Welsh / Scottish / Northern Irish / British	B	£100,000 to £149,999 per year	5	Own the leasehold/freehold outright
29	Male	English / Welsh / Scottish / Northern Irish / British	A	Prefer not to answer	1	Rented from local authority
33	Male	English / Welsh / Scottish / Northern Irish / British	A	£70,000 to £99,999 per year	5	Rented from private landlord
40	Female	Any other Mixed / Multiple ethnic background	E	£35,000 to £39,999 per year	4	Own the leasehold/freehold outright
49	Female	English / Welsh / Scottish / Northern Irish / British	B	Prefer not to answer	3	Buying leasehold/freehold on a mortgage

52	Male	Arab	B	£100,000 to £149,999 per year	2	Buying leasehold/freehold on a mortgage
58	Male	English / Welsh / Scottish / Northern Irish / British	D	£20,000 to £24,999 per year	1	Own the leasehold/freehold outright

3.14 Limitations found in the methodology for Chapters 5-9

Although during this research, visits entailed a diverse number of retail firms, the sample was not exhaustive due to time limitations. In this sense, the researcher and team did not include other retailers such as system integrators, consultants, building specialists or online sellers that are also a large part of the smart home market. Another limitation, also due to lack of time, was that the research team was unable to conduct household interviews.

For the expert interviews, 77 participants were contacted. However, only 31 contributed to the study. In this sense, many did not reply to the email invitation and others felt they were not knowledgeable enough to answer the questions. Another limitation, during the focus groups, for instance, was that the researcher and team had to reschedule the activity since only three participants confirmed their participation. Moreover, during the focus groups, due to a car accident in Surrey, three participants arrived 45 late.

Overall, as Yin (2018) shows, during these stages of data collection, participants could have been biased due to the Hawthorne effect. That is, participants could have answered what the researcher wanted to hear since they know they were being observed. However, despite this, the researcher strongly believes that through conducting focus groups this research has revealed insights that it would have miss in surveys and other qualitative research.

Chapter 4. Reviewing behavioural change strategies for improving the sustainability and effectiveness of cookstove programs

4.1 Summary and introduction

Some of the findings presented in this chapter have been submitted to the academic journal Energy Research and Social Science under: **Furszyfer Del Rio, DD,** F Lambe, J Roe, N Matin, KE Makuch and M Osborne. "Do we need better behaved cooks? Reviewing behavioural change strategies for improving the sustainability and effectiveness of cookstove programs", revised and resubmitted to *Energy Research and Social Science.* Although this work is inspired by the manuscript where colleagues from Stockholm Environment Institute (SEI) collaborated. In this PhD, the researcher further explores areas within the adoption of improved cookstoves dimension, emphasizing, for instance, gender roles and cultural drivers.

In this sense, this chapter based on a systematic literature review entailing the years of 2013-2017, the author of this PhD explores what behavioural change techniques are the most successful in the adoption and maintained use of improved cookstoves. In this sense, the author sourced 31 peer reviewed published academic papers and identified the following most commonly used behaviour change techniques in the adoption of improved cookstoves: Shaping Knowledge (n=13), Reward & Threat (n=5), Social Support (n=7), Comparison (n=2), Identify/Self-Belief (n=2), Regulation (n=0), Change in the Physical Environment (n=1), Goals & Planning (n=6). After presenting the results, the author identifies gaps in the literature to later provide eight policy recommendations to promote the adoption and continued use of improved cookstoves.

Moreover, in this chapter, the author introduces Goodwin's et al (2014) theoretical framework, same that it is used throughout the thesis under the context of the adoption of smart home technologies. In fact, the influence of Goodwin's et al., (2014) theory is such, that in the conclusion section, the author presents how this framework could aid industry and policy makers to accelerate the deployment and adoption of smart home-connected products.

This chapter, furthermore, seeks to answer the following research question and sub questions:

- In what ways do behaviour and behavioural interventions shape cookstove adoption?
    - How do rewards (e.g. financial incentives and subsidies) influence in the adoption of improved cookstoves
    - Do demographic factors shape decision making regarding the adoption of these technologies?
    - How does social support impacts on users' perspectives of improved cookstoves?

4.2 Literature Review

This section offers a brief review of two different streams of scholarship relevant to the study. In this sense, first the researcher presents why the need to switch from traditional to improve cookstoves, providing an overview of why this is a global issue that needs to be addressed. And second, the author argues why behaviour change techniques may be a good mean to accelerate the deployment and adoption of these technologies. In this section the author also presents Goodwin's framework and explains the relevance of it in this research.

4.2.1 Contextualizing the need to switch from traditional to improved cookstoves

Approximately 40% -3 billion people- mostly from low and middle income countries still rely on traditional biomass (including charcoal, fuelwood, crop residues and dung) to meet their cooking and heating needs (IEA, 2013). The use of traditional biomass is associated with a significant negative effect on public health, with an estimated 4.3 million global deaths directly associated with indoor air pollution (World Bank, 2014). The damaging respiratory effects of such domestic cooking and heating practices are felt disproportionally by women and children, whose typical household roles increase their relative exposure to harmful pollutants (OECD/IEA, 2014; WHO, 2014). Indeed, research indicates that indoor air pollution is the single largest environmental risk factor for female mortality and the leading cause of death of children under the age of five (World Health Organization, 2018). In addition, indoor air pollution is also the eighth-leading contributor to the overall global disease burden, causing respiratory and cardiovascular damage as well as tuberculosis and cancer (Forum of International Respiratory Societies, 2017).

This is not limited to negative impacts on human health, the environmental effects in terms of deforestation are also significant, however, these remain highly uncertain (Bailis *et al.*, 2015). Historically, woodfuel demand was believed to be a key driver of land cover change (Eckholm, 1975). Recent research, nonetheless, dispute this and show conflicting results (Singh, Rawat and Verma, 2010; IPCC, 2015), suggesting that geography is a crucial determinant of woodfuel sustainability (Bailis *et al.*, 2015), with some studies indicating that woodfuel demand represents up to a 30% loss of forested areas in some countries (Jagger and Jumbe, 2016)[1]. As a result, there is an increasing scarcity of firewood in some parts of the world. Whereby, the use of traditional woodfuels for cooking and heating represent approximately 55% of global wood harvest and 9% of primary energy supply (REN21, 2012; Bailis *et al.*, 2015; FAO, 2015). Moreover, Mehetre et al., (2017) shows that the

[1] Malawi is the most representative case for Africa, as the deforestation rate is 2.8% per year[11]. Whilst in Aravalli Hills, India, fuel collection by women for cooking purposes is the primary cause of deforestation[12]

use of biomass for cooking and heating results in emissions of carbon dioxide (CO2), methane (CH4) and other short-lived climate forcers (SLFC). Thus, as noted by Bailis et al., (2015) wood-fuels present society with two important links between local and global impacts. First, incomplete combustion releases pollutants that not only damage health but also warm the atmosphere. And second, unsustainable harvesting practices drives forests' degradation and climate change.

Despite efforts over the past several decades on the part of governments and development partners to shift people away from traditional biomass for cooking, we are yet to see a large-scale transition to more efficient cookstoves and cleaner fuels (Barnes *et al.*, 2014; Rehfuess *et al.*, 2014). Current analyses suggest that without a substantial change in policy, the total number of people relying on traditional biomass will remain largely unchanged by 2030 (World Bank, 2014). Households that adopt ICS often continue to use existing stoves (known as fuel or stove 'stacking') to meet diverse cooking needs and address deficiencies in stove characteristics (Ruiz-Mercado *et al.*, 2011; Ruiz-Mercado and Masera, 2015), abandoning ICS and reverting to traditional cookstoves undermines key health and other benefits (Masera, Saatkamp and Kammen, 2000). Behaviour change interventions have been found to be effective means to achieve changes at individual, community and population levels (Barnes et al., 2014;Goodwin *et al.*, 2014; Michie, S. F., West, R., Campbell, R., Brown, J., & Gainforth, 2014; WHO, 2017). However there is a research gap in understanding how user-based and socio-cultural influences on cooking practice (Rehfuess *et al.*, 2014; Lewis *et al.*, 2015; Vigolo, Sallaku and Testa, 2018) interact with existing services and technologies to influence ICS uptake and sustained use (Jagadish and Dwivedi, 2018; Jürisoo, Lambe and Osborne, 2018).

Indeed**,** research on behaviour change related to ICS adoption increased from about 2011 onwards, due to renewed policy attention on the issue of household air pollution and inefficient cookstoves and the emergence of the Global Alliance for Clean Cooking (now renamed the Clean Cooking Alliance). The systematic review by Goodwin et al published in 2014 showed limited use of BC approaches; that is there was a predominance of BC interventions geared towards only 3 BCTs: i.e. Reward and Threat, Shaping Knowledge and Social Support were the most consistently applied BC approaches (Goodwin *et al.*, 2014), with little evidence targeting other BCTs. The researcher was interested if and how the uptake of BC approaches might have broadened overtime given the increased policy attention and funding targeting ICS interventions. Thus, the main objective of review and hence this chapter was to explore the use of BCTs and behaviour change frameworks to understand ICS adoption between 2013-2017.

4.2.3 behaviour change techniques: a quick glimpse to Goodwin's framework

For the purpose of this review, the author defines a behaviour change technique (BCT) as the "*active component within a clean cooking intervention that helps produce behaviour change to improvement to human health and /or environmental impact*" (Goodwin *et al.*, 2014 p.19). Behaviour change techniques conceptualised as building blocks of behaviour change interventions are a core element of the Behaviour Change Wheel framework, developed by Michie et al. (2011). In this framework, capability, opportunity, and motivation interact to generate behaviour in a system known as COM-B (Michie, Stralen and West, 2011). These components can be linked to BCTs that Michie et al. have systematically generated and applied collections or "taxonomies" of BCTs and from there, developed a "cross behaviour" taxonomy which includes 93 distinct BCTs (Atkins and Michie, 2013). To enhance usability and accuracy of the taxonomy, the identified BCTs were organized into 16 groups (Michie, Stralen and West, 2011; Atkins *et al.*, 2017).

Goodwin et al., (2014) have further simplified this taxonomy to 8 core clusters, providing a more manageable framework to report outcomes from their synthesis of the evidence. In this sense, Goodwin's BC framework considers elements of other frameworks such as SaniFOAM developed by Devine (2009) and Population Services International developed by the World Bank (PSI, 2004), but different to those, Goodwin's framework has the advantage of being theoretically driven by NICE

recognised model of health behaviours (Goodwin *et al.*, 2014) (see figure 6 below).

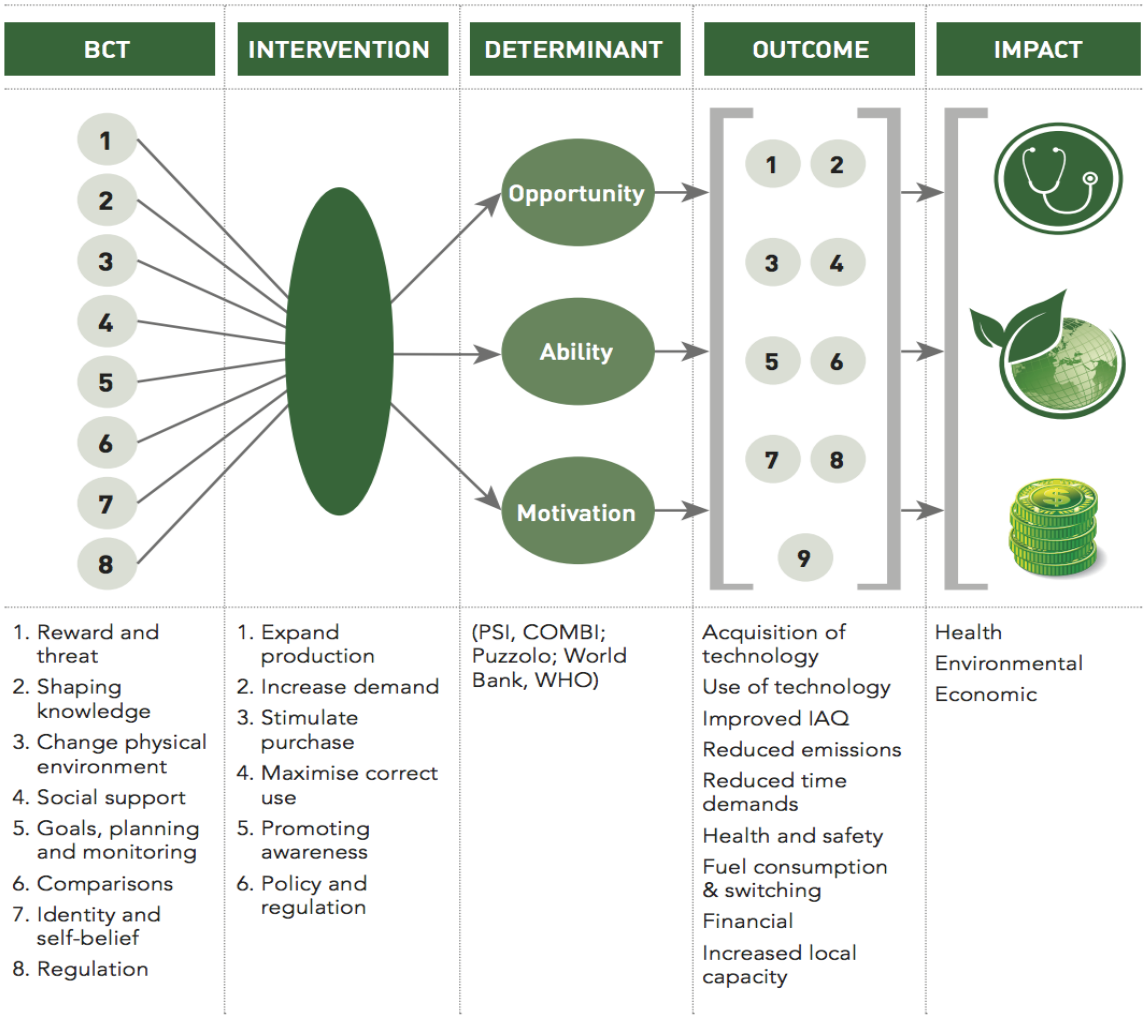


***Figure** 6 Goodwin et al., Behaviour Change Framework, 2014*

Source Goodwin et al., (2014) page 51

As **figure 6** illustrates the adoption and lasting use of improved cookstoves is influenced by myriad of factors, including the degree to which technologies satisfy customers' needs, the provision of training, financial incentives and policy. Certainly, for Goodwin and colleagues (2014), training is key element since with it, users can learn how to fix the stove according to manufactures instructions, household members could also be trained on adapting new fuels (e.g. dry wood cut to correct size), however, training measures are not limited to users, but also stove and fuel suppliers shall also be trained for the successful implementation cookstoves programs.

In this sense, and to have a better understanding around Goodwin's et al., (2014) framework, the taxonomy approached in this chapter groups behaviour change techniques into 8 core clusters, namely:

1. Reward and threat
2. Shaping knowledge
3. Changing the physical environment
4. Social support
5. Goals
6. Planning and monitoring
7. Comparisons, identity and belief, and
8. Regulation.

Now that the author has introduced the importance of switching from traditional to improved cookstoves and in addition has also provided a short summary of Goodwin's theoretical framework, the researcher moves forward to present the results and findings emerging from the literature review analysis.

4.3 Results

4.3.1 Search terms results

From the search terms applied (see chapter 3, Methodology, section 3.6.1) a total number of 31 relevant papers were identified, with additional material added monthly (around 2-3 relevant papers emerging per monthly Science Direct alerts). Four of these papers were systematic reviews (Puzzolo E, Stanistreet D, Pope D, Bruce N, 2013; BR, 2014; Goodwin *et al.*, 2014; World Bank, 2014); one theoretical paper (Clark, Heiderscheidt and Peel, 2015); and one a synthesis of debates within the sector (Simon *et al.*, 2014). The remaining were experimental in design and/or took an intervention pre- and post- evaluation approach. After reading and assimilating results from all 31 papers, this left 21 that fitted the BCT evaluative framework, with ten others informing the BCT framework. It's beyond the scope of this study to review behaviour change theory widely; this study focuses on recent evidence of theoretical frameworks applied in the clean cookstove sector only.

4.3.2 Geographic context

Country/region	Number of interventions

India (Thurber *et al.*, 2014; Freeman and Zerriffi, 2015; Lewis *et al.*, 2015)	3
Kenya (van der Kroon, Brouwer and van Beukering, 2014; Shankar, Onyura and Alderman, 2015; Stanistreet *et al.*, 2015; Treiber, Grimsby and Aune, 2015; Tigabu, 2017)	6
Central America (Manning and Taylor, 2014; Ramirez *et al.*, 2014)	2
Bangladesh (Hassan, Pelkonen and Pappinen, 2014; Rosenbaum, Derby and Dutta, 2015)	2
Southern Spain (García-Maroto *et al.*, 2015)	1
Indonesia (Johnson and Chiang, 2015)	1
Uganda (Beltramo T, Levine DI, 2014; Beltramo *et al.*, 2015; Hankey *et al.*, 2015; Namagembe *et al.*, 2015; Theotokis and Manganari, 2015; Simons *et al.*, 2017)	5
Malawi (Jagger and Jumbe, 2016; Cundale *et al.*, 2017)	2
Ghana (Piedrahita *et al.*, 2016)	1
Senegal (Bensch and Peters, 2015)	1
USA (Champion *et al.*, 2017)	1
Not defined (Puzzolo E, Stanistreet D, Pope D, Bruce N, 2013; BR, 2014; Goodwin *et al.*, 2014; Simon *et al.*, 2014; World Bank, 2014; Clark, Heiderscheidt and Peel, 2015)	6

Table 6. number of studies found by geographic context

Most of the intervention studies were carried out in a rural context for which we found 22 interventions. Whilst for the peri-urban context, the author detected seven interventions. For the rest of the studies, the location of the interventions was either unavailable or unclear.

4.3.3 Methods Cited

Most research undertook a mixed methods approach (Quantitative + Qualitative, n=8), Qualitative only (n=2), Quantitative only (n=2) with sensor monitoring (n=2), plus one choice experiment, and one social network analysis. The found only two longitudinal studies (Thurber *et al.*, 2014; Namagembe *et al.*, 2015). and thus, we suggest the need for more robust experimental design i.e. more randomized control trials, (RCTs) since we found only one in our analysis (Beltramo et al., 2014).

4.4 Findings: behaviour change techniques used in the adoption and maintained used of improved cookstoves

Rewards (e.g. financial incentives and subsidies), Shaping Knowledge (health messaging particularly and workshops) and Monitoring and Goals in the form of time savings and through the use of stove-use monitors (SUMs) are all commonly use BCTs in the post-2013 academic literature. See Table 7 below for the number of papers reporting each of these approaches.

BCT	**Descriptor**	**# Interventions referring to BCT approach**
Reward and Threat	Fuel cost/stove cost incentives/cash buy back offers/rent to own option	5
Shaping Knowledge	Health information; environmental impact information; demos	13
Changing the physical environment	Includes more user-centred design of cookstoves	1
Social Support	Cooking demonstrations	7
Goals, planning and monitoring Re-name *Goals and Aspirations.*	Time reduction; ICS that can also charge mobile phone; taste preferences	6
Comparisons (Peer impact)	Neighbourhood-friends purchase impact on adoption	2
Identity and Belief	Agency based empowerment training in ICS programmes	2
Regulation	Legislative frameworks	0
Additional: Changes in social environment	Migration	1

Table 7 behaviour change techniques found in the literature

4.4.1 Reward and threat

Financial incentives, fuel costs and availability are consistently reported to be core drivers for sustained adoption of improved cookstoves (Puzzolo et al., 2013; Thurber *et al.*, 2014; van der Kroon, Brouwer and van Beukering, 2014; World Bank, 2014; Hankey *et al.*, 2015; Ruiz-Mercado and Masera, 2015; Treiber, Grimsby and Aune, 2015; Cundale *et al.*, 2017). Subsidies to help households buy improved stoves were particularly important in poorer rural communities that traditionally use foraged fuelwood, charcoal and indigenous low-cost cookstoves (Bensch and Peters, 2015; Bensch, Grimm and Peters, 2015; García-Maroto *et al.*, 2015; Simons *et al.*, 2017). Providing credit to low-

income communities to ease their financial burden was also a popular choice. Other programmes' incentives included delivering cookstoves free of charge to poorer users (World Bank, 2014; Simons *et al.*, 2017). In this analysis the researcher found, for instance, that in Senegal under the Reward and Threat approach, subsidies played a vital role as they led to higher adoption and maintained use rates (Bensch and Peters, 2015).

4.4.2 Shaping knowledge

The results obtained with the collaborative work with SEI, showed that Shaping Knowledge is the most popular intervention (van der Kroon, Brouwer and van Beukering, 2014; Goodwin *et al.*, 2014; Ramirez *et al.*, 2014; Thurber *et al.*, 2014; Hankey *et al.*, 2015; Lewis *et al.*, 2015; Namagembe *et al.*, 2015; Rosenbaum, Derby and Dutta, 2015; Jagger and Jumbe, 2016; Champion *et al.*, 2017; Cundale *et al.*, 2017; Tigabu, 2017). Thus, Shaping Knowledge through marketing messages in rural Uganda 'the stove can improve health' or 'stove can save time and money', (Beltramo T, Levine DI, 2014) consistently increased willingness to purchase ICSs. Similar results were obtained in Oorja, India where the adoption of ICS was significantly influenced by health orientated messaging marketing and awareness via word of mouth or practical demonstrations (Thurber *et al.*, 2014). Other examples that increased adoption and maintained use were cooking demonstrations, these were reported as being important, particularly in relation to sustained usage (Namagembe *et al.*, 2015). Finally, the impact of health and environmental messaging is a significant driver of adoption in some contexts, as noted by van der Kroon et al., (2014) and Shankar et al. (2015).

Having a broader understanding of cultural standpoints is essential. For example, Champion et al. (2017) illustrate how flames are perceived by The Navajo Nation, USA. For them, the blue flame created when combusted with natural gas is often associated with gaseous fuels that are believed to have negative effects on the body and it is thought that this flame burns hotter. Moreover, in this community, harvested cedar and oak are optimal for use in heating stoves, although pine and piñon are also acceptable. These woods produce red, yellow, or white fire flames, which for this community is perceived as the natural flame that represents Navajo's sacred relative fires. They retain these practices, even though they have negative health effects, particularly on the lungs (Champion *et al.*, 2017).

4.4.3 Social support

Social Support plays a key role in the adoption of ICSs. In the literature review researcher and team found that in Uganda and Malawi social networks have been found to be most effective when there

are reciprocal relationships between individuals (van der Kroon, Brouwer and van Beukering, 2014; Clark, Heiderscheidt and Peel, 2015). Whilst in Kenya and The Navajo Nation, USA, the reputation of new technologies is positively influenced by favourable opinions among community members, especially, from leaders opinion's which need to actively participate in the intervention process (Champion *et al.*, 2017). Word of mouth communication through influential people – i.e. leaders and government officials, teachers, housewives and business people – was one of the most effective approaches (Clark, Heiderscheidt and Peel, 2015; Rosenbaum, Derby and Dutta, 2015). Furthermore, community sales agents who were trained on household air pollution are key players in disseminating the health benefits of ICS (Namagembe *et al.*, 2015). Other strategies include using change agents, community leadership, communities of practice, and outreach workers to generate cultural acceptance of ICS (Ramirez *et al.*, 2014; Namagembe *et al.*, 2015; Shankar, Onyura and Alderman, 2015; Jagger and Jumbe, 2016; Champion *et al.*, 2017; Tigabu, 2017).

4.4.4 Goals/planning and monitoring

Behaviour change goals work well when directed toward individual and household goals, aspirations and lifestyle. For instance, one study suggested that men were more interested in ICS if the stove could also charge their mobile phone (Beltramo T, Levine DI, 2014). To reflect such themes, the researcher and team suggest this dimension be renamed to "goals and aspirations".

Moreover, this research found that time savings associated with ICS are critical and need better promotion. Moreover, these benefits could be better directed towards individual and household goals and aspirations. For example, targeting how opportunities from time saved – say from laborious wood collecting – can be directed towards aspirations in the form of other work-related and recreational goals. This could be illustrated from Bangladesh and Malawi's cases, where the emphasis of the non-health considerations is ranked as follows. First, women valued the ability of non-traditional cookstoves to reduce fuel use the most. Whilst the second most valuable attribute is the ability to reduce cooking time (Cundale *et al.*, 2017). Finally, we found that the use of stove use monitors (SUMs) showed that the Hawthorne Effect and the act of surveillance can change later behaviours of those being surveyed (Beltramo *et al.*, 2015). However, as studied by (Schwartz *et al.*, 2013), there is a risk that after the experiment, individuals return to their normal routines.

4.4.5 Lifestyle drivers

Overall, there is very little evidence on how lifestyle drivers impact on choice. During this research, one study found aspirational factors (e.g. improved quality of life) was not a driver of ICS adoption

(Namagembe *et al.*, 2015). Whilst in Kenya, social status is connected to fuel choice (e.g., use of charcoal indicates a richer family and is the chosen method when cooking for guests) (Treiber, Grimsby and Aune, 2015). Furthermore, another study suggests that men are more aware of status attached to improved stoves (van der Kroon, Brouwer and van Beukering, 2014); this suggests that gender needs careful targeting with respect to goals/aspirations. Further, in the study conducted by Bensch and Peters (2015), women repeatedly noted that ICS allows them to regulate the temperature more easily, which, in turn, makes it easier for them to do other things while cooking. Mostly, to develop other household chores or other economic and social activities, including studying. This aligns to the point that time-saving is one of the main drivers to the maintained use of ICS (Furszyfer Del Rio *et al.*, 2020).

4.4.6 Changes in the Physical environment

Another area where the researchers clearly demand further research is related to changes in the physical environment. Studies revealed that there is a need to better understand housing tenure, homes' design and their impact on cooking and health (Ruiz-Mercado *et al.*, 2013; Simons *et al.*, 2017). Clark et al., (2015) further reviewed evidence for physical changes in households and the positive impact that some of these can have on indoor air pollution (Furszyfer Del Rio *et al.*, 2020).

4.4.7 Comparisons

Providing a choice of options of ICS and fuels available is central to behavioural change (see discussion on fuel stacking below). However, the researcher and research study team found that this dimension is possibly the weakest in the existing framework. Thus, this research suggests it needs further redefinition (Furszyfer Del Rio *et al.*, 2020).

4.4.8 Identity and belief

Little evidence was found of targeted messaging to men and women, but interesting differences amongst gender responses suggest that carefully targeted messaging has much potential in addressing behavioural change. For instance, an entrepreneurial program delivering empowerment training for both men and women found that sales of ICS doubled across both gender groups, but delivered greatest strides in relation to women's decision-making – women outsold men by a margin of almost 3:1 (Shankar, Onyura and Alderman, 2015). This research thus suggests that internally focused training –and internally focused aspirations, (i.e., focusing on intrinsic motivations/what is meaningful for someone) - are key future strategies needed to be explored (Furszyfer Del Rio *et al.*, 2020).

4.4.9 Regulation

In this thesis analysis, the researcher found that none of the peer-reviewed academic papers reported regulatory frameworks as being drivers for ICS uptake and or/related behavioural change. Looking at the structural determinants of behaviour change is a major omission in the field to date (i.e. the political, legal and institutional drivers and conditions) (Furszyfer Del Rio *et al.*, 2020).

4.4.10 Summary highlights

Reflecting on Goodwin et al (2014) , Reward and Threat, Shaping Knowledge and Social Support were the most consistently applied BC approaches. However, these are often used in tandem, thus, making it hard to separate the impacts of one strategy over the other. In consequence, the researcher found the need to better design experiments in relation to isolating key variables.

4.5 Emerging themes beyond behaviour change

4.5.1 Gender trends

The researcher found numerous gender trends that although do not belong specifically within the category of behaviour change techniques, the author considered worth exploring. In this sense, this research found that where women are decision-makers within a household, they show higher demand for improved stoves (Hart and Smith, 2013). The Clean Cooking Alliance and the World Health Organization (WHO) argue that women's demand for cleaner technologies is due to their central responsibility not only as main consumers and users of cookstoves but also, as central managers for household energy and cooking needs (Clean Cooking Alliance, 2017; WHO, 2018). Household characteristics play a significant role too, mainly in terms of education and women's decision-making power, as female-headed households tend to adopt cleaner fuels and technologies (van der Kroon, Brouwer and van Beukering, 2014; Cundale *et al.*, 2017). Therefore, it is vital to have broader understanding regarding gender dynamics as with this, it will be easier to advance future uptake of ICS (Bensch and Peters, 2015; Ruiz-Mercado and Masera, 2015; Tigabu, 2017).

Other studies, for example, emphasise the role of word to mouth communication among women, since research identify it as primary persuasive method to adopt improved cookstoves (Vigolo, Sallaku and Testa, 2018; Global Alliance for Clean Cookstoves, 2019). On the same vein and to highlight the links between BCT and gender roles, Thakur and colleagues (Thakur *et al.*, 2017), found that in Bangalore, if some women were unhappy with the stove, they would influence other community members who, in turn, refuse to even give it a try. Surprisingly, despite women's household roles,

they seem less aware of indoors health risks associated with air pollution than men (McArthur, 1988). Moreover, household dynamics and gender pattern for communication are complex (Ramirez *et al.*, 2014); for instance, males play a leading role in diffusion over long distances, women in shorter distances; men play a critical role in dissemination process, as men-to-men communications are highly effective. Communications between women at a local level might play a more critical role in adoption of ICS than information diffusion across the regional scale. It's therefore important to consider communications across geographic scales. In this area, Van der Kroon et al., (van der Kroon, Brouwer and van Beukering, 2014) reveals that men are more aware of status attached to improved stoves, suggesting that gender needs careful targeting with respect to goals/aspirations.

One related study on adoption of wood pellets in domestic heating systems in Southern Spain, suggesting that women are more risk averse, and therefore, opt for a proven heating system (García-Maroto *et al.*, 2015). The study conducted by Beltramo et al., (2014) suggests that adoption of ICS "*may be more successful by designing and disseminating non-traditional cookstoves with features valued more highly by men and addressing liquidity constraints*", instead of approaching potential users through marketing messages related to the health and private economic benefits ICS offer, but there are possibly some misconceptions about this. There is a large negative effect on willingness to pay if a participant is female - on average men are willing to pay 21-23% more than women for an ICS (Beltramo T, Levine DI, 2014). However, the higher willingness to pay amongst men, may be due to low bargaining power of women in the home and lower control of household finance in general (Rehfuess *et al.*, 2014).

4.5.2 Cultural drivers

Cultural drivers, although escape behavioural change techniques framework, according to the literature, are other factors that push for greater levels of adoption and maintained use. Thus, the researcher has considered including this in its study. In this way, an interesting emergent theme in the post 2013 literature is the impact of ICS on specific food to be cooked and tasks to be performed. For instance, taste plays a key role in decision-making in rural-peri-urban Kenya. Trieber's study (2015) finds that households do indeed have choices (i.e. not all decision-making is down to a constrained economy). It shows how the cultural practice of cooking and specific fuel needs impact on ICS adoption (in Trieber's study, 7% of respondents stated that tradition drove their main choice). For cooking, in general, ICS (Jiko Kisasa model for firewood), is preferred, but breaks under the weight of heavy foods. And firewood, is reserved for special dishes (smoky flavour); charcoal is used for everyday usage (Jan, 2012). In addition, some are using traditional stoves to keep their culture

alive (i.e. three stone fire). Treiber, Grimsby and Aune, (2015) conclude that fuel stacking[2] is the most commonly found fuel model in Kenya and that efforts to switch households to one cleaner fuel type – at least in Kenya's context– are not feasible. Barnes (2014) in a systematic review, also found fuel stacking (i.e. mixed fuel combinations) is the preferred household energy model. However, this decision comes with negative impacts on users' health, as indicated by (Wilkinson *et al.*, 2009), to achieve any health benefit at all, it is necessary to completely transition from traditional to clean stoves.

Overall, the findings on cultural drivers of improved cookstove adoption are mixed. Some studies report cultural drivers do not impact sustained adoption of ICS (Barnes et al, 2014; Thurber *et al.*, 2014). Puzzulo et al.'s, (2013) synthesis identifies some interesting cultural components in relation to food preferences. For example, some users reported satisfaction in terms of taste, colour and texture of the food whereas others did not. The lack of clarity over this potential significant, and yet apparently under-researched area should, the researcher suggests, encourage further exploration in the future (Furszyfer Del Rio *et al.*, 2020).

Indeed, Ruiz Mercado et al., (2013) criticise the traditional approach of substitution of cookstoves and traditional fuels, as rarely both can be perfect substitutes for all traditional fuel devices, for reasons given above and below. Consequently, in order to fulfil their needs, households tend to continue stacking (Piedrahita *et al.*, 2016). In the same vein, with this approach, it could be argued that the problem is oversimplified given the fact that traditional open fires not only satisfy cooking needs, but also cultural and other practical ones. For Ruiz-Mercado and Masera (2015), the use of solid biofuels in open fires in Mexico, provides other benefits such as: heating living space, lighting the home, heating water for bathing and washing, drying clothes and driving insects away.

4.5.3 Demographic factors of significance outcomes

This research found two key elements that although are not related to BCT, played a fundamental role in the adoption of ICS. First, education, which was nine times cited as a driver (Hassan, Pelkonen and Pappinen, 2014; Ramirez *et al.*, 2014; Simon *et al.*, 2014; Thurber *et al.*, 2014; Freeman and Zerriffi, 2015; Rosenbaum, Derby and Dutta, 2015; Treiber, Grimsby and Aune, 2015; Champion *et al.*, 2017). Where women's education, as well as education beyond secondary school, played a role as a significant determinant to increase adoption. This does not mean that higher education leads to higher awareness, but to having knowledge about the benefits that these technologies offer.

[2] When households use different combinations of old and new technology at the same time to satisfy their energy, cooking and heating needs. For example, families could use LPG and charcoal

Second, having a stable income in Kenya, Uganda and Malawi was a key determinant of adoption and maintained use of ICS (Beltramo et al., 2015). This can be explained due to the fact that households with higher income can afford ICS and in cases where the ICS stop working, household members are able to pay for the repairs. Moreover, the work by Calzada and Sanz (2018) illustrates another income trend: as income increases, households tend to switch to cleaner and more efficient fuels to satisfy cooking needs.

This research found that time efficiency, taste preferences, design requirement to satisfy heating and cooking needs, price and income are all relevant factors in the uptake and embracement of improved cookstoves (Furszyfer Del Rio *et al.*, 2020). Household characteristics play a significant role too, mainly in terms of education and women's decision-making power, as female-headed households tend to adopt cleaner fuels and technologies (van der Kroon, Brouwer and van Beukering, 2014; Cundale *et al.*, 2017) Therefore, it is vital to have broader understanding regarding gender dynamics as with this, it will be easier to advance future uptake of ICS (Bensch and Peters, 2015; Ruiz-Mercado and Masera, 2015; Tigabu, 2017).

4.6 Gaps in the literature identified by the researcher

Although the researcher and team explored in-depth this fascinating area of study, they were still able to identify gaps in the literature that ought to be addressed

1- No BCT approaches appear to consider emotional drivers in decision making and adoption;
2- None of the evaluation appears to consider seasonality issues in decision making processes, other than stating that fuel availability is variable by season;
3- There is a need for objective indoor air pollution sensor monitoring since there is discord between self-recorded uptake of ICS and objectively recorded data (Namagembe *et al.*, 2015).
4- Given the conflicting messages – particularly over health messaging – the local geographic context is very important.
5- There is a need to explore cookstove interventions from the perspective of women's empowerment and inequalities prevalent within the structural context of a culture.
6- There is a need to explore structural determinants of BC (i.e. state regulations, local government administrative capacity, informal governance, discriminatory social relations) and opportunities for interventions (e.g. regulatory reform). Incentive schemes & subsidies need to be explored.

4.7 Discussion and policy recommendations

It is important to mention that whilst behaviour change theory is beginning to be integrated into the cookstove sector, there is a need for a standardised and systematic method, that has academic rigour and, at the same time, can be easily grasped by NGOs and agencies, and applied to both; the design of interventions and measurement of outcomes. This is not to say that all interventions need to follow and adopt the same framework, but rather that when behaviour change framework, once selected, should be applied and tested in a standardised manner to allow for much needed learning in this sector on what works. In this literature review analysis, the researcher suggest that Goodwin's shortened Michie et al., (2011) behaviour change taxonomy holds most promise, concurring with other models in the field (i.e. PIS Bubbles and SaniFoam) that apply a Motivation, Opportunity and Ability framework, and also has demonstrated reliability, proven via a systematic review of 48 studies. But there is a need to explore dynamics and interactions within the model framework, (i.e. that more than one BCT can be operating at a time); and also, to extend the model. For example, to include emotional drivers of change, personality dynamics and changes in social environment (e.g. migration of young adults and the impact on household labour availability).

Finally, Ramirez et al (2014) and Khandewal et al., (2017) argue that for interventions to be successful, lasting use of advanced cookstoves is essential. Mainly, since evidence suggests that the use of cleaner cooking technologies decline over time due to poor maintenance. Hence, we suggest that it is paramount to shape local knowledge (for instance, through women as an empowerment mechanism) and build skills within the community so that people may be able to repair ICSs and promote their continued use.

Chapter 5. Critically Reviewing Smart Home Technology Applications and Business Models in Europe

5.1 Summary and Introduction

Some of the findings presented in this chapter have resulted in two academic publications, In this sense, although some of the quotes and references presented in this chapter are taken from the papers below. In this PhD research, the author considered more references and included more insights from the interviews to better situate the findings and show the plurality of existent options in the smart home technologies arena.

- Furszyfer Del Rio, DD, BK Sovacool, N Bergman and KE Makuch (2020). *"*Critically Reviewing Smart Home Technology Applications and Business Models in Europe,*" Energy Policy, 144. https://doi.org/10.1016/j.enpol.2020.111631*
- Sovacool, B.K. and Furszyfer Del Rio, D. D. (2020) 'Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies', *Renewable and Sustainable Energy Reviews*, 120. doi: 10.1016/j.rser.2019.109663.

This chapter based on 31 expert interviews and 38 site visits to retail stores focuses in presenting two key themes: defining what smart home technologies are and what are the business applications of these technologies. Regarding the first subject, this investigation found that the definition of smart home technologies revolve around four key components: smart homes are digitally connected, enhance household control, attempt to reach higher levels of automation, and promote learning (either by households or technology). The author based on this evidence proceeds to present its own definition on smart home technologies in section 6.3.1. Concerning the second theme and based on the data collected, in this chapter the author presents fifteen separate business models for achieving smart home development, this range from energy services provision, demand response and capturing economic benefits to presuming peer to peer and blockchain. By the end of this chapter, the author lists a set of conclusions and provides a comprehensive discussion of the impacts of these business models in the social, environmental and energy fields.

In this sense this chapter aims to answer the following research questions this PhD posed in its chapter 2:

- How does one define smart home technologies (SHTs)? What are they?
- What business models have the most promise?

5.2 Literature Review

This section offers a brief review of three different streams of scholarship relevant to the study those related with the current state of the market of smart home technologies, where the researcher introduces current and future trends. Later, to provide better context of the results to come the author provides a list of definitions of what smart home technologies are. This section finalizes with a short overview of enabling business models for smart homes.

5.2.1 The state of the market and future projections

Smart home technologies, smart grids, and smarter energy use have become centred themes in recent years. There is little doubt these technologies are spreading and growing in influence. For instance, the World Economic Forum and Accenture calculate these technologies will add $14 trillion of economic value to the global economy by 2030 and an additional $100 billion in operating profits across industry (World Economic Forum, 2018). Others have noticed substantial year-over-year growth in the number of connected devices as sales growth by 17% from 2016-2017 (Mckinsey, 2016). Based on this, some argue that for consumers, at least in the UK and Europe, the smart home revolution has arrived (Sovacool and Furszyfer Del Rio, 2020a). Indeed, Jungwoo et al. already estimate that smart home technologies had diffused to 7.5 percent of households globally and generated expected revenues of $44.2 billion in 2018 (Jungwoo, Park and Lee, 2018). Market analysts Berg Insight estimate that at the end of 2017 there were 22.5 million smart homes in Europe alone, or 9.9% of European households (Berg Insight, 2018). They forecast a growth of ~30% a year, or 84 million smart homes by 2022, with France, Germany, and the United Kingdom leading the European market (Sforza, 2019). De Souza et al. similarly predict that by the end of 2020, 35% of all households in North America and 20% of households in Europe can be classified as smart homes (de Souza Dutra, Anjos and Le Digabel, 2019).

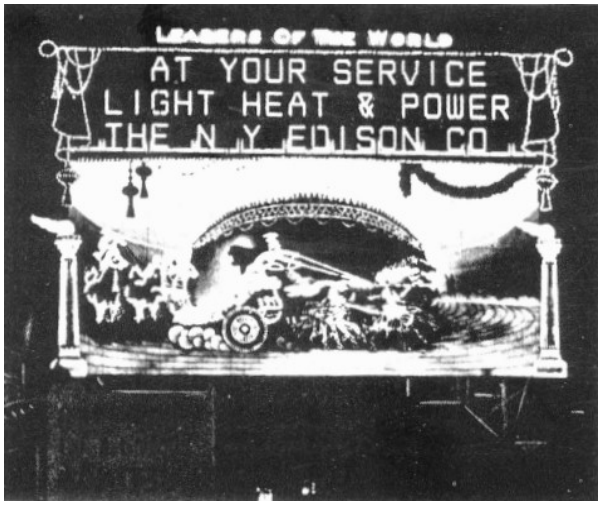
An example of a technology that has had a major impact in recent years is the smart speaker with voice assistant (Berg Insight, 2018; Sforza, 2019). Yet the term “smart” can refer to a variety of things and there is no single agreed definition; some consider (Accenture Strategy, 2015) that these technologies ought to include internet of things (IoT) and smart devices, along with (real-time) monitoring, sensor technologies and data analytics, customer interfaces and demand response

technologies. In this sense, Consultancy Berg Insight, groups 'smart home system' into seven categories: "1. security and access control systems; 2. energy management and climate control systems; 3. audio-visual and entertainment systems; 4. lighting and window control systems; 5. healthcare and assisted living systems; 6. home appliances and 7. service robotics" (Berg Insight, 2018). Whilst PWC's report (2018) identified 12 categories: 1. smart home assistants; 2. wearables; 3. air conditioning and smoke alarms; 4. lighting; 5. security and safety; 6. doorbells; 7. heating; 8. speakers; 9. entertainment; 10. appliances; 11. smart energy meters and 12. plugs. This part of the thesis attempts to unpack the business models around smart home technologies, and the importance of relevant policy.

5.2.2 history, definitions and conceptualizations of smart home technologies

Smart home technologies, although not defined as such, have a much longer history than many may realize (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). The development of an idea of homes that could be 'smarter' in relation to the comfort and convenience they provide can be traced back to at least the 1890s and early 1900s. This idea of 'smarter', for example, arguably originated when wealthy people used the introduction of electricity to create homes with greater degrees of automation and levels of luxury, relaxation, and indulgence (Gram-Hanssen and Darby, 2018; Sovacool and Furszyfer Del Rio, 2020a). As presented in Figure 7, Thomas Edison patented automated, coloured lighting for homes during 1910 and this, was used later that year to promote public advertising for New York Edison (Sovacool and Furszyfer Del Rio, 2020a). Similarly, efforts were conducted by the Rural Electrification Administration and General electric (Sovacool and Furszyfer Del Rio, 2020a). The first, helped in promoting electric appliances to go hand-in -hand with efforts to electrify rural farms whilst the latter, launched the "Live Better Electrically" campaign in 1956, efforts that awarded homes a gold medallion if they converted all of their appliances to electricity (Sovacool and Furszyfer Del Rio, 2020a).

Figure 7: Efforts at Smart Lighting and Homes from Thomas Edison (1910)



Source: taken from (B.K. Sovacool and Furszyfer Del Rio, 2020) with permission.

More recently, in the decades from 1990s to 2000s, smart homes have been marketed as key elements of making homes more efficient, by providing not only economic savings, reductions in energy consumption and carbon emissions, but also, by making homes a safer and more pleasurable and enjoyable space. In the next paragraphs, this PhD presents the most prominent definitions of smart homes available in the literature. The author listed them in chronological order to show the evolution of the concept and allow the reader to make comparisons between one and the other. After introducing the definitions, the author later presents, based on these and data collected during the expert interviews, a definition on its own.

The first prominent definition of smart homes the researcher found is provided by Lutolf in 1992. The concept refers to the integration of different services within a home by employing a common communication system. It assures an economic, secure and comfortable operation of the home and includes a high degree of intelligent functionality and flexibility. Aldrich, (2003) almost ten years later, conceptualized smart home technologies as: a residence equipped with computing and information technology, devices to anticipate and respond to users' needs, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond.

Other academics focused instead on the systemic nature of the home, highlighting integration or cooperation of different elements such as this upfront definition – notice how the home is an 'it' which responds as a single entity (Furszyfer Del Rio, et al., 2020)..

> A smart home is a home-like environment that possesses ambient intelligence and automatic control, which allow it to respond to the behaviour of residents and provide them with various facilities. (De Silva, Morikawa and Petra, 2012)

Other works which focused on academic literature (articles and book chapters), found that most scholars referred to technological attributes in defining smart homes. For example, building on several previous papers, Balta-Ozkan et al. (2013) offer this definition:

> A smart home is a residence equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants. (p. 364)

A more interactive definition is provided by Rinaldi and colleagues. For them, smart home technologies are a two-way communication system between the house and its occupants (Saul-Rinaldi, LeBaron and Caracino, 2014). Another definition from the private sector also emphasises information and control:

> Smart Buildings can be described as a confluence between architecture, urban planning and ICT. The principle components of Smart Buildings are automation systems, sensors, integration into Smart Grids via smart meters, energy use analytics, forecasting and the better detection of faults through the use of monitoring technologies. For instance, data collected via smart meters and other smart home solutions can be communicated to users via their smart device, allowing users to monitor their energy use, control building functions such as lighting, cooling or heating, and detect faults or abnormalities early – all remotely. These solutions could be applied to large commercial and industrial complexes or smaller homes and condominiums, helping to drive the more efficient use of resources and energy. (Accenture Strategy, 2015).

Definitions emerging from the private sector, e.g., consultancies and the ICT sector, and even groups such as the think tank Green Alliance (Green Alliance, 2007) have less of a focus on users' needs. For example, a market analysis consultancy emphasises communication and home 'solutions':

> Smart homes and home automation are ambiguous terms used in reference to a wide range of solutions for controlling, monitoring and automating functions in the home. Berg Insight's definition of a smart home system requires that it has a smartphone app or a web portal as a user interface. Devices that only can be controlled with switches, timers, sensors and remote controls are thus not included in the scope of this study. (Berg Insight, 2018).

Marikyan et al. (2019) further defines smart homes through the services they provided – managing energy systems and improving users' comfort, or emphasising the healthcare context for an ageing population, enabling independent living. Overall, Marikyan et al. (2019) suggest three characteristics

in common in the definitions they found: 1. technology, 2. services and 3. the ability to satisfy users' needs.

The empirical data collected throughout this thesis supports this plurality of definitions of what smart home technologies are or can be or can accomplish (Furszyfer Del Rio *et al.*, 2020). However, a more in-depth analysis of this is later presented in the discussion and policy implications and at the end of this PhD, in the conclusion section (Chapter 10), where the author introduces his own definition. In addition, a list of the 31 definitions provided by experts can be found in appendix 2, which could help illustrate the diversity of definitions that the experts provided.

5.2.3 Enabling Business models for smart home technologies

The transition towards smart homes entails a collective and perhaps potentially a deep reformulation of urban structures, strategies, ecosystems and technologies. In other words, this transition may fundamentally challenge long-established business models around homes and the value they offer, as well as unlock new business models (Schiavone, Paolone and Mancini, 2019). This research agrees with Kavadias and colleagues (2016) when they refer to business models as a system whose various features interact, by different and complex means, to determine a given venture, technology, or company's success. However, different to traditional approaches, successful platform-based business models share four elements in common: they are open, connected, intelligent and scalable (Guillen and Reddy, 2019).

Schiavone and colleagues (2019) use the term "smartization" to assess the broad canvas of activities that smart technology may entail, those that can affect not only the role of partners and ecosystems in urban value creation and its entrepreneurship mood (Aljēna, 2015) but also individual benefits and shared goals. This framework takes on more relevance when others have used it to analyse smart cities. For instance, Diaz-Diaz et al., (2017) focuses on four blocks of the model (customers, offers, infrastructure and financial viability) to reveal that IoT devices generate value by cutting costs in the long term. Indeed, research in IoT-enabled business models has also been explored by others such as (Dijkman *et al.*, 2015; Kralewsky, 2016) who based their work on the elements of Osterwalder and Pigneur's framework (2010).

Also operating in this space, Suppatvech et al., (2019) employs a different method, a "servitized" approach that classifies emergent business models utilising IoT and reports on a wide range of applications. These may include *subscriptions*, where customers are charged for unlimited access to the product service and *pay-per-use*, where customers are only charged for the usage off the

product or service. Based on this, Suppatvech et al., (2019) work from the premise that servitized business models operate, again, at two levels. First, the operational level, that is, the functionalities of smart devices used in offering services. And second, a strategic level, where devices are classified according to their use. In this sense, smart home technologies offer additional services to the existing product or service. In turn, firms can gain additional revenue from providing such services (Dijkman *et al.*, 2015; Kralewsky, 2016; Rachinger *et al.*, 2019) and "*generate income more steadily as long-term contract replaces sales"* (Suppatvech, Godsell and Day, 2019)" .

However, even when tapping into these levels and layers of smart business models, industries may still encounter barriers (Furszyfer Del Rio, *et al.*, 2020). As identified by the World Bank (2017), for business models to thrive, infrastructure must exist and be reliable. Specifically, the lack of consistent standards ruling smart connected products networks such as low-power wide-area could dampen large-scale investments. The same report indicates that lack of market readiness represents one of the biggest barriers. Certainly, the government needs to prescribe the market through further regulations and policies since these aspects have not been defined yet. In this sense, the Organization for Economic Co-operation and Development (OECD) (2016) argues that the risk is not sufficiently reduced or defined for business to act. In this way, although for internet giants such as Google and Amazon, using consumers data to drive revenues is at the core of their business models, data ownership remains fragmented and no business model have yet emerged with respect to monetization of data (McKinsey Global Institute, 2015; World Bank, 2017).

The author through a revision of the literature has provided chronological definitions of smart homes, the current state of the market and what business models and applications smart home technologies possess. The author now moves forward to present its results, same that includes 16 potential business models and their applications.

5.3 Results

5.3.1 Defining smart home technologies: what are they?

As previously introduced, the researcher was unable to find an agreed definition of what smart home technologies are. To further validate this assumption, the empirical data collected in this PhD, supports this plurality of definitions of what smart home technologies are or can accomplish. However, the researcher as by the end of this subsection presents, raise concerns that a missing definition of what smart home technologies are, allows regulation gaps (e.g. in terms of waste of electrical and electronic equipment). Moving forward, Appendix II, for example, shows all 31 definitions offered by respondents, none of which is the same. However, this investigation found

that such definitions did revolve around four key components: smart homes are digitally connected, enhance household control, attempt to reach higher levels of automation, and promote learning (either by households or technology). In this sense, 19 expert respondents suggested that digital connectivity was a key component of smart home technologies; 12 mentioned automation; 10 mentioned control; and 9 mentioned learning (Furszyfer Del Rio *et al.*, 2020).

For instance, R2 suggested that "*SHTs are a diverse constellation of technologies which provide households with greater controllability over a variety of domestic systems, processes and services. This can range from heating and lighting to electricity use and appliances, to security, safety, and so forth*." R6 elaborated that they distinguished "*two fundamental categories of types*." One was "*switching and sensing what used to be the province of human beings in the home getting delegated to the technology*." The other was "*connectivity, how smart technology changes the boundaries of the home by bringing it more obviously into the IT and electricity system*." Based on the evidence collected the author of this PhD provides a comprehensive definition of what smart home technologies are below:

"*Smart home technologies are connected devices that can communicate with each other and react to internal or external signals to enhance the energy services delivered to consumers whilst generating benefits to the system, where the system could be local, national or international. These technologies must possess the ability to interpret available data through a learning algorithm that can predict behaviours and recognize those that are unusual to call for users' attention. These devices ought to automatically program themselves and act on predefined routes to provide the services that the user requires. Technologies could be controlled either by users or delegate it to the system and could be controlled in-site or remotely, so users can have access to the services delivered by the home*".

Indeed, this definition nicely incorporates differing scales of smart home technology, from the local to the transnational, as well as different forms of control, directly by households or energy suppliers to system operators or third parties remotely. This definition is key to further understand the different levels of smartness smart homes have, finding presented in chapter 6.

5.3.2 Business models for achieving smart homes

Given that smart homes do not follow a prescribed standard model, and also that they have developed across different phases, it may come as no surprise that the empirical material led to an abundance of business opportunities or models. As Table 8 summarizes, the fifteen business models

are presented here, ordered by the frequency by which they arose across the expert interviews (Furszyfer Del Rio *et al.*, 2020).

Table 8: Smart home technology business models mentioned by expert participants (N=31)

Rank	**Frequency by interviews**		**Business model**
1	19	61.3%	Energy services provision (electricity, heat)
2	14	45.2%	Household data and surveillance capitalism
3	9	29.0%	Bundling and integration of services
3	9	29.0%	Subscription models and digital platforms (e.g., Netflix, AirBnB)
4	7	22.6%	Health care
4	7	22.6%	Convenience or accessibility
5	6	19.4%	Demand response
5	6	19.4%	Security and safety
6	5	16.1%	Capturing savings (economic, energy, time, emissions)
6	5	16.1%	'Prosuming', peer-to-peer trading and/or Blockchain
7	4	12.9%	Mobility, Electric Vehicles (EVs), and Vehicle-to-Grid (V2G)
7	4	12.9%	New advertising channels
8	3	9.7%	Pay as you go
9	2	6.5%	Coupling with retrofits
9	2	6.5%	Insurance models

Source: Author

5.3.3 Business model: energy services provision

By far the most frequently mentioned business model application for smart homes were those related to energy management, energy services provision, or energy monitoring. Hargraves and Wilson (2017) assert in their assessment of smart home users how Rheinisch-Westfälische Elektrizitätswerke (RWE) had a commercially available monitoring and control system for space heating. British Gas had the Hive that allowed users to set different heating and hot water schedules.

Vera's Z-Wave offered real-time feedback on electricity use as well as electric appliances using smart plugs (Fell et al. 2017).

R13 mentioned that "*the idea of energy as a service is probably something where companies will be interested in and is very simple for consumers. I can easily see people engaging. I mean people know what they are buying: they are buying 21 degrees for three hours this evening. To me, this is as a quite viable business model*." R14 underscored that "energy is the gateway into the home" insofar, once energy systems become familiar to households, they are likely to be more willing to consider other smart home offers:

> *It will be smart energy services that potentially unlocks and enables so many other business models. The core is that the consumer is able to say what they want, choose an outcome or a range of options, and the service provider can charge them for that outcome or service. Unless you have that ability for the consumer to specify the outcome and the supplier to specify and put a price on it, it is very difficult to lead to other business models. So, the core energy service model is the most important, whether it's cascading to mobility as a service, or heat, or retrofitting the home. Energy is the enabling factor or the other business models, for the private sector to understand consumer expectations and also get consumers familiar with smart home technologies products*.

Energy monitoring, through the use of smart meters, was a recurrent theme. The results from Hargreaves et al. (2013), Pereira et al. (2012) and Ueno et al. (2006) demonstrate that energy users start paying less attention to feedback and the interaction between user and device decreases over time. This was also a concern identified through our participants' experience (Furszyfer Del Rio,*et al.*, 2020). To that, R18 commented: "*the work that we have done with smart meters, is that a lot of the energy consumption reductions come immediately, so it is like you get your smart meter, you get your In-home display unit, maybe you are surprised by one or two appliances that use energy and you change your habits and you get some reduction immediately. However, the worry there is that behaviour decays over time. But, there are other appliances like with Nest, that you might expect to get better over time due to its algorithm*".

5.3.4 Business model: household data and surveillance capitalism

The second most mentioned business model relates not to energy services, but data and even "surveillance capitalism," as it is argued that data driven optimization is at heart of the digital society, generating revenue or capturing value from individuals' behaviours, habits and household data (Sandys, Hardy and Green, 2017). R20 put it this way: "*My observation is that the companies*

that are pushing smart home technologies the most effectively, are so called platforms companies. Which a hundred years ago we would have called monopolies, their business model is surveillance capitalism." R22 added that "*the real value we are dealing with right here is information; is the data. So, we might move away from the business model where we are selling energy, to a little bit closer on how a lot of services online are now working. Where we are getting Facebook and all of that supposedly for free but paying with our data. And if the short-run marginal cost if we want to get technical of energy keep going down, it might make sense to allow people to get energy and just collect the data*."

One element of this business model is related to moving beyond households to collecting data on actual people through "smart clothing" and accessories such as smart watches or jewellery. Figure 8 shows an array of such "smart clothing" for sale at a retailer shop in London.

Figure 8: Smart clothing and accessories for sale in London, January 2019



Source: Picture taken by the author in February 2019

Data is a key element surrounding SHTs, thus, if unethical data practices and privacy concerns are not addressed, this could retard or even impede the uptake of potentially data-based solutions, including those related with smart energy services (Wilson, Hargreaves and Hauxwell-Baldwin, 2015;

Véliz and Grunewald, 2018). Hence, as the use of data could enhance the benefits of smart home technologies – the more data users 'give away' the better the services they will get – it could entail a barrier or a risk, both to personal privacy and falling foul of regulations such as the European Union's Data Protection Regulation (GDPR)[3],if not regulated properly (Furszyfer Del Rio *et al.*, 2020).

5.3.5 Business model: bundling and integration of services

A third business model focused on how smart technology can bundle or integrate previously disparate services or products. Sandys et al., (2017) showed that local authorities are already implementing this approach by delivering bundled service offers with integrated energy supply built into new housing, with balancing and distributed energy resources included in rental agreements (Furszyfer Del Rio *et al.*, 2020). R8 explained bundled services on its own experience as follows:

> *The Smart home does not sit nicely into a particular market and different markets have different business models that are dominant. If you are a mobile phone operator, then you come into the home with broadband. My mom has a BT broadband, so she has a BT television smart box. In my family we all have iPhone, so it made sense to have Apple TV and Apple products. Those with Google will go with that line of products, such as Nest. You can see packages and services coming together. They are all competing business models, converging on the house.*

R12 added that "*I see whole home solutions as the most attractive business case, as they can bundle or integrate solar photovoltaic with say smart appliances, home energy management systems, batteries/storage and electric vehicles. Firms can work on offering more efficient, independent, controllable homes with a bundle of technologies.*" R30 concurred as well, stating that "*the most successful business models would be those that offer a package of things, like Virgin Media that offers, internet, telephone and TV. But maybe, in the future, a particular company might offer certain elements of security and health too. So maybe we should look at what business models could be integrating it and definitely at a cheaper rate than the current ones*." If these projections become true, they also illustrate the power that incumbent technology firms will have in supplying homes a suite of options, perhaps even making them dependent on home energy services from a single provider.

[3] Regulation (EU) 2016/679 — protection of natural persons with regard to the processing of personal data and the free movement of such data

There are also risks of data and monopoly of services in the digital arena of bundled services. The tech giants (Amazon, Google and Apple) are expanding their influence on non-platform companies, by integrating other services within the smart homes market. For example, Amazon bought Whole Food's Market, and security camera maker, Ring (Stone, 2018). On the other hand, we have Google Nest, deploying an array of bundled smart home devices, ranging from thermostats, to security cameras. Google is even developing Wyamo - self-driving cars which sits nicely in smart home of the future. Energy providers such as Centrica, through Hive, are building their own smart homes, by also offering security sensors, thermostats, plugs and hubs. Consequently, we can see an oligopoly where despite the intentions of GDPR where firms cannot lock out competition, we can see few companies fixing prices and limiting the ability from consumers to switch from one ecosystem to another (Furszyfer Del Rio *et al.*, 2020).

5.3.6 Business model: subscription base model and digital platforms

Another collection of business model relates not to technology in the home, such as BT broadband or kits from Amazon, but the facilitation of digital platforms that often rely on subscription models for access. A report by OECD (2018) highlighted the potential of a subscription model as it enables the possibility to pay for the hardware costs upfront, or alternatively, to stagger them so they cover the duration of the contract as part of the subscription (Furszyfer Del Rio *et al.*, 2020). This model also provides consumers the do-it-yourself option, where if consumers want enhanced services, they can pay a subscription to the manufacturer to obtain additional functionality (ibid). Similar to the OECD findings, R21 remarked that:

> *We have studied this a lot and the most promising is a platform or subscription base model. Because, if it is about having a product, people buy the hardware and they feel like they own it. A subscription-based model is the one that continues to make sure that people can use it, it takes care of all of the updating, maintenance, security, and data management for you. You pay for the service, not the technology*.

R24 clarified that the business model that could be "*the most useful for consumers*" was one that simply relies on a "*subscription to get smart features, stuff like geolocation and the algorithm learning of your plans. To me, that it is kind of the way we should go to, because you, as a customer, will have a direct service. I think Nest and Hive will have to do it as well and they have to bring a new revenue stream*." Such models could be similar to the energy as a service or mobility as a service markets where users pay not for hardware or technology but a particular desired service (Nolden et al. 2016; Nolden and Sorrell 2016; Axsen and Sovacool 2019; Sovacool et al. 2019).

5.3.7 Business model: health care and assisted living

A fifth business model centred on improved health care services and assisted living. As noted by the OECD (2018), this model goes beyond household electronics and extends to household objects that traditionally have never been digitally or electronically connected, such as smart mattresses that can track your sleep, heart rate and respiratory rate (Furszyfer Del Rio *et al.*, 2020). Or smart toilets, for which R11 mentioned*: "there are companies putting sensors in toilets to track how many times toilets are flushed and with that data, evaluate users' healthy habits*. *Some may even track hormones, if users smoke, drink alcohol, or have high blood sugar, offering such information and health profiles to insurance companies.*" Then, R11 added on health care "*home care is an extremely viable business model … because if you look at the demographics among western countries, and countries like the UK, our care services are not in great condition. The budgets of our health service is stretching all the time, you can see a significant growth market on finding ways to ensure that people can be cared through their homes just because is the most economical way to manage elderly care*." R28 added that "*in terms of health, smart health devices would not only provide benefits to the consumer but would also reduce the loads on the public services*.**"** R31 concurred and stated that "*in health care you can see some of the biggest personal and national benefits in smart technology. Since we have a lot of problems with an aging population… You can also tell if people are heating their homes properly and make sure of that. Which eventually, can lead to help saving the National Health Service a lot of money. These technologies can also let you know if elderly people are actually using energy or not, how often they use the kettle and if you spot something wrong, you can phone your mama to see that everything is alright*." Figure 9 shows some monitoring devices available in the UK. Indeed, Fell et al. (2017) conducted a review of the smart systems available for health care in the UK and documented many services using smart plugs or monitoring to raise alerts if when occupants deviate from normal or expected patterns.

Figure 9: Health monitoring smart home watches and phones for sale in the UK, 2019



Source: Picture taken by the author during January 2019

5.3.8 Business model: convenience and accessibility

This business model focuses on two key elements of what the researcher found to comprise "smart": control and automation through a range of in-home technologies that allow users to control on site or remotely (Furszyfer Del Rio *et al.*, 2020).

For example, learning algorithms can allow smart technologies to automate certain household chores, which could ultimately result in enhanced convenience to users. As Apple displays on its Home App's website (Apple, 2019) "*Your home at your command…control your house from just about anywhere…put your home on autopilot…and you're done*". In this sense, convenience through automation can take many forms. R20 illustrated that: *"you've got people trying to sell the robot vacuum cleaner model because who the hell wants to vacuum. So, the robot does it for you…although, God knows how they are regulated from the energy perspective*". Furthermore, R5 explained that "*there is a large market for technologies or applications about making homes more useful or simpler with the technology they have … This business model is not about smart home technologies are necessarily new but enabling things that we already have but in a smarter way,*

convincing people that you could do it anyway but now better and easier. It is about putting everything together in one thing and in a way that is fun to use."

Others discussed elements of convenience that enhanced accessibility or fit into pre-existing norms and routines (Furszyfer Del Rio *et al.*, 2020). R18 reflected that these business models "*ask very little from the consumer in terms of how active they need to be, they don't require changes in behaviour, they just make existing behaviour more effortless or easier*." R9 added there were a whole class of consumers wanting to "*be able to control the home better … When users buy an Amazon Echo it's not a radical revolution in the home, they are merely enhancing another form of convenience*." R21 agreed when they said "*people buy these devices is because they seek convenience. They are essentially buying convenience, so they can control their homes, check and have access to their homes when they are away or travelling at any time. If they forget something, they do not need to be at home to do something, they can do it remotely, which is why convenience is the main thing*."

Certainly, much of the smart home technologies narrative is around convenience. However, as indicated by Strengers and Nicholls (2017) the use of smart home technologies could entail new forms of household labour, given that many of these technologies involves programming, updating technology and customisation: activities which could be viewed as essential labours or everyday chores, such as washing the dishes or doing laundry (Strengers and Nicholls, 2017). This duality was well expressed in R8's answer, where they explained: "*Convenience is probably what people are looking for, but there is an effort, a cost-benefit relationship, where if you have to put a lot of effort into getting the technology to work for you, then people don't tend to do it. And then technology is just intended to work for his user. Which is a little bit of a circle really*".

5.3.9 Business model: demand response

Demand response stood out as a distinct model for its ability to enable energy suppliers or network operators to manage flows in homes, as opposed to business model 7.4, which lets consumers do it (Parrish *et al.*, 2020). R15 mentioned that "*one business area with much potential is demand response. We are very interested in evidence on take up of smart devices, such as fridges, washing machines, and autonomously controlled appliances. The potential for mutually beneficial savings is real*." R27 added that "*demand response as a business model takes away risks on the behalf of the consumer and therefore, in order to manage that risk, that where some sort of autonomous controlled of the devices in homes become really attractive, because the energy service provider probably would know which kind of services require the least amount of energy inputs, certainly the*

least demand of high peak priced energy input and therefore, been able to moderate your demand through all the various connected devices. It is the energy suppliers who already have a deep understanding of your energy use and may know how to manage it best." In the United Kingdom, for example, the Smart Systems and Flexibility Plan update (Ofgem, 2018) highlights the Government's call for evidence on the Capacity Market and Emissions Performance Standard Review, seeking views on "how new smart technologies, including demand side response, can be facilitated fairly in the Capacity Market" (p. 39). At the European level, smart homes can help in integrating renewables by enabling grids to better match energy demand. According to the IEA (2017), increased storage and demand response could reduce the curtailment of solar photovoltaic (PV) and wind power from 7% to 1.6%. Such an integrated practice could potentially avoid around 30 million tonnes of CO_2 emissions by 2040.

5.3.10 Business model: safety and security

Other respondents supported the security and safety business aspects of smart homes. This business model goes beyond the traditional security systems as some of them (e.g. Netatmo, Ring and Arlo) use artificial intelligence and machine learning to run their facial recognition software, allowing them to recognize what represent real threats (Furszyfer Del Rio *et al.*, 2020). As stated in Arlo's website: "*Arlo smart adds intelligence to your camera. With Arlo Smart, you know what caused motion…this allows you to configure the system to filter cars and animals and receive alerts only when your camera detects a person…this means that an alert comes only you're your attention is really required*".

This category is not only limited to security cameras, it also includes smoke alarms, carbon monoxide detectors and water sensors which offer automated control to help mitigate damage. On this, R27 commented: "*We are doing fieldwork and I found some of these technologies a bit creepy. So, video cameras with face recognition that are outside your house. It recognizes how your family looks and only alerts you with strangers. I found a bit creepy just having a camera inside and outside your home which is always watching you.*" Indeed, this could be "creepy" for two reasons. First, if users can login to devices remotely via their smartphones that means someone else could penetrate users' home network too. An investigation by the New York Times (Bowles, 2018) revealed that networked home devices have been used as a new pattern of behaviour in domestic abuse to harass, stalk, intimidate and monitor people, where most of the victims were females and the perpetrators were male (this issue is further explored in Chapter 8 of this PhD). And second, the data these devices collect within users' home, allow manufacturers to have greater insights about users' preferences, habits and behaviours, allowing them to better target services (Stokel-Walker, 2018).

In contrast, R5 argued that "*Security seems promising … better being able to deter thefts or break-ins or notify emergency services such as the police or fire stations.*" R21 agreed that "*improving the safety of the home is an alluring business offer*." Indeed, Figure 10 shows some security or safety options on offer, from Ring suggesting you can "*create a ring of security around your home*" to Yale suggesting that you can "*protect your belongings, or more importantly, your family*."

Figure 10: Security, safety, and smart alarms for sale in the United Kingdom, 2019





Source: photographies taken by the author during February 2019

5.3.11 Business model: capturing economic benefits

This business model was one of the most diffuse, and it related to capturing value or savings from things like displaced energy consumption, improvements in efficiency, time savings, and avoided emissions (Furszyfer Del Rio *et al.*, 2020). R1 commented that "*smart technologies that automate savings in homes so people can find cheap energy carriers have potential*." R18 discussed an approach where "*household energy appliances are given away for free, but then companies make money on the energy they save. In the United States, some solar companies operate under this business model where they install solar panels for free and then take a percentage of the money that is generated from the solar panels over the first ten years*." R27 also elaborated on how smart devices that save time, lower costs, or avoid emissions could offer "*amazing opportunities for new business models*."

Tying smart systems to saving energy and reducing emissions is a theme that has been around for over a decade, with the Green Alliance (2007) linking the Climate Change Act to smart meters (which the government must 'get right') and smart homes more broadly. They recommend using existing (at

the time) policy mechanisms – e.g. Home Information Packages building regulations – alongside new ones to encourage smart features. In the context of meeting the UK's emission targets, the governmental LCICG (2016) highlights how innovations in domestic building operations could potentially save "the most carbon, most quickly, predominantly from the existing building stock", and highlights economic benefits of energy savings and global market potential of innovative products.

Although, research statements regarding energy saving in the smart home technologies arena need to be careful, as real savings are unclear and difficult to assess (Horner, Shehabi and Azevedo, 2016). This uncertainty was also addressed by R27 when they stated:

> *I think Artificial Intelligence will slightly increase the baseload of energy required because it adds an increment on to it, doesn't necessarily increase it in your home; some of the bits will, but it will also increase somewhere else. So, there is obviously these processes algorithms and services that are connected and that a dumb lightbulb obviously doesn't need. So, there is that, I think you are committed to an incremental per device energy usage increase. But then comes the question if with that data you can optimise the system in a better way so everything from learning more about our homes, occupants and energy performance and then run the system in a better way? But do we need all that data to realize the system benefits? So, are you adding an increment because of having everything smart or could you have done it with smart meters only? I think this is a grey area that will certainly come up in the future.*

This statement underscores some of the uncertainty and anticipation that arises when trying to calculate future economic or environmental benefits via business models.

5.3.12 Business model: prosuming, peer to peer and blockchain

A tenth business model cuts across active energy production (e.g. 'prosuming'), peer-to-peer trading and/or the possible "making" of Bitcoin or the use of other blockchain technologies (Furszyfer Del Rio *et al.*, 2020). R15 noted the potential for smart homes to lead to "*peer-to-peer trading, new providers of energy services.*" R13 agreed when they noted that "*peer-to-peer trading is probably something that might take-off, because there is quite a lot of investment into domestic renewable energy, like solar and I can easily see something that engages people who are interested already in that area*." R27 added that "*When looking at segments of electricity and utilities customers, one significant tranche do not trust anyone. When we offered them which business models they would like to have, they answered peer-to-peer because it puts them in control, and you cannot ignore segments of people who will inherently not trust anyone*." Indeed, a report by OFGEM (2018)

mentions the lack of trust from energy consumers to the energy industry. Hence, peer-to-peer could become something beyond a label, since it offers consumers a possibility to know their supplier directly, building potential bonds of trust and transparency between both; consumer and energy producer.

R3 lastly added that "*smart homes could also tie homes truly into the Internet of Things, they could even start using blockchain and making crypto currency*." In this context, the IEA (2017) stressed that since blockchains are transparent and trustworthy, they could facilitate direct exchange of value between parties, such as peer-to-peer, without the need for a third party intermediary. The IEA see potential for blockchain to solve vital energy sector challenges, such as but not limited to co-ordination between increasing number of heterogeneous devices, operators in smart grids and automated trading to enable flexibility.

5.3.13 Business model: mobility, EVs and V2G

This business model focuses on better integrating and managing mobility or passenger vehicles into homes, something known as "vehicle-to-grid," "vehicle-to-home," or "vehicle-grid integration" as found in the literature (Noel et al. 2019). R6 made this point when they said "*the business model for EV charging in a single home application has immense potential. Already car manufacturers selling EVs with smart chargers as part of the package. Seems like a very concrete and obvious business model*." R11 noted that they have been "we are *doing a great deal of work on EVs, so households now get the ability charge and manage EVs at home. That is a very significant driver of electricity demand, potentially going forward, good news for our utility guys*." R8 agreed when they said that "*energy companies are very interested in using surplus energy from homes or the grid to feed into EVs, and then you can put it from your electric vehicle back into the home or trade it to the grid*."

Sandys et al., (2018) stress the need for how mobility and EVs create new business dimensions and the need for stronger contracts and enhance consumer protection. R27, illustrated this idea with electric vehicles in a connected home: "*in the future, it is quite possible that you are going to own an EV that it may or may not come with its own energy contract and you might have an electricity supplier and home storage batteries. If the car goes wrong and it's not charging at the right time or whatever it might be, it shouldn't matter if you go to Volvo, E-on or Tesla for the battery, one of those should pick it up and say: yes, we will sort it. And they will seamless do that because you are going to need that in the future. This has to be spectacular good in a connected world*".

Figure 11 for instance shows an advertisement from Tesla about coupling EVs with sources of home energy storage and renewable energy production.

Figure 11: Tesla advertisement for an EV-solar-powerwall hybrid to "Self-Power Your Home", London, 2018



Source: Photography taken in January 2019 by the author

5.3.14 Business model: new advertising channels

This business model revolves around the provision of new marketing and advertising messages, rather than energy services or cost savings (Furszyfer Del Rio *et al.*, 2020). R20 mentioned that "*clearly the kind of the big tech business model has nothing to do with the recovering cost out of products. Many business models, like VISIO, are based on monetizing your data and then advertising specific things to you. So, the goal of the business model is to create a revenue stream based on your data and advertising opportunities with seven years of life you keep that TV for*." R23 added that "*for making money, advertising is obviously a huge business model smart home technology facilitates, everyone kind of forgets that in amongst all of their phones, PCs and smart home kits, Google is in the business of selling adverts, that is what they do, they are an advertising company*." R21 noted that even Alexa, the famed Amazon voice activated system, tried to do advertisements for a while, but people reacted negatively to it, so they stopped it. As R21 concluded, in consequence "*in this sense, the advertisement revenue model is very volatile*." Nonetheless, R28 suggested that "*if your*

business model is advertising, if you build a very cheap robot you can deploy them for free and offset the costs with marketing campaigns." Figure 12 already shows multiple digital apps (with the capability to provide advertisements) displayed on the screen of a smart refrigerator. Certainly, this is an area that needs to be better regulated. As other concerns are raised on profiling and how, although GDPR addresses this issue in its Article 22, their scope and limits are open to debate due to the lack of authoritative guidance concerning their interpretation (Privacy International, 2018b)

Figure 12 A smart home refrigerator showing multiple popups and apps for Facebook, Twitter, and others



Source: Picture taken by the author of this PhD thesis in February 2019

5.3.15 Business model: Pay as you go

Many homes in both Europe and the United Kingdom do not have contracts or monthly bills for energy services, they instead use "pay as you go." Some respondents discussed how smart home technologies could only enhance the availability or effectiveness of pay as you go platforms. R4

stated that "*many interesting business models involve pay as you go... smart homes could combine trends of cutting-edge technology and move away from asset ownership. I think those models become really exciting. People should pay for the service they get rather than wanting to own something, but only pay for the service they use*." R31 focused more on the ability for pay as you go help destigmatize those in poverty (Furszyfer Del Rio *et al.*, 2020). They remarked that "*smart prepay is brilliant, I use it and it makes absolute sense for people and I think generally speaking, people owning prepay are the ones that gained the most from this rollout of smart meters …. Smart prepay will completely remove the stigma of being on prepay meter and a lot more people will migrate because it is easier to manage. With pre-pay metering, you are not just handing money to your energy suppliers, you are literally paying for what you use and that is what we should be doing*."

5.3.16 Business model: Coupling with retrofits

A business model of coupling smart home technologies with the retrofitting of homes came up in some interviews (Furszyfer Del Rio *et al.*, 2020). R12 explained this approach as follows:

> *Whole home solutions seem attractive, and a business case can be made for integrating solar PV with say smart appliances, home energy management systems, batteries/storage and electric vehicles. Firms can work on offering more efficient, independent, controllable homes as either new builds or retrofits. In fact, retrofits seem like an excellent window of opportunity to install new kits because the home is already accessible to installers.*

Balta-Ozkan et al. (2014) picked up on this theme and identified "retrofitting existing homes" as one of the three most promising pathways for smart home development and adoption.

5.3.17 Business model: insurance models

A final business model was the least frequently mentioned, but it involved one particular sector, insurance, and many aspects above (household data and surveillance capitalism, bundling of services, health, advertising) integrated together (Furszyfer Del Rio *et al.*, 2020). R11 suggested that "*rather than smart heating controls, smart meters, or more efficient appliances, I see the real advantage of smart homes as not getting you to use more or less energy, the real advantage might be in providing this as an insurance product to health care, pharmaceutical companies or some other*

industry. Those business models have not emerged yet, but you can see a pathway where they are likely to emerge over the upcoming years." R23 put it this way:

> *I know that a lot of insurance companies are getting really into the mix of health and general lifestyle. Which, to be honest, turns out to be a bit sinister because there are reasons to know about it is not always healthful… But an insurance business model would first look more precisely at household data such as what food are you buying, how often you go the gym, if you drink, smoke, or where do you live, that is interesting because probably the street where you live tend to have less healthy people, so you lose points for that. And then you become a customer based on that whether you are a desirable customer or not… And it is actually the smart home that will generate that wealth of data, which allows them to go through everything into machine learning.*

Affirming this point, a report conducted by Mckinsey (2018) suggests that by 2030, Artificial Intelligence (AI) will inform every major decision an insurance company makes under the basis of shifting the paradigm of "detect and repair" to "predict and prevent". Thus, this business model may in fact be layered on top of other business models, with perhaps insurance companies coming to purchase other smart home providers or entering into cooperative agreements to share data and pool resources. In fact, we can already start seeing alliances between smart wearables and insurance companies. Take for example, Vitality and Apple watch. Where policyholders can earn discounts, rewards and gift cards for hitting healthy lifestyles points. In this sense, it is worth questioning if users that do not hit "healthy targets" would that mean that Vitality could thus punish customers failing to meet their targets?

5.4 Discussion and policy implications

As presented in this chapter, it is a positive development to have many options available in the smart home products dimension, yet, moving forward with these requires significant capital expenditures and operating expenses investments. For instance, Business Model Mobility, electric vehicles EV and V2G – which might contribute to transport emissions reductions – represent a major challenge for private and public entities (Furszyfer Del Rio *et al.*, 2020). In Europe, the cumulative cost for public charging for the 2020-2025 period is estimated at €12 billion (European Commission, 2019). At the local level, combined investment and installation costs for charging points (EV connector and connection cable) are €12,000 (San Román *et al.*, 2011).

However, the implications of EV business models are not limited to investment costs, but also challenges for grid infrastructure associated with increases in total electricity and peak demand

(Sbordone *et al.*, 2015). If current trends continue, it is expected that most people will charge their vehicles when they arrive home from work, when the grid is already working at or near maximum capacity (Hardy and Morris, 2019). As such, this model of electric transport could have significant impacts on local electricity networks which would affect other business models identified within this research, such as 'Prosuming', Peer-to-Peer, Energy as a Service, Demand Response and Coupling with Retrofits (Furszyfer Del Rio *et al.*, 2020). Where prosumers, if they manage this right, could become the most important value creators within the smart grid (Parag and Sovacool, 2016).

The next subject the author discusses relates to Data. Given that digital technologies operate by collecting and communicating data, the biggest material risks for industry and users are determined by cyber and data security (Djankov and Saliola, 2019; International Monetary Fund and World Bank, 2018). Thus, the author first suggests that cyber security and privacy measures, be fully integrated into the development of new processes from the start. Further, in order to enhance smart home technologies' regulations, policies for standardization on data and cyber security should be implemented. This PhD thesis recognizes that the EU's General Data Protection Regulation (2018) represents a good starting-point for delivering a contemporary legislative regime related to privacy and data usage in many situations (Furszyfer Del Rio *et al.*, 2020). However, the GDPR set the legal relationships between institutions and individuals around digital data and retains a 'household exemption' clause, which leaves domestic data practices beyond its reach (Goulden, 2019).

The GDPR is further accompanied by 173 Recitals which expand on the context, application and interpretation of the 99 legally binding articles in the regulation (Voigt and Bussche, 2017) . However, as noted by Testa and Marelli (2018), this instrument still has several weaknesses, for instance, Recital 159, which given the broad definition of activities that fall under "scientific research" users can unknowingly provide companies with sensitive personal data. Another weakness, as Wachter (2019) indicates, is that GDPR focuses mainly on protection at input stage, when data is collected, but rarely during or after analysis. Consequently, threats to privacy can arise following data collection owing to inferential analysis. Thus, this PhD author suggests that governments and industries prioritise privacy over convenience and make it easier for users to navigate and understand consent forms. Perhaps, governments and industries should make the default for users to opt in if they want to have their data collected (Furszyfer Del Rio *et al.*, 2020). Unfortunately, achieving this will be difficult in practice as it would reduce the ability of governments and industries to understand, predict and manipulate our behaviour (Zuboff, 2018) and so they will likely not pass such legislation.

However, privacy issues are not only limited to privacy-by design, but also to themes related, for instance, to privacy during data transfer. The issue on this matter relies on how to guarantee users that their data, when transfer to a country outside the EEA, follows appropriate safeguards for their protection. In this sense, Deloitte (2017) provides best practices for organizations operating at a global scale. First, they suggest the incorporation of binding corporate rules in order to offer greater legal certainty to organizations seeking to adopt similar frameworks to GDPRs. And second, they indicate that standard models could operate as a protective scheme, since its clauses are essentially contracts already approved by the European Commission and that can be adopted for the transfer of personal data beyond the EEA. Certainly, issues around data and privacy keep evolving at a faster pace than technology does. In fact, some argue that indeed, vast amounts of data offer great opportunities but new and riddled dilemmas that are threatening the concept of privacy as we know it (Martin Enserink and Chin, 2015).

In addition, other risks related to privacy may arise, for instance, privacy during decision-making. This process could take place under different forms, from targeted advertising and healthcare screenings to predictive profiling. Privacy international (2018b) identifies three risks associated with this practice: 1) generating new or unknown information which is often highly invasive. 2) it contests shared views about informed consent, but also raises issues about control, not just over personal data, but also around the user's identity. And 3) inferred or predicted profiles may be inaccurate and/or biased. In turn, processes around decision making may also lead to individuals being misidentified, misclassified or misjudged. It is under this context where Privacy International argues that when *"profiling is used to inform or feed into a decision that affects individuals, such inaccuracies may result in harm* (Privacy International, 2018b)*"*

Moreover, based on the expert interviews and the literature previously introduced, this research also calls for further regulation on energy use from data collection, transfer and remote processing, given that the entire digital universe is expected to reach 44 zettabytes by 2020 (Desjardins, 2019). This energy use could potentially offset the energy savings offered by smart devices. Indeed, a recent report from Cisco expects that global internet traffic will nearly increase threefold in the next five years for two reasons. First, Cisco (2018) estimate that the number of internet users will increase from 3 billion to 4.1 billion in 2020. Second, global internet protocol networks would have to support 26 billion new devices and connections (Cisco, 2018). As a result, data centres would require over 100 TWh of electricity a year by 2020 (Shehabi *et al.*, 2016). Hence, this thesis urges thorough regulation on data collection since with it, we could address both of privacy and energy use.

Moreover, due to the rise in IoT devices, one study estimates that the market is expected to grow to over $3 trillion annually by 2026 (Newman, 2019). This research raises concerns regarding energy and materials use. Given that smart home technologies need to be connected to appliances to deliver optimal services (e.g. thermostats, fridges and security cameras), which consumed roughly 3-5% of the world's electricity in 2015 (Andrae and Edler, 2015), this PhD indicates that if poorly regulated, these appliances could lead to increased electricity consumption. In fact, some estimate that the global emissions from the information technology sector could surpass aviation and shipping, reaching 14% of the global total carbon emissions by 2040 (Rob van der Meulen, 2017; Vidal, 2017b).

Nonetheless, not all studies reach the same conclusions. For instance, Grubler et al., (2018) in their Low Energy Demand (LED) scenario, consider the development of information and innovation, which involves: ICTs, sensors, processors, wireless communications and control functionality in energy-using technologies and daily routines, as a key element for a feasible supply-side decarbonisation within a 1.5°C emission budget. In their work, Grubler and team consider these technologies crucial to reduce energy-demand and achieve the 1.5°C target, without the need to deploy negative emission technologies with significant sustainable development co-benefits (Grubler *et al.*, 2018). Wilson et al., (2012), complements this when they argue that greater efforts from governments and industry are needed to untap the full potential of efficient end-use technology to achieve climate protection.

For efficiency to be improved, energy consumption optimized, and sustainability achieved, however, smart home technologies shall meet sustainability goals and have transformative impacts for achieving reductions on energy demand. As for now, as noted by Sovacool and Furszyfer Del Rio (2020), policies to address this issue appear to be working in silos, rather than being integrated into a policy framework that not only protects consumers, but also set restrictions to ensure that devices meet climate and energy goals. In this sense, although the EU introduced specific requirements for network connected devices in 2013[4] (European Commission, 2017a), this PhD suggests that EU eco-design requirements should be modified. Such changes should focus on technologies adopting a smaller ratio than 3 to 12 Watts to meet the target of reducing emissions by at least 40% below 1990 levels by 2030.

[4] Since 2009 connected devices are required to switch into a low power mode (such as standby) after a reasonable amount of time. In addition, such devices must not consume more than 0.5 Watts in standby or in off mode

Regarding material use, the trend of possible waste and inefficiency seems to escalate as well. Mckinsey estimate that the number of IoT connected devices will increase worldwide to 43 billion by 2023 - almost a threefold increase from 2018 (Mckinsey, 2019a). Certainly, the rapid development of smart home technologies is leading to electrical and electronic equipment becoming one of the fastest growing waste streams, with around 12.3 Mt generated in the EU 2016 and 44.7 Mt worldwide (IMPEL, 2019). Moreover, as noted by Hittinger and Jaramillo (2019), although materialization and efficiency improvements of electronics could lead to a smaller manufacturing footprint, the rapid increase in number of IoT devices being deployed in the market may lead to an overall increase in energy use, not only for material extraction and processing, but also, for component manufacturing. Thus, policy issues surrounding material and energy use and waste streams must be addressed in tandem (Furszyfer Del Rioet al., 2020). The researcher places strong emphasis to avoid ameliorating one environmental concern through the creation of another. Smart devices, such as those that regulate energy consumption, should not have planned obsolescence built into them but instead have long lifespans paired with free downloadable software.

Moreover, the successful implementation of these business models holds the promise to promote social inclusion for underserved populations (Djankov and Saliola, 2019). Not only by creating opportunities to reduce energy costs and enabling energy suppliers to offer lower tariffs through better balancing the grid, but also by narrowing information asymmetry, as digital channels, unlike physical infrastructure, could enable millions of people with mobiles phones to access myriad of services (International Monetary Fund and World Bank, 2018).As this research has shown, this is not limited to the payment of services (i.e. water and electricity through pay-as-you-go), but also access to insurance, investment and credits (OECD, 2018a).

Chapter 6. Smart home technologies in Europe: A critical review of benefits, risks and policies

6.1 Summary and introduction

Based on an extensive original dataset involving 31 expert interviews, 38 site visits to retailers, and a comprehensive review of the literature, this chapter centres its finding in the following themes. First, the author offers a new classification of smart home technologies, same that involves 13 categories, covering, in turn, 267 specific options commercially available from 113 companies (Sovacool and Furszyfer Del Rio, 2020a). In this sense and to have a better understanding about what smart home technologies are, this research then situates these different technology classes together with six levels of smartness, from 'dumb' home to the fully automated and sentient home. After this, the author elaborates on the 13 distinct benefits smart homes offer and 17 risks and barriers to their adoption and deployment. Such findings ought to take relevance within the smart home technologies literature since advances previous results from (Wilson, Hargreaves and Hauxwell-Baldwin, 2017; Marikyan, Papagiannidis and Alamanos, 2019). On the second to last section, this chapter lists key policy recommendations to accelerate their uptake and finishes linking the results to sociotechnical systems and with a rich discussion around smart home technologies and an agenda for future research.

The author, in this chapter, aims to answer the following research questions:

- What technologies or options for SHTs are available in the UK?
- What are their biggest benefits?
- What are their biggest barriers?

Relevant findings presented in this chapter can also be found in the academic publications:

- Sovacool, B.K. and Furszyfer Del Rio, D. D. (2020) 'Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies', *Renewable and Sustainable Energy Reviews*, 120. doi: 10.1016/j.rser.2019.109663
- Furszyfer Del Rio, DD, BK Sovacool, N Bergman and KE Makuch (2020). *"*Critically Reviewing Smart Home Technology Applications and Business Models in Europe,*" Energy Policy, 144. https://doi.org/10.1016/j.enpol.2020.111631*

6.2 Literature review

This section offers a brief review of three different streams of scholarship relevant to the study. The author to better contextualize the results, first situates which policies have been implemented in the UK that address subjects around smart home technologies. Later, it covers the benefits these technologies offer, not only from the individual perspective but also, the benefits smart homes could offer at a systemic level. Before presenting the results, the author briefly discusses emerging risks identified in the literature.

6.2.1 Smart home energy systems in the UK and the EU

Working from the definition previously introduced in chapter 6, where smart home technologies refer to devices that are digitally connected, enhance household control, try to reach higher levels of smartness and must promote learning (Furszyfer Del Rio, *et al.*, 2020) it is not surprising that these technologies have become a centred piece in the home automation debate (Parag and Butbul, 2018). In this sense, a number of studies highlight smart home technologies for achieving "net energy buildings," "zero energy buildings" (Marszal *et al.*, 2011)," and "life cycle zero energy buildings (Hernandez and Kenny, 2010)." Other studies, for instance, rather focus in the necessity of moving building stock towards "home automation" and "intelligent systems" to reduce resource use (Koomey, Matthews and Williams, 2013). Nicholls et al., (2020) further envision a future in which "*households monitor and automatically manage their energy consumption using smart energy and communication technologies*".

"Smart homes" are one of the ten pillars in the European Union's (EU) action areas for strategic investments in energy (European Commission, 2015b). Certainly, at the European Union level, the 'Smart' initiatives seem to be in two groupings: 1. smart meters and smart grids, and 2. smart cities and communities. The first, seeks to automatically monitor energy flows whilst helping to make distribution grids more flexible and to cope with variable renewable energy sources and new loads (European Commission, 2016b). The second seeks, with digital and telecommunication technologies, to improve services such as transport, water supply and security. It asserts that information and communication technologies (ICT) could help meet the needs (e.g. mobility and medication) of the ageing population (European Commission, 2018). In addition, there is support for the 'internet of things' (IoT) and a single digital market (EC, 2015; e.g., EC, 2017). The European Commission even set up the Smart Grids Task Force (SGTF) in 2009 (Smart Grids Task Force, 2011). The SGTF Mission Statement mostly applies to the supply side; however, it includes smart meters in the plans for modernisation of European Grids.

Moreover, within the smart meter literature, there is a focus on empowering consumers, which suggests there might be benefits to consumers from smart meters and grids, such as greater control over their consumption and provision of real time information (European Commission, 2015a). While smart homes are not explicitly discussed in all documents, there seems to be a similar drive as in the UK, with smart meters and grids, alongside smart appliances, allowing an effective demand side response and "full participation of consumers in the market" (Bertoldi and Serrenho, 2017), meaning, among other things, that there is a possibility to produce, store and sell one's own electricity. In this sense, Ofgem emphasizes that "smart homes and businesses" are key to their plans to achieve the further decarbonisation of electricity as well as integrate more substantive demand response programs (Ofgem, 2018).

6.2.2 The emerging benefits and risks in the energy dimension of smart home technologies

Smart homes have a variety of potential benefits – some of which are unproven expectations. A recent review of smart home technologies, (Marikyan et al., 2019) distinguishes between studies that look at *potential* benefits of smart technologies and looks at users' *perceived* benefits of smart technologies. Marikyan and team grouped benefits in four categories: 1. health-related, 2. environmental, 3. financial, and 4. psychological (i.e., wellbeing and social inclusion), and found the largest number of papers discuss health benefits.

Marikyan et al. (2019), later provides a number of papers suggesting energy and emission savings through monitoring, consultancy, management & optimisation and controlling consumption patterns. Others studies continue on this trend and suggest these technologies offer great energy savings and enable large emissions reductions, significantly more than offsetting the growing direct energy usage of ICT (Accenture Strategy, 2015). Same report estimates that ICT avoided emissions are equivalent to 9.7 times the ICT sector's "emissions footprint". Finally, Hittinger and Jaramillo (2019) review (Hamilton et al., 2013; Ryen et al., 2015; Shrouf and Miragliotta, 2015; Zhou et al., 2016) and conclude that although there is no clear evidence to the increased energy used to power Internet of Things (IoT) devices, IoT is likely to result in a net reduction in energy used to provide fixed level services.

The UK Low Carbon Innovation Coordination Group (LCICG) (2016) suggested large savings to domestic energy use from innovations including smart technologies and systems, but "*Note also that these savings are reliant on energy performance improvements due to smart systems occurring as well as expected. More research into the effects of such systems is needed, as the interactions*

between householders and such systems are complex and not yet fully understood (Low Carbon Innovation Coordination Group, 2016 pg. 8)."

Certainly, this research agrees with the previous statement and it adds that actual effects on energy use and greenhouse gas emissions are complex and cannot be forgone conclusions. For instance, there is a fear that increasing data and the 'internet of things' could greatly increase global electricity usage (Vidal, 2017b). The International Energy Agency (IEA, 2017) acknowledges that although these technologies could improve energy efficiency, some could also induce rebound effects that increase overall energy use, particularly, those outside the energy sector, such as e-commerce and e-services, which could enhance convenience, but ultimately lead to encouraging consumers towards a greater use of these services *(Furszyfer Del Rio, et al.*, 2020).

Energy savings achieved by smart home technologies are questionable, for example, in recent reviews of smart meters being rolled out in the UK. Research suggests that household reduction in energy consumption and energy bills could be considerably less than anticipated by government, with energy savings averaging 1–3%, as opposed to the projected 5–15%, and bill reductions as low as £11 a year (Sovacool *et al.*, 2017; Patel, 2018). The Centre on Innovation and Energy Demand (CIED) research on the socio-technical challenges facing the smart meter roll out addresses questions of consumer resistance and ambivalence, expectations under changing policy goals, and suggests small (≤3%) energy savings (Sovacool *et al.*, 2017; Hielscher and Kivimaa, 2018). Similarly, energy savings from 'smart thermostats' have been revised by Tirado Herrero et al.(2018) and the UK Behavioural Insights Team (2017). The latter found evidence of around 5.8 % savings in household gas consumption, equating to savings of £25 per year for medium houses and between £35-40 per year for larger houses.

Based on the previous paragraphs, this research argues that much of the research on smart technology has as many questions as answers about energy savings and highlights current hype and inconsistencies. To further illustrate this, a recent review of ICT usage revealed significant differences in estimated energy savings, giving both positive and negative numbers (Horner, Shehabi and Azevedo, 2016). Lunde et al. (2016) found that the smart grid "*embodies several implicit expectations that serve to guide research and investment and to attract new players into the field*", and they suggest a scenario process that can articulate such implicit assumptions – a process based on developing probable futures, analysing conditions for realising specific visions, and including a large number of participant institutions in the process.

6.2.3 Users' perceived benefits and barriers of smart home technologies

Turning to the systems and their users, findings are also divided, with a common call for more research. For example, reviews of the smart homes literature (Wilson, Hargreaves and Hauxwell-Baldwin, 2015; Gram-Hanssen and Darby, 2018) find that most of the literature consists of technical studies focusing on control and security, these studies based on what they have reviewed, call for a better understanding of who users are and how they might use smart homes. Energy savings are also predicted as remotely accessible apps and displays raise users' awareness of their energy consumption and allow a response from a distance and from real-time notifications. In addition, data analytics allow urban planners, utility companies and architects to understand demand patterns for better planning and maintenance (Accenture Strategy, 2015).

Recent research in this dimension argues that there is little evidence for substantial energy savings from smart home technologies, and in fact, they could reinforce unsustainable energy consumption patterns from its users (Hargreaves, Wilson and Hauxwell-Baldwin, 2018; Tirado Herrero, Nicholls and Strengers, 2018). This is in line with research on ICT more broadly, e.g., a review of indirect energy effects of ICT (Horner, Shehabi and Azevedo, 2016) suggests that while the technical potential of net energy savings from ICT is 'likely positive', the magnitude and sign of real savings is unclear and difficult to assess, depending on user interaction and broader societal impacts. They suggest that empirical studies are needed to gather more data on how ICT systems are deployed and used in practice, in order to better identify the parameters driving energy use in ICT-heavy systems.

In their review, Marikyan et al. (2019) further look at users' perspectives on barriers to implementation of smart homes. The study found that the most important factor is 'technology fit', that is, users' perception of the technology's reliability, compatibility and connectedness. Usability – which they see as reliability and ease of use – could have a crucial role in acceptance, as complexity could lead to rejection of the technology (Marikyan, Papagiannidis and Alamanos, 2019). Lack of knowledge along with trust and experience of smart homes technologies entails another barrier, as people have limited awareness of technologies and their (current) capabilities or availabilities. Finally, financial barriers from a users' perspective include the price of installation, maintenance and repair, combined with a lack of understanding of how a smart home could save them money (Marikyan, Papagiannidis and Alamanos, 2019).

A different perspective emanates from an Italian study, which suggests the three main barriers to the smart home technology market are 1. the installation of products, 2. the integration of the offer with valuable services and 3. the presence of established brands (Osservatori Digital Innovation del Politecnico di Milano, 2018). The same study reports that more than half of the products on sale are offered by start-ups with little strength and brand recognition, often not perceived as sufficiently

mature and reliable by consumers. On the other hand, trust in traditional brands, (e.g. Google, Amazon and Apple) and the help of a trusted installer, play leading roles in the market (Osservatori Digital Innovation del Politecnico di Milano, 2018). Finally, sensitivity about privacy and data, and concerns over cyber security, also affect consumers' decisions (Osservatori Digital Innovation del Politecnico di Milano, 2018). This was also mentioned in (Marikyan, Papagiannidis and Alamanos, 2019) who found a number of studies showed privacy intrusion as a major barrier.

Meanwhile, research conducted also in Italy suggests that consumers' "lack of digital competence" is one of the barriers to smart home market development (Sforza, 2019), with only 15% of consumers who bought smart devices regularly using the 'smart' features. Giulio Salvadori, Director of the Internet of Things Observatory, suggested that consumers "need[s] to understand better the added value of the smart functions of the devices" (ibid.).

Strengers and Nicholls (2017) highlight the contradiction in the visions between a promised simple life and the complexity inherent to the expanded range of devices, services and choices. They critique the 'convenience' and 'pleasance' narratives promoted by smart home advocates and call for further research which seeks to disrupt these narratives. In this sense, recent research suggests design should be about the 'home experience', not the gadgets and applications, and design should integrate with everyday life (Eggen, van den Hoven and Terken, 2017), and take into account the difficulty of changing routines (Tirado Herrero, Nicholls and Strengers, 2018) and how disruptive SHTs can be (Hargreaves, Wilson and Hauxwell-Baldwin, 2018). This matches the critique of Strengers and Nicholls (2017) who show how the 'convenience narrative' of a home full of smart devices could transform everyday practices in ways which increase not only energy consumption but household labour too. Indeed, this area is further explored in Chapter 7, where the researcher presents the role of smart home technologies in housekeeping and daily domestic life.

Now that the researchers paved its way by introducing the main benefits, risks and barriers of smart home technologies identified in the literature. The author now presents their results, with the hopes to answer the questions presented in section 6.1: summary and introduction.

6.3 Results

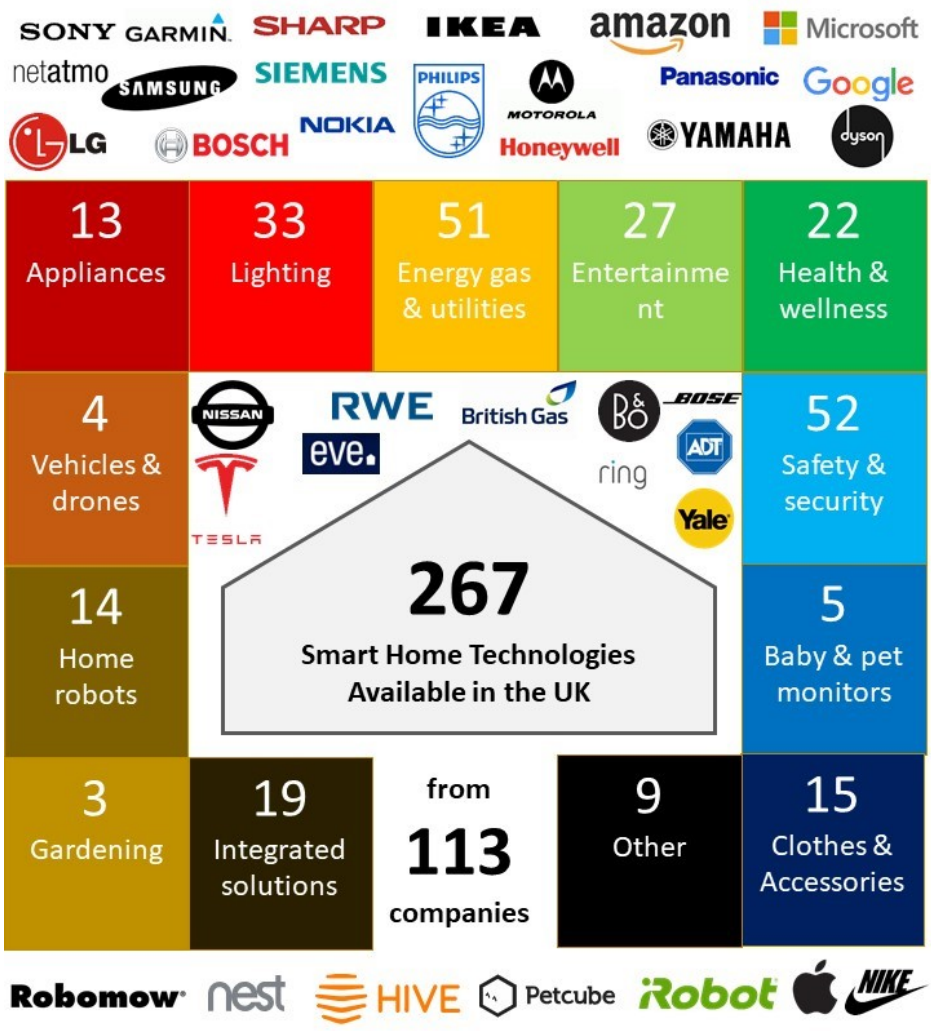
6.3.1 Smart home technologies availability and site visits to retail stores

The empirical material collected via expert interviews and retailer visits, identified a remarkable number of smart home technologies available on the market during February 2019. As Figure 13 reveals, this research found 267 different technologies commercially available across 13 categories,

such as but not limited to baby monitors, speakers, lightbulbs, watches and accessories among others. These technologies are provided by 113 different companies, (e.g. Google, Amazon, Apple and Samsung) (Sovacool and Furszyfer Del Rio, 2020a).

As explained by R10, the fast expansion of SHT could be a consequence of two key factors, decreases in price and manufacturers pushing them into the market: "*connectivity is finally cheap enough, that for a couple of dollars, anything on the planet can be turned into a connected device*". They continued: *"now, everything is been pushed by manufacturers, when you have more products and connectivity between them, will it likely be consumer driven as opposed of what is happening now*".

Figure 13: Smart home technology options available in the UK and Europe, 2019



Source: figure retrieved from (Sovacool and Furszyfer Del Rio, 2020a) with authors' permission but inspired on the previous work from Gruenwald (2017)

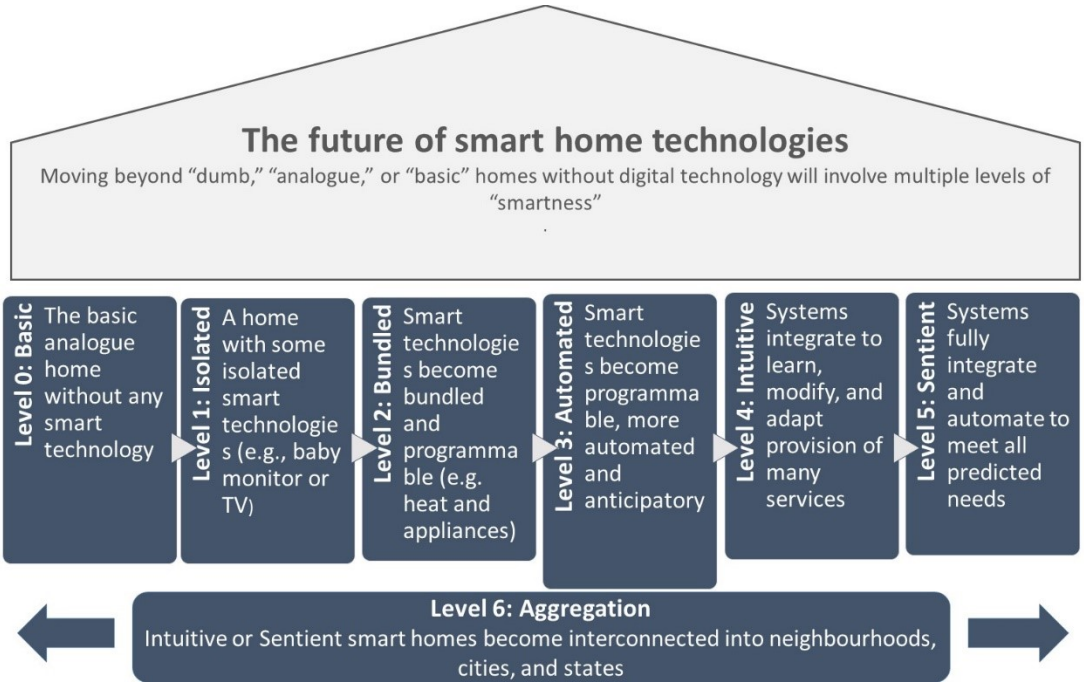
As figure 13 reveals, this plurality of options was not an isolated occurrence. Indeed, as illustrated in the publication resulting from this work (Sovacool and Furszyfer Del Rio, 2020a) during the shop visits, 23 shops had at least four different categories of smart home technologies available on store, and six shops had 10 classes or more of smart home technologies available. In terms of the categories of smart home technologies most available, 29 shops (of the 37) had smart safety and security devices, 27 shops integrated solutions, 27 shops smart clothing and accessories and 25 shops smart lighting. Even the two classes of least frequently available smart home technology options, baby and pet monitors as well as gardening, were still present in 5 of the shops (Sovacool and Furszyfer Del Rio, 2020a). The popularity of smart speakers, for instance, could be illustrated by a staff member from PC Curry's when he mentioned: "*Amazon Echo and google Home are quite popular. For Christmas we ran out of stock and it is quite common that we actually have to request them from other stores, and there, they sometimes run out too. Cameras, Nest and Hive are popular, but never as the speakers".*

6.3.2 levels of smartness

Moreover, one of the main contributions of this work consists in categorizing smart home technology options into different levels of smartness. Marikyan et al. (2019) for example, identify a spectrum of smart home types, from moving between a "traditional home" up to a "fully smart one." R16, mentioned three degrees of smart home technologies, focusing particularly on heating and cooling: "*There are three levels we could already see: the basic learning, which essentially monitor behaviours over several weeks on how you are using the cooling and heating in the building and then, relative to those behaviour patterns and information, particularly around weather, it predicts the use. The second would be related to consumers interacting with the grid. So, it could, for example, now that you have cheap electricity prices, it could do something like pre-cool or pre-heat the buildings because the prices are cheaper than they would be when you are about to come home within an hour. Then, the third, is one has a fully operable and interacted with the grid. Here, your data is collected and then identifies were to retrofit and improve the energy efficiency*"

As a result of the investigation and as Figure 14 shows, in a "analogue home," at level zero, households have no smart home technologies. A level 1, home has a few smart home devices, such as a television or baby monitor or perhaps a solar photovoltaic (PV) system, and perhaps, users could receive basic levels of feedback, but users still decide in an analogue way how to reply, and the technologies are not interconnected and remain in silos (Sovacool and Furszyfer Del Rio, 2020a).

Figure 14: Levels of smartness with smart home technologies



Source: figure retrieved from Benjamin K. Sovacool and Furszyfer Del Rio, 2020a with authors' and journal's permission

A level 2 of smartness, home starts to see technologies bundled together and integrated to better provide some household services, such as heat (perhaps smart meter with in-home display plus heat pump and advanced thermometer) or entertainment (a smart TV coupled a smart sound system) (Sovacool and Furszyfer Del Rio, 2020a).

A level 3 home moves towards some degree of greater automation, with systems beginning to interconnect and even anticipate certain users' needs, such as turning the lights off when the occupant leaves the house or turning appliances on before an occupant returns home. A level 3 home can also be programmed to meet preferences across multiple devices, including different lighting environments and setting temperatures in different rooms (Sovacool and Furszyfer Del Rio, 2020a).

As level 4 home systems begin to learn for themselves and adapt their provision of services to context even outside the home, i.e. turning the lights on if a storm is coming or turning them back off when the sun comes out and instead pull the blinds up. It is at this level, where sensors and monitors can enable technology to know the conditions of the home, and feedback loops that ought to result in facilitating some learning, so the home becomes more autonomous and can adapt to what it thinks the occupant wants (Sovacool and Furszyfer Del Rio, 2020a) .

A level 5 home becomes almost sentient and can automatically meet and even anticipate all household needs (Sovacool and Furszyfer Del Rio, 2020a). At this highest level, monitoring, feedback and learning merge across multiple integrated systems (heating, lighting, entertainment, security and mobility) so that the house itself can flawlessly provide services to occupants. Homes, at this level, would most likely start talking to occupants, and also, perhaps, each other. This would be an "artificially intelligent" home or one that is "fully smart." One salesperson the researcher visited at John Lewis in London joked that at this level, *"We will not do anything in a couple of years, these appliances will do everything for us!"*

Some respondents discussed a possible sixth level, beyond that of a single home, of smart neighbourhoods, communities, and cities (Sovacool and Furszyfer Del Rio, 2020a). These would be comprised of interconnected level 5 smart homes with complex baskets of interconnected smart home technologies. As R12 noted, *"this level goes beyond the house or mere smart kit to the true smart grid or smart society.*"

6.3.3 Benefits of smart homes identified by experts

This research identified 13 different types of benefits smart home technologies can offer to households, businesses, or society. Table 9 illustrates a frequency analysis of these benefits across the interviews conducted, with the most popular being energy savings, convenience and controllability came second, and the third most popular was financial benefits (Sovacool and Furszyfer Del Rio, 2020a). Different to other studies, the results here presented expands upon the exiting literature. Balta-Ozkan, for example, classified only seven types of benefits across the three classes of energy consumption, safety, and lifestyle support (Balta-Ozkan *et al.*, 2013); the systematic review from Marikyan et al. (2019) identified only five classes of benefits (comfort, monitoring, health, and support, consultancy); Hargreaves et al. (2017) identified four motivations to adopt smart homes: saving energy, interest in new technology, protecting the environment, and a desire for improved control; Gram-Hanssen and Darby argue that the two areas of greatest interest are "health care" and "energy consumption of management." (Gram-Hanssen and Darby, 2018).

Table 9: Smart home technology benefits discussed by expert interview respondents (n=31)

Rank	Frequency (by interview)		Topic
1	25	80.65%	Energy savings
1	25	80.65%	Convenience and controllability
2	15	48.39%	Financial benefits and saving money

2	15	48.39%	System benefits for grids, networks, operators
3	14	45.16%	Environmental benefits including carbon, pollution, waste
4	13	41.94%	Aesthetics including style, design, feel, and fashion
5	11	35.48%	Health benefits and assisted living
5	11	35.48%	Social benefits including inclusion, networking, status
6	9	29.03%	Educational benefits and learning
6	9	29.03%	Entertainment including music, movies, streaming
6	9	29.03%	Safety and security
7	8	25.81%	Other enhanced experiences (e.g., shopping)
8	4	12.90%	Free services or promotional gifts

The most mentioned benefit was the ability for smart home technologies to better manage energy services or reduce energy consumption. This relates partly to how *inefficient* the building stock is in Europe, especially the United Kingdom (Darby and Pisica, 2013; Darby, 2018). For instance, one survey of 21,900 homes in England showed that 98% had a gas boiler for central heating (so no heat pumps or district heating) and that these had only simple controls such as an on/off switch or a timer (Munton, A.G., Wright, A.J., Mallaburn, P.S, & Boait, 2014). The study also revealed that heating density plots show that people just leave heating on all the time; throughout the morning and during all night (Munton, A.G., Wright, A.J., Mallaburn, P.S, & Boait, 2014). R31 illustrated this point when they mention: "*half of people they interviewed who had a pet heated their house all day, to keep pets warm, when veterinary associations indicate this is not needed. This is a massive waste of energy that smart devices can address*."

Evidence from the UK government, for instance, suggests that of the 95% of all United Kingdom homes that have a boiler, 800,000 have no controls at all, and almost 8 million have no room thermostat (BEIS, 2018). BEIS, based on this evidence, suggests that this could explain why space heating and hot water is responsible for 75% of domestic energy consumption (BEIS, 2018). Thus, as R2 noted, "*the biggest or best potential for smart home technologies relates to reducing energy demand and better*

demand management." As one example, trials of smart heating controls alone suggest they could save something like a 5-7% annual reduction in household energy consumption (Toby, 2017). R15 added, "*controlling energy and awareness of how much energy houses are using is a key benefit, as it creates opportunities to save, reduce, or optimize when you use energy"*.

An equally prominent benefit was improved convenience and controllability over a household (Sovacool and Furszyfer Del Rio, 2020a). As R2 put it, "*many smart home technologies aren't about saving energy or doing good, they are about convenience and controllability, hence this interest in voice control such as Alexa, such technologies make life easier, more fun, and more interesting."* R12 added, "*For me, the most important benefit for most people is the comfort, convenience and control that smart home technologies can offer*." R21 noted: "*The main benefit is convenience, mainly as we do not really need these technologies to live our lives. Essentially, people are buying convenience, so they can control their homes, check and have access to their homes when they are away or travelling at any time. If they forget something, they do not need to be at home to do something; they can do it remotely."* R23 mentioned "*Anything that make consumers life simpler is a benefit, anything that helps them reduce their mental load on tasks*" whilst R13 mentioned on a similar way that*:* "*Anything that makes you more comfortable and easier for you to get the outcome you want without having to consciously think about how to achieve that outcome."* R18 suggested that the key benefit then is: "*The clear benefit is giving consumers more control over their home environment*"

Financial benefits such as saving money came third and include the ability for households to better track spending and also switch to better tariffs and cheaper service providers (Sovacool and Furszyfer Del Rio, 2020a). As R13 stated, "*from an energy standpoint, even in general terms, positive outcomes can be becoming more consciously connected and aware in ways that save you money*." With this in mind, R25 mentioned in during the interview: "*The single potential benefit, at least at the moment, is to the electricity system and through that, to consumers. Because is the rate of efficiency of the system which will therefore reduce the cost for consumers".* Whilst R11 suggested that *"the biggest thing we talk about is how do you get more consumers engaged. Smart homes should increase the engagement of the consumer with different markets. That has huge potential savings for the customers*".

The fourth most mentioned benefit for SHTs was system benefits for grid operators, with R15 commenting that "*the industry benefits from smart home technologies through better data and no longer needing to do manual meter readings*." In terms of automation and efficiency, R26 mentioned: "*The biggest benefit, thus, is to reach a system whereby automating behaviours that are*

inefficient, you can make the whole system more efficient". R22 speculated that SHTs could help enhancing national energy systems when they commented: "*This could also have benefits for the systems operators, it could be the distributors or the national system operators, and they have the benefit to balance supply and demand with greater control. Surely, that should be seen as a benefit. Along with a more efficient system operation, as this could allow them to come up with complete new business models and service offering".* Whilst, R28 put it in terms of demand response *"There are benefits for the electricity grid too, you can better manage demand and then you have better data which allows you to better control power stations*". R27 pinpointed how smart home technologies could enhance services: "*indeed, smart homes are becoming more useful because the datasets are getting bigger, the algorithms are getting better and therefore, some companies are learning lots on behaviour. Which allows them to optimize and to provide better services*" (Sovacool and Furszyfer Del Rio, 2020a).

Environmental benefits included reducing carbon emissions, cutting air pollution, or waste, achieved through a mix of better monitoring, better energy management systems, and greater control over the sources of domestic carbon emissions. Energy savings are predicted as remotely accessible apps and displays raise household awareness of their energy consumption and allow them response from a distance and allow for real-time notifications (Sovacool and Furszyfer Del Rio, 2020a). In addition, data analytics could allow urban planners, utility companies and architects to understand demand patterns for better planning and maintenance (Sovacool and Furszyfer Del Rio, 2020a).

In this context, R18 noted: "*if households became flexible users of energy that could increase the amount of intermittent renewable energy could penetrate in the grid. By having homes that are using energy at the time when the grid need it, would result in an environmental win, even if we weren't using less energy*". R31 suggested that "*individuals might feel that helping the environment is quite a big task, so if you can introduce smart home technologies which allow things like automation, it takes that difficult decision out of your hands and it actually knows when the grid is generating greenest energy*". R29 highlighted the importance of these technologies in tackling climate change: "*on my personal view, I think that consumers' engagement in particular in relationship to heat is going to be absolutely essential to hit our 2050 goals and then the goals that will continue after*". they continued "*I think the trilemma cannot be achieved without these technologies and will be achieved with their use*".

Hence promotional material such as Figure 15, noting that adopting smart meters in the UK will save as much carbon dioxide as planning 10 million trees (Sovacool and Furszyfer Del Rio, 2020a).

Figure 15: Smart meter advertisement from Smart Energy GB. Image retrieved in November 2018. This image, however, is no longer available online, thus, the website address could not be presented in this research. This image was also presented in the work (Sovacool and Furszyfer Del Rio, 2020a)



Aesthetic benefits include liking how smart home technologies look, are designed, and add symbolic value to a house as an item of fashion or style (Sovacool and Furszyfer Del Rio, 2020a). R4 stated that "*I think that people are positioned more in the emotional and aspirational side of the home, rather than the benefits. People want to have these technologies in their homes because it looks really cool and it's something you can show off to people and it is like: hey, I'm futuristic*." R12 stated, "*Smart home technologies are currently driven by status – not environmental motivations. It's technophile, rather than technophobia, with people needing to possess and purchase the coolest gadget to have*." As R14 added "*To some people, the benefits of adoption relate most to aesthetics, to people just being drawn to beautifully designed or new things, to show they are ahead of the curve*." (Sovacool and Furszyfer Del Rio, 2020a).

Fell at al., (2017) in their review, found that health benefits, including the ability to alert relatives or health professionals to emergency events, aiding health diagnosis, and enabling aggregate level health analytics. Marikyan et al., (2019) asserts this and adds that health benefits can be critical for the elderly and aging, vulnerable people, or people with chronic medical conditions. Indeed, R14 stated,

"*assisted living is very interesting, enabling people to live at home longer or to live healthier lives. Charging an eclectic wheelchair, or figuring out treatment regimens for extreme medical conditions, or having NHS prescription medicines monitored, reordered and delivered automatically*." R11 linked smart homes and mental health: "*Some of the signs of people with dementia is that they forget to drink water and therefore they become dehydrated. So, there are companies looking at putting controls in the house to measure how many times the kettle is boiled, how many times the toilet is flushed, so they can use this data to actually track if people are actually drinking water. So, this is a way of using smart home technologies in a different way*" Whilst R28 and 31 addressed the benefits by cutting expenses on public health. Respectively, they answered: "*in terms of health, smart health devices would not only provide benefits to the consumer but also reduce the loads on the public services indirectly*" and "*in health care you can see some of the biggest personal and national benefits in smart technology. Since we have a lot of problems with an aging population. You can also tell if people are heating their homes properly and make sure of that. Which eventually, can lead to help saving the NHS a lot of money. These technologies can also let you know if elderly people are actually using energy or not, how often they use the kettle and if you spot something wrong, you can phone your mama to see that everything is alright*".

Social benefits related to inclusion—adopters feeling like they belonged to a community or a social club—or networking with others for professional or personal reasons (Sovacool and Furszyfer Del Rio, 2020a). This relates to smart homes facilitating people to better socialize with others and overcome feelings of depression or isolation. As R6 explained, "*SHTs can become a way of being positively connected to others.*" R14 "*Other benefits can be about connecting you to people who you love*". R23, mentioned that the main benefit of smart home technologies would be inclusion: "*I think the main benefit is helping people navigate in an increasingly and confusing world"* R31 noted that "*Benefits can also be national, improving the care that we give people and helping them to live independently"* (Sovacool and Furszyfer Del Rio, 2020a).

Educational benefits related to the enhanced learning opportunities that smart home technologies can bring, include accessing new forms of knowledge (e.g. Ted Talks) undertaking digital training (e.g. Skillshare, Wisdom Destinations and LinkedIn Learning) or simply finding new ways of receiving information or developing new skills (Sovacool and Furszyfer Del Rio, 2020a). During one of the site visits to the Apple Store, a salesperson remarked that "*Some of the robots we have here are not only for children. Adults can use them too and learn how to code. In a way, I think all these new stuff is quite interactive and are pushing a new way of learning useful stuff.*" R28 perceives smart home as a platform of information: *"smart home technologies are a channel of communication, even if it's to communicate the number of heart beats when you are running or how much electricity you are using.*

I see them as a as a platform of information in which you can coach and provide better services to the population". Whilst R27 also mentioned learning as a mean to take control: "*So smart home thermostats could either be a way to not have to worry about your heating, because you are leaving it to the machine to work out what is best. Or could be a way to learn more about the performance of your home and then, optimise your own heating cycle based on what do you know. So, either you can cede control, or you can take it back"*

Entertainment benefits centred on easier ways of listening to music, watching movies, or online streaming. R25 identified entertainment as a key benefit, since people demanded it this feature: *"people want to watch Netflix, so you need an internet enabled TV, so no TV manufacturer is going to make one that it isn't. That is where the smart technology is simply delivering something that consumers really want. And yes, it is a self-reinforcement circle in the sense that somebody didn't know that wanted Netflix, but when they bought the TV, they had the possibility and explored it. But in that particular case, there was a consumer desire for this service and the smartness just delivered that. People just don't go and buy a smart TV; they go and buy something that allows them to watch Netflix. And I think you can see the indicator to that for non-smart TVs, you can turn it smart with your Chromecast. So the fact that manufacturers are making these adds for the non-smart TVs, is to me an indicator that the stuff is going to be smart, because it is always the way, you get something to add on and then the new stuff integrates it".*R28 identified entertainments as a hook to educate: "*Entertainment has a lot to do in all of this, because now is kind of difficult to disentangle education and entertainment; you want to be educated and you want to be taught but it has to entertaining otherwise you might not sign-up for those programs I think the hook starts with entertainment and then you work from there*". R21 added "*There is other stuff, like smart speakers where they can listen to all you say or smart cameras. Here, not many people are adopting them because of convenience, but for entertainment…have you heard some of Alexa's answers? Some of them are unbelievably funny*".

Safety and security related to notifying the police of emergencies or preventing fires and/or severe accidents. As R6 explained, "*Sometimes, smart tech can act as a fallback, to prevent serious things happening, for example carbon monoxide detectors, smoke detectors, a way of turning off the heating if nobody is in the house* (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). *Detecting leaks, natural gas or water, serving a critical backup function*." R7 mentioned security as a crucial element: "*it really depends on what problem they are solving. Certainly, making the users feel more secure inside and out their houses".* Whilst R29 approached security benefits as a mean of helping people feeling more secure and looking after them outside and inside their homes (Benjamin K. Sovacool and Furszyfer Del Rio, 2020).

Other enhanced experiences came second to last, (e.g., new forms of shopping), with R15 explaining that "*the hope is there will be additional apps built around smart home technologies that will create a smart ecosystem where new ways of shopping arise*." Whist R5 linked enhanced experiences with comfort: "*That is probably why Alexa is successful, it is very cheap, and it does not do anything you were unable to do before. You could buy things on amazon before by opening your laptop, now you just ask Alexa for it"*.

A final category of benefits was the likelihood of smart home technology providers giving away free or promotional items to "members" of their own communities, from R16's "*free coffee*" to R30's *"a free iPhone upgrade every two years.*" R18 suggested: "*Another approach could be giving appliances for free, but then taking a cut as a company. So if you have an appliance that you believe would save the household money or generate it; if you really believe it as a company, then you could operate a model where the risk is in some sort in the company rather than the household to create that return of investment".* R28 added: *"I think most of these technologies are offering a payback period, so if you spend certain amount of money buying a device, after some time of using it, you will save enough to offset the cost. So, if you are a company, you could offer these technologies for free".*

6.3.4 common barriers and risks identified by experts

As with everything, the benefits earlier presented do not come without risks and barriers. Indeed, this research identified 17 of these, presented in Table 10. In this thesis, risks refer to the potential downsides to adoption, and by barriers, the author means the factors impeding adoption of smart home technologies. Given risks and barriers relate to each other, but mostly they were often discussed together in the interviews, in this PhD as well as in the publication resulting from this work (Sovacool and Furszyfer Del Rio, 2020a), the researcher has grouped them together for the analysis. These cut across the more standard dimensions discussed in the literature, such as Hargraves and Wilson's (2017) classification of challenges across hardware and software, acceptability and usability, and domesticating technologies into lifestyles, or the Osservatori Digital Innovation del Politecnico di Milano (2018), who suggest that the three main barriers to the smart home technology market are the installation of products, the integration of the offer with valuable services and the presence of established brands.

Table 10: Smart home technology risks and barriers discussed by expert interview respondents (n=31) (Sovacool and Furszyfer Del Rio, 2020a)

Rank	Frequency by interview		Topic
1	25	80.65%	Privacy, security and hacking
1	25	80.65%	Technical reliability, warranties, and obsolescence
2	24	77.42%	Usability, user acceptance and learning
3	23	74.19%	entrenched market and political power
4	20	64.52%	Uncertainty, lack of sharing, and difficulty monetizing benefits
5	15	48.39%	Interoperability and resilience
6	14	45.16%	Energy rebounds and wasteful consumption
7	9	29.03%	Loss of personal control and autonomy
8	8	25.81%	Resource intensity, materiality, and sustainability
9	7	22.58%	Lack of home ownership
10	6	19.35%	Cultural differences to global diffusion

10	6	19.35%	Poor connectivity, lack of standardization, and supply chains
10	6	19.35%	Corporate longevity, accountability, and consumer choice
11	5	16.13%	High cost
11	5	16.13%	Fear of new technology
12	2	6.45%	Social isolation and loneliness
13	1	3.23%	Health

As perhaps expected not only by the literature but also by media reports, the top two barriers and risks are related to concerns about consumer protection and data security, as well as technical reliability and smart home technologies working properly and not becoming quickly obsolete (Wilson, Hargreaves and Hauxwell-Baldwin, 2017; Nicholls, Strengers and Sadowski, 2020; Sovacool and Furszyfer Del Rio, 2020a). In this sense, in order for these technologies to maximize their efficiency and performance, and also to escalate to greater levels of smartness (see figure 14 above), smart homes need to collect a vast amounts of information about houses, affiliated technologies (such as appliances and even vehicles), and user demographics and consumption patterns (Sovacool and Furszyfer Del Rio, 2020a). However, the fact that users are giving away great deal of personal information also creates a severe risk that such data can be stolen, hacked, or misused. As R12 stated, "*At the highest levels of smartness, homes are especially most vulnerable to hacking and security breaches. So, it's a paradox, the smarter your home is, the more vulnerable you become. Current security experts talk about how even a simple smart device like a toaster can be an entry for a hacker into the entire home. It creates a soft underbelly that thieves and hackers can exploit.*" A related concern is whether the companies collecting this data, notably Google or Facebook, can be trusted. R27, suggested that the only real risk with the deployment of smart homes technologies is data: "*Ultimately this is really about been able to identify you and your home and the status of your home at any given time. That is the real risk it holds, there is not much more other material risks, kind of like it starts to reveal local networks and electricity, but the real issue is about personal data. So, companies out there, can you trust them with your data?*"

The other top barrier and risk is related to technical reliability and obsolescence, as one expert suggested, "*A smart home, what a smart home would really be, is never be going to be as resilient as a traditional or a dumb house would*. *What if the lights go out in a smart home*"? Certainly, the smarter homes become, the more complex and interconnected they are, but that could also create dependences that can erode reliability—for instance, many smart devices would simply not work in

an electricity blackout, or may confuse a cat with a burglar (Sovacool and Furszyfer Del Rio, 2020a). R2 noted part of this concern can be due to faulty installations and lack of familiarity with new devices. As they elaborated, "*In our own trials of smart home technology, gas engineers and electricity engineers were not familiar with the technology, some installations were botched, things put in backwards*." R6 added that "*smart systems are layered and interdependent. A smart home is really using two sociotechnical systems, the electricity system layered on top of the IT system. One cannot work without the other, they are coupled together in ways that lack of one can cause failure of both. We need to expect in smart systems that we will have problems from time to time, because they are clever, complex, and require expert knowledge, we need to keep our expectations realistic, and always have a plan B*." R12 noted that even when they are properly installed, there is "*the risk of performance and systems crashing. We already expect smart phones or laptops to start to perform worse after a year or two, their screens freeze, they get viruses, they need to frequently restart. Imaging now that these problems afflict your home. Even if you only have to restart a whole home on an infrequent basis, it can still be a major hassle.*" Other respondents discussed built in obsolescence and how given the speed of innovation within the sector. R6 stated that a major issue is "*permanence, or rather impermanence. There will always be a subset of the population who buys the SHT bells and whistles stuff. They will use it for a bit, may use it if they are on their own, quite a lot, but over time they may get tired of it, and use it less and less, especially if it breaks, or needs upgraded. And upgrades can be related to hardware (becoming obsolete or out of date) but also software*." R24 added that: "*At the moment, I think what is working now are those that operate simply. Because once you pass the initial interaction, for example, asking Alexa for reminders and setting timers in the kitchen, then the interaction is quite limited. And I think the smart home designers are becoming aware of this"*.

Usability and learning came up next, this barrier include that many smart home devices may be perceived as not being easy to use or intuitive enough, this is not limited to households but other elements of the smart ecosystem. They require uses to "adapt" or "domesticate" them into their lifestyles (Sovacool and Furszyfer Del Rio, 2020a). R6 framed this challenge in terms of "*Smart home technologies require user learning, but learning isn't limited to users. System operators and business facilitators also have to learn, so do regulators, learning occurs across all of these, and accountability becomes even more important in a smart system, precisely because it is so distributed*." Pilots of smart heating controls for example have found that previous familiarity smart homes helped make adoption easier, and they already learned how to use touch-screens (Wall and Healy, 2013). Hargreaves and Wilson (2017) suggest that smart home technologies must also not overwhelm or overpower possible users with too many options or difficult to utilize controls. R3 brought this point too*: "Not everybody would like to accept too many choices of smart design. Personally, I do not like*

to be much preoccupied with too many choices at home. Imagine that some applications are more energy efficient but maybe, the benefits are not too important for the user as the ease of operating the system".

R3 also distinguished between different types of learning necessary for adoption: practical learning (how to configure and use the technology), cognitive learning (understanding what they can do or be used for), and symbolic learning (incorporating devices into routines and practices) (Hargreaves and Wilson, 2017). When any of these forms of learning break down, users can become frustrated—with some smart home users staying that "*It's just taken months to just use it and realize where it's useful.…It wasn't intuitive what parts of it you can do straight away*" and "*It's too bloody complicated and there's no point in it and it's doing me no benefit, not worth it*." (Hargreaves, Wilson and Hauxwell-Baldwin, 2018). Whilst R5 and R18 both stated that the biggest barrier is users' acceptance: "*A quick answer is acceptance of users, people accepting these technologies and people getting a bit scared of these technologies making decisions for you in your house*" and "*Another barrier of course, is consumers' acceptance, as all these new services require data collection and maybe, people aren't willing to share their personal data. More, as currently is quite difficult to be protected against misuse of data*". R22 illustrated usability with the following example: "*I read the other day that someone bought a smart kettle and he spent eleven hours trying to boil the water with the smart kettle, because there was so much setting up to do and connecting things. So, one of the barriers is all this technological wonderfulness needs to work well to make life easier. I mean logging-in into your kettle is not probably as smart as switching on/off the kettle.* (Benjamin K. Sovacool and Furszyfer Del Rio, 2020)*"*

The researcher found, surprisingly, that issues centred on entrenched markets and political power came as the fourth most mentioned barrier (Sovacool and Furszyfer Del Rio, 2020a). This relates to entrenching market and political power among big smart home technology firms, who may use the data, revenues, or knowledge they collect to suit their own ends, rather than social goals of sustainability or poverty reduction (Lucie, 2018). R15, in this sense stated that "*With all technologies, there is always a risk of them being easier to use and access by some and not others. We would be interested in whether smart thermostats are usable, especially by people less tech savvy. Or those who are physically disabled. This is why we did usability tests and smart heating controls. Smart meters have also been looked at vulnerable groups, and how to ensure that they benefit. Last thing we want is a smart system to only benefit some in society We must always hedge against this distribution risk.* In addition, R13 noted on a similar line*: "Distributional impacts specially in the energy market and the impacts on energy bills, if people are unable to access these technologies then will be unfairly paying more, because they might not be able to switch tariffs during peak times.*

These people might be excluded from these technologies and we need to bring them along to this journey or at least offer them some protection". Yet R12 explained that "*there is a risk in terms of companies and incumbency. Smart home systems are becoming the domain of big established companies, some of the biggest in the world, including Apple and Amazon but also Panasonic, Samsung, and Philips. This means the smart home agenda is controlled and dominated by a small number of voices with very big interests*." With the consolidation of these two elements namely market power and data could, in the extreme, undermine democracy, entrench new forms of power, and threaten recent gains in equality (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). Given that smart technology firms often operate in a regulatory environment that is opaque, they are often technologically ahead of regulation, are also loosely regulated when it comes to taxes and prone to immense lobbying, a smart home society would create a "toxic cocktail for democracy (Cathy, 2017)" or a new era of "surveillance capitalism" (Zuboff, 2019) where humans that are not tech savvy enough to master technologies could become the slaves of it (Zuboff, 1988).

Uncertainty over the future as well as whether smart home benefits will be shared or monetized was mentioned as a frequent challenge (Sovacool and Furszyfer Del Rio, 2020a). R22 illustrated monetization as a barrier in the following way: "*Another barrier, of course, form the commercial standpoint is the monetization. So yes, you can provide smart fridge services but how do you actually get the money saved from the energy system? and that I think that is a bit of a challenge. Just as an accounting challenge: how do you proof that a change in demand for example, somebody avoided peak demand how can they proof that? Or in fact, how much they reduced by, because you actually do not know the counterfactuals of what the demand would have been. How you get rewarded for grids services that at the moment demand does not provide and doesn't engage in contracts*". The current development of the technology and the use consumers give to it was mentioned by different means in our interviews (Sovacool and Furszyfer Del Rio, 2020a). According to R25, "*This is an anecdote, but when I go to other people's home and they have these things, I feel it is more a gimmick than a genuine service. People seem to have fun with it, but I haven't seeing it become part of people's daily life to the extent that it would deliver a service.*" R24 mentioned that "*There is a lot of niche stuff, smart light bulbs, I do not understand them quite well. You change the colour over again, but you might get bored of it and never do it again. But again, at the moment, it is more about novelty more than anything else*" R19 added: "*There is another issue, I think the technology is not quite there yet, thus people will stop using them because the device didn't work well*".

Issues related to Interoperability and homes not being becoming resilient captured the risk that not all equipment, devices, appliances, or systems will operate together, especially when they may be from different retail suppliers or use different networks and protocols (Benjamin K. Sovacool and

Furszyfer Del Rio, 2020). R6 cautioned that "*Interoperability issues and incumbency can get in the way of smart tech take-up. It may also mean people get left with stranded assets, some specialized piece of tech that no longer works, and the company making it has gone out of business*." During our interview R23 exposed been "locked" due to interoperability as a barrier: Hargreaves and Wilson (2017) have already mentioned the interoperability issue and they challenge it in three dimensions: needing smart home technologies that are compatible with non-smart homes and appliances, with busy lives and routines, and with existing support systems. Interoperability is especially challenging given that it requires not only technologies to work together under a system, but different smart home companies and operators to establish better cooperative relationships with providers, and that items can be replaced without disrupting the operational performance of a smart home (Jungwoo, Park and Lee, 2018).

Energy rebounds and wasteful consumption (e.g. smart equipment been always turn to operate and deliver results) referred to the fact that many smart home technologies are not about saving energy or becoming more sustainable, but prioritizing other issues such as comfort, luxury, or convenience (Sovacool and Furszyfer Del Rio, 2020a). R2 nicely commented that "*some emerging evidence, and intuition, says that smart tech can result in waste, hence the proliferation of robot lawn mowers or vacuum cleaners that are always on. Smart home technologies can embed more energy-intensive routines and practices, and do so more deeply and invisibly into our lives … Humans are remarkably creative at coming up with new ways to use energy … The human capacity to invent new ways to waste energy is profound*." To this, R24 commented on his own experience: "*another risk is the energy theme, I tried the Amazon Show, it is similar to Echo but it has a screen. I do not know if my version was poked but the screen never goes off, it is basically having 24 hours a day a luminous tablet screen in the kitchen that it is always on. It has some massive wastes of energy…The sustainability thing is scary for me; how much energy is been used and sits in the background? So yes, I'm a bit sceptical about the energy savings and connected devices are always on, so it can listen*" R12 agreed and noted that "*there is little evidence smart technologies have a positive effect on sustainability. They are driven by other, non-environmental desires that often lead to increases in energy demand … People who adopt smart tech feel good, embodied in the sensory feedback of the devices, and other people say they look good with their smart tech, so the whole thing works against a culture of energy demand reduction. The culture of the home focuses on high tech, but not thoughtful consumption, not on efficiency, or simplicity. It is not a culture that not privileging energy demand reduction as key form of social feedback"*. There is thus a fear that increasing data and the 'internet of things' could require a "tsunami of data" and greatly increase global electricity usage (Vidal, 2017a). Strengers and Nicholls show how the convenience narrative full of smart devices could transform everyday practices in ways

that increase not only energy consumption, but household labour (Strengers and Nicholls, 2017), or lead to greater energy intensive loads for things like air conditioning or electricity. Tirado Herrero et al. also revealed that smart home technologies can reinforce unsustainable energy consumption (Tirado Herrero, Nicholls and Strengers, 2018). R30 commented on this aspect too: "*Overall I like the idea of smart homes, but like with every technological development there is this risk of rebound effects where you end up using more"*

Smart home technologies could lead to loss of personal control and autonomy, with households becoming more dependent on smart technology. This could create dangerous conditions where people serve the system, rather than having the system serve the users (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). R2 called this the "*paradox*" of smart homes, that homes "*get [enhanced] control only by linking homes and heating to broader systems of provision, particularly the internet and digital technologies, connecting them into a broader network. Smart technologies with cloud-based data, storage and processing provide more control and functionality, but also embed those individuals in a larger whole, a larger system. This makes it relational dimension with mutual dependences*." R6 framed this in terms of "*an exchange of roles*," with the traditional model being about energy services for a household, but a new model can be "*the home is there only to provide services to the network … Smart is sold as being liberating, but that liberation comes with hidden dependencies. Smart stuff is so clever that only experts fully understand it, especially particular components such as the algorithms, which only the backroom boys know. We invest an extraordinary amount of trust and power in those who write the algorithms and who design the smart system. If something is going wrong with smart tech, chances are you won't be able to fix it yourself*." R12 lastly noted that in their perspective, "*the key risk is ceding autonomy and independence in the home. While smart systems are supposed to provide more control, because we don't fully understand how they work, we quickly end up out of control when things go wrong. When a smart tech fails, we need to ring somebody up to help fix it, these technologies are impossible to fix yourself*." Indeed, a representative national survey of UK homeowners (n=1025) conducted by Wilson and colleagues already found that ceding autonomy and independence in the home for increased technological control were the *main* perceived risks from the sample (Wilson, Hargreaves and Hauxwell-Baldwin, 2017).

Although framed as efficient and 'green tech', many smart home technologies are resource or material intensive as well (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). R6 captured this nicely, when they explained that "*There is a risk of using smartness in an over-abstract way, something 'whizzy and weightless'. We used to have an IT support person who always said to us sternly, you think of the cloud as some abstract immaterial entity, but I think of someone else's*

physical computer or server. A cloud is lumps of metal somewhere, lots of processors, materials, and energy usage. In the same way, smart technology requires extraction and processing of an abundance of materials. It has meaningful and measurable social and ecological impacts, given that many of those materials come from troubled parts of the world." R12 added that a smart home revolution could even change our culture in ways that embed material consumption and notions of abundance: "*Smart homes become a way of showing off to friends but also demonstrating competency. So, people who work at home—cooks, musicians, childminders—may start to indoctrinate the idea that to do these things well you need smart home systems. This can spread and change the dynamic and trajectory of energy practices in a more energy intensive direction across multiple households, adding to the treadmill of consumption, not slowing it down. It is social feedback the wrong way … Its sole purpose is to keep going further and faster along current trajectories, not about transforming the system or questioning its underlying assumptions*." R20 stated that "*E-waste risk is obviously bad, it is quite a hidden thing, and not many people have looked into the environmental footprint of the manufacturer of these devices. At the moment, I think just smart phones' annual production has the same carbon footprint as the whole of the UK transport sector and it is growing. That is just carbon in production, it has nothing to do with the end-of-life situation.*"

Lack of home ownership was a significant barrier, although not as popular as others, when experts commented on this issue, they said this by far represented the biggest barrier. This, given that many times people need to own their own property, rather than rent or lease to have any incentive to buy a smart home technologies (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). R17 pointed out to this barrier in terms of incentives "*One key barrier, is that only around 20 to 30 percent of people actually own their apartments, the rest they just pay the rent. So I'm wondering whether home-owners would be interested in investing in these technologies*". In a similar vein, R31 mentioned home-ownership as a key deterrent: "*There is a lot of people who aren't going to be incentivize to buy this sort of technologies and landlords are not incentivized to give it to tenants either. I think property ownership it has been a huge barrier for us with the smart meters and I think, it's been a huge barrier for other areas. For example, with the rollout of super-fast broadband, governments now have to intervene because landlords didn't give access to broadband fibres to install superfast connections*".

Cultural differences could exist to global diffusion, R22 mentioned this in our interview: "*We need to look at the cultural differences as well, it is quite interesting the cultural differences between Germany and the UK. Here [in the UK] we are quite casual with the personal data. In part, for good reasons because they haven't had any bad experiences. In Germany, you have the living memory of the Stasi*." Whilst R5 covered different regions of the globe: "*Europe is well ahead in this area*

because it seems to be a very pro-consumer approach. There are political structures that allow consumers' organizations to defend consumers. Whilst in the US, it is more driven by the manufacturers instead of government. That is how the system works, it is more like companies realizing what the downsides are. In parts of Asia are more like Europe, other parts of Asia are more like the US. And there is China, where my favourite quote I heard from one of our potential customers was: "I'm Chinese why do I worry about security? My government does that for me". R28 also mentioned that the deployment could vary amongst countries "*it really depends on where you are looking at, probably in Japan first, which is a high-tech country, people there are probably more likely to accept these technologies first. In France and the UK, they might be a bit more reluctant in adopting these technologies*".

Other respondents discussed how lack of connectivity to the internet, such as in rural areas or the developing world, could greatly impede adoption (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). Also included in this category were barriers related to lack of proper standards and certification across smart home technologies and only nascent developed supply chains. R16 mentioned: "*in less developed countries, we're still talking very much about plain vanilla technology, both in terms of buildings construction, as well as the type of devices that they are putting in the market".* R7 added*: "Connectivity it's a huge barrier, so even if the Wi-Fi penetration is quite high, it is often incomplete in social housing. Also, if we look at Low Power Wide Area Network System or any other IoT there is a big question of infrastructure that right now, one of the biggest challenges for the hardware providers is that nobody really knows how is going to win this IoT battle. Is it going to be 3G, 4G, 5G or LoRa. What's going to be rolled out? I think that is one of the key issues and as a result, a lot of the smart home companies are trying to become multi-networks so they could switch between systems*". R20 covered this point with a similar: "*the difference between Bluetooth and Zigbee as two competing standards for the automation of signals presence makes me think we are not quite there yet*".

Corporate accountability, while similar to the erosion of democracy, was more about companies honouring smart home commitments and being open and honest about problems and transparent about their marketing and promotional material (Sovacool and Furszyfer Del Rio, 2020a). R27 illustrated this point by stating*: "Another issue, this is because my previous job in regulation. If something goes wrong, can you get great customer service to get it fixed very quickly and you could seek redress harm, or any detriment caused. The reason why I say that, is because if you got a platform of platforms like Amazon web services and then you have different branded connected devices working through that, who do you go to when it goes wrong, would you go Nest or Amazon? Because in an ideal world, it should not matter who you go to, with the very bundled smart home you should be able to go to any of the of the components parts to fix it."* R13 addressed this issue by cautioned about: *"in*

our research, we questioned how confident are we that consumers could navigate consumer redress process and knew who to contact when something goes wrong. Specially during multiple interaction products and multiple company interaction. So, making sure who to contact when something goes wrong". Whilst R23 linked corporate accountability with the use of AI: "*The other issue is when you get into AI and machine learning. Where you get these huge datasets and rather than anyone looking at it and analysing it, it is through into a machine. That could be very risky because accountability goes away and all organizations, even where I work, people do not like been accountable, if you just through it to the system it becomes a lot harder for consumers to challenge it. Because we will reach a point where people cannot even explain the formula*". As previously mentioned a study conducted by (Osservatori Digital Innovation del Politecnico di Milano, 2018) showed that a wide variety of smart home technologies are been sold by start-ups. This idea links well to a concern related of been locked in to a particular company's products, with multiple respondents mentioning how some smart home technology could be proprietary, meaning only certain applications would work only with certain brands, trapping people into having less choice (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). This becomes especially severe when one "inherits" a bundle of smart home technologies when moving into, or purchasing, a new house. R23 warned about these risks: "*Another big barrier is been locked-in, particularly in rental properties. If you move into a house and it got an Apple smart kit and you are bringing with you a Google smart kit and they can't talk to each other, you are in a position where the consumer now has to buy all the Apple stuff."*

The cost of smart home technology, surprisingly, was not more frequently mentioned, even though all smart appliances, devices, sensors, and systems cost much, much more than their conventional counterparts (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). As R12 indicated, "*The most obvious barrier to me is cost. As these are high end products, cost is the single biggest barrier. Many times, smart home devices are the most expensive options, therefore people simply do not buy them*." This theme was also picked up during our retail visits, with one Home Base salesperson commenting that in their opinion, *"Smart home technologies are not much requested nor bought. They are still too expensive for the regular customer."* This statement becomes all the more apparent when one realizes a smart coffee machine currently costs as much as £1300 (see Figure 16).

Figure 16: A smart coffee machine on display at John Lewis, UK. Picture taken by the author in January 2019



Fear of new technology was mentioned as an additional barrier. R1 noted that even more than privacy, "*fear of the unknown*" is a significant obstacle, given "*the perception users have on smart meters played out in terms of how the press created some fear around smart technologies*." As one salesperson confided during a visit to Peter Jones, *"Only one person has actually been interested in buying a connected washing machine and oven. In general, at least for these appliances, people still prefer the traditional versions."*

Two respondents mentioned social isolation and loneliness as risks, a counterpoint to the social inclusion benefits above. Technology comes to replace actual interaction with humans, and can lead to distress and depression (Gram-Hanssen and Darby, 2018; Sovacool and Furszyfer Del Rio, 2020a). R6 questioned "*in a society where loneliness is a major case of distress, smart home technology is also cold substitute for actual warm people. Is that ultimately a good thing*?". Certainly the review conducted by Marikyan and team (2019) highlights that smart home technologies could exclude people in two ways: by replacing human communication with virtual communication, and by excluding non-users from new online communities.

Only one participant mentioned the potential health concerns R30: "*I think of all these wireless connections we still do not know the long-term health implications of that either. I think it connects to the smart homes because we are probably adding more signals*".

6.3.5 Eleven policy recommendations for smart home technologies

The experts that participated in the interviews did not discuss only benefits and barriers and risks, but also, they suggested 11 policy changes that need to be implemented to make smart homes more sustainable. Table 11 offers a summary of these suggested policies.

Table 11 A list of policy recommendations for smart home technologies

Rank	Frequency by interview		Topic
1	18	58.06%	Consumer protection, privacy, data security
2	16	51.61%	Restrictions or configurations to ensure low-energy or low-carbon
3	12	38.71%	Stronger regulations for energy services or Internet of Things
4	11	35.48%	Provide research, innovation, and learning
5	8	25.81%	Remove barriers and encouraging market competition
5	8	25.81%	Provide knowledge, information and evidence
6	7	22.58%	Set standards (marketing and advertising plus technical)
7	6	19.35%	Address poverty, equity, and vulnerability
7	6	19.35%	Promote interoperability and upgrades
7	6	19.35%	Redirect efforts to other policy areas
8	5	16.13%	Mandate and ensure consumer benefits

Source: (Sovacool and Furszyfer Del Rio, 2020a)

By far, the most strongly suggested policy recommendation experts recommended the researcher was the need to enhance consumer protection, privacy, and data security. This covered many aspects of smart home technologies, that is, it not only focussed on users' personal information, but also entailed issues related to data control and restrictions, to encryption, to clear guidelines for ownership of data, as well as safeguards against hacking and piracy (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). As R2 noted, "*better data and privacy and consumer confidence … are needed to ensure service providers behave in a way that does not undermine confidence and trus*t." And as R15 concurred, "*stronger consumer protection and regulation is a must, regulation to protect consumers is essential*."

A second recommendation, given the potential for energy rebounds and waste, relates to ensuring that smart home technologies deliver better results in terms of energy consumption, sustainability and energy efficiency (Sovacool and Furszyfer Del Rio, 2020a). R2, for instance, elaborated that "*I am most interested in scripting, how to design hardware, control systems, algorithms, and other factors that push energy downwards. This means SHTs are not neutral, cannot be controlled any way they like. We need to make smart tech directional, to design it to explicitly reduce energy. There are a multitude of ways to do that, from building it into the kit, or making it the default, a "harder" path, to merely allowing people to set controls a certain way, a "softer" path. The result would be setting constraints on people, smart home technologies allow people to do some things, but it also doesn't allow them to do others*." R12 added that without scripting, "*until reductions in energy demand or carbon are guaranteed, there is no case for smart energy homes*." Such scripting would automatically cut off smart home devices if they exceed a certain threshold in terms of emissions or energy consumption (Sovacool and Furszyfer Del Rio, 2020a).

Participants also commented on the need for stronger regulations for energy services or Internet of Things (Sovacool and Furszyfer Del Rio, 2020a). To this, R27 mentioned: "*so all models like peer-to-peer and service base models, need to move away from prescription towards something more ethical based regulation, so that you are not dictating the business model, but you are saying: whatever business you are doing, here are the things you have to adhere to by the principles of what you are doing. Kind of the principles to treat consumers fairly*". Moreover, R25 added: *I think we also need to understand, and this is vital, what is the total energy use is of this stuff and whether this is a net benefit or not. There should be a place for regulation for having all these connected devices and services and we need to think about it. I think there is role for government and manufacturers to make sure that consumers understand the most efficient way to do things*. For this dimension, R21 added: "*I know Wi-Fi and also Bluetooth they are all trying to compete with each other. That is also with Lopan and Lora. They are all trying to have their own security standards. So now, we should find a space to standardize a coding across the whole spectrum. And you have to consider two sides as well, one for the developer and the other for the consumer, to make the consumer happy with a certain interface where they do not need to buy different products, for different things*". With this in mind, R1 noted: "*Essentially we need policies around improving communication protocols between devices such as easy to use and set ups"*

Other than these top three policy recommendations, another suggestion consisted in governments to support research as a platform for innovation and learning. This includes, for example, more investment in independent science as well as the sponsoring of pilot studies and trials (Sovacool and Furszyfer Del Rio, 2020a). As R14 noted, "*creating spaces for different institutions to learn together*

is important … A Living Lab environment where people can experience changes and companies and research institutions can work with them to figure out how to improve the experience and also fix things that go wrong, seeing which work best, and also maintaining consumer protection, would be ideal … Governments need to create this environment where the sector can learn how to deliver the outcomes society wants, and government can make sure they protect consumers and meet the target." R15 added that "*Government plays a critical role in innovation, BEIS in particular has a £500 million innovation program for energy … This innovation money is intended to support businesses through the valley of death. Innovation funding and R&D is really important*." R27 added to "*in order to open up these businesses models, it needs to be more space for innovation within the regulatory framework, since at the moment, for example, certainly for electricity and gas utilities, the business model it is pretty much prescribed through the license, not the industrial codes. Which is why they all look quite similar*".

Other experts discussed how important is to remove barriers and encourage more open market competition (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). In their systematic review of the smart homes literature, Marikyan et al. (2019) advice that regulation and legal stipulations have fallen behind of innovation, with many gaps in national and international policy and legislation. To this, R26 linked the smart meter implementation program with competition: "*If we are thinking about the energy smartness, I think policies that would allow competitiveness and policies that reduce the sort of prescriptiveness. So, for example: forcing the rollout of smart meters and IHD is a good example. It was a good idea to force the rollout of smart meters but to force the in-home display, for me, is not the best idea, because you are putting into people's homes technology that most likely to be technologically redundant in a few years, so allowing competition on elements of that, would be far more interesting". Whilst R29 noted*: "*First and foremost, I would say that the regulatory indictment is inadequate, so we are seeing really good innovative companies either not coming into the market or worse, leaving the market. So, first and foremost clearly there is a clear regulatory policy and architecture problem. So, I think you can then divide that into: excessive complexities for new entrance. Second thing, I would say no roots to markets*" The experience from R28 aligns to the previous point: "*Since I want to make my own start-up and design my own smart devices. As a start-up, I realized that I have no legitimacy to approach people and will be very hard to enter this new market*".

The provision of reliable information and knowledge was articulated as another recommendation, including material printed or online supplements (Sovacool and Furszyfer Del Rio, 2020a). As R15 explained, "*Sharing knowledge and evidence is key. Industry has knowledge but it's always hard to get out. Government is needed to make strong data and evidence publicly available to all*."

This suggestion was followed by setting standards—across different dimensions, including technology as well as advertising and marketing. This, as well, covered many aspects of smart home technologies, from better standards for installers and technology providers, to guidelines for consumers, to advertising efforts and improving labelling (Sovacool and Furszyfer Del Rio, 2020a). In terms of advertising, R12 suggested that "*energy efficiency labels should be made and applied to all smart home devices, like the rating scheme we have for lighting or boilers, to ensure the environmental benefits are clear"*. R15 mentioned that "*Standards can allow smart controls to be a requirement*." Hargreaves and Wilson (2017) in their work have suggested to create a national system of independent certification schemes for smart home technology assessors, installers, and finance providers. The author of this PhD supports such initiative.

Furthermore, protections need in place to avoid a "digital divide" and ensure that smart home technologies do not aggravate poverty and vulnerability by leaving vulnerable individuals behind in the digital revolution. R12 emphasized that "*we must make sure that vulnerable groups are not excluded from any smart home revolution so that no one is left behind. We can tailor literacy, training, and learning, so that those unfamiliar and excluded can come to feel confident and comfortable, or also enhance the welfare of those who cannot afford smart home systems*." R14 agreed and added that "*smart home technologies will not meet social objectives like tackling fuel poverty or decarbonizing without government intervention and strong policy*." A similar point was brought by R31, when commented: "*The energy market is about to become a lot more complicated and that is something were the analogue energy market absolutely failed at doing, which was protecting the most vulnerable people and that is something that the smart energy market obviously must not do and has the potential to not do".* Hargreaves and Wilson (2017) have already noticed this issue and mentioned that lower income households, the elderly, or those in rural areas with poor internet access are later adopters of smart home technologies. To avoid the digital divide, in this research it is suggested that grants, subsidies, and free technical advice could be targeted at these groups, as well as efforts to improve high-speed internet access (Sovacool and Furszyfer Del Rio, 2020a).

Experts also commented that the promotion of required interoperability and upgrades is another vital area for governments to regulate. Hargreaves and Wilson (2017) reveal that clear national policy guidelines can ensure hardware and software is compatible not only within the home, but also with communications portals as well as energy suppliers or system operators, especially during periods of peak usage. Both R8 and R23 commented on tackling interoperability to benefit consumers and avoid been locked-in (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). Respectively, they advised: "*Interoperability needs to be addressed. Ecosystems have to play well*

with each other. We are not really there, but we are getting there. You might get stuff to play well within an ecosystem, but that ecosystem needs play together with others as well. So, users are not trapped in a particular system". R23 added: *"we are always very big on interoperability and interchangeability. So, consumers do not find their selves stuck. Because we always find that the big guys can lock-down their position"* R27 commented the role of industry on this*: "I think we need central policies on business converging on standards for interoperability to avoid misspending capital… I think these technologies should be interoperable by default."*

Experts also commented in not putting all efforts on smart technologies but also address issues related to energy efficiency or fuel poverty, simultaneously with smart investments (Sovacool and Furszyfer Del Rio, 2020a). As R6 explained, "I *am not sure I actually want policies to accelerate smart homes until we tackle other problems. Here in the UK, we have a real, enormous and serious problem of homelessness, all the hidden homeless alongside those on the streets. Among the homes we have, 8 million could do with getting loft insulation for the first time or topped up to a decent level. We have an enormous amount of work to make homes more liveable, getting energy demand down from those, and eradicating fuel poverty. If you really want to improve lives, lessen the environmental impact of our energy system, and create jobs, you don't want to focus on smart, you want to focus on ordinary energy efficiency upgrades, such as retrofits and refurbishments. We have so much policy attention on smart home technologies, but so few on creating decent social housing for the chronically poor*." R9 estimated that "*turning the temperature down 1 degrees saves £75 a year, you don't need smart tech to do that!*"

Instructing and guaranteeing consumer benefits came next. Policies around this subject were brought respectively by R23 commenting: "*ideally, rather than accepting companies' terms and conditions they have to accept yours … if companies want your data, it has to be some type of even exchange. Even if consumers do not really understand the value of their data, at least make them an offer, instead of just taking it and send their data out there. This could lead to certain leverage*". R25 noted: "*policies are not designed with 'me' in mind, are designed with the system in mind. So, principle number one, is when you thinking about new polices, we need to think about what it looks like from the consumers' perspective, would it persuade consumers to do what we want them to do? Too much data flows from the consumer but very few rewards flow to consumers."*

6.4 Discussion and policy recommendations

Linking back results from this chapter to the theoretical framework previously presented in chapter 4, the author emphasises the need to decentre the home in the analysis of smart home technologies, and to expand it to look at the socio-technical system at other scales including communities, cities, states, and even at regional levels (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). R12 made this point about a sociotechnical system focus explicitly, when they suggested that: "*There is an important agenda to expand smart home research beyond feedback, from beyond a device like a smart meter, to the whole home, then to smart grids and smart cities and a smart planet. The notion of smart operates across a variety of scales*." Expanding the analysis from homes to systems would remind us that smart home technologies also involve global organizations, (as presented in the business model chapter) institutional rule systems and structures, and cultural values (Benjamin K. Sovacool and Furszyfer Del Rio, 2020). This demands a shift in focus from individual technologies to the broader scope of systems of systems (Grubler, Wilson and Nemet, 2016)." This was further corroborated by R25 when they added: "*We need to get away from the obsession we got in policy terms of supporting a technology … we need to think about the home as part of the system."*

Moreover, as the author has presented in the in this and the previous chapter, much of the smart home technology narrative centres around the notion of "control," as Figure 17 illustrates, the author, along with co-supervisor as introduce in the publication (Benjamin K. Sovacool and Furszyfer Del Rio, 2020) argue this notion needs further contextualisation. Indeed, R22 remarked that "*smart homes open a very interesting debate about control and to use a popular political phrase of recent times, all these technologies are been sold on the grounds of taking back control. But, if we look carefully, a lot of control might be taken away from people.*"

Figure 17 A Curry's PC World Advertisement for Smart Homes centring on "Control," London, November 2018



Source: photography taken by Benjamin K Sovacool during November 2018 (Sovacool and Furszyfer Del Rio, 2020a)

In the control sphere, research highlights problems with smart controls, suggesting there are two opposing narratives: The first involves informing and empowering consumers to make better 'energy choices', and enabling smart technologies to act with minimum consumer participation (Tirado Herrero, Nicholls and Strengers, 2018), while the second suggests that smart technologies would work better by 'circumventing' users to optimise energy use (Wilson, Hargreaves and Hauxwell-Baldwin, 2017). This dual representation has been criticised in the context of domestic smart technologies: the first presents an informed consumer as an unrealistic automaton (Goulden *et al.*, 2018), while trials suggest users limit themselves to the more basic functions of SHTs (Hargreaves, Wilson and Hauxwell-Baldwin, 2018; Tirado Herrero, Nicholls and Strengers, 2018); the second implies an indifferent consumer, leaving no room for an engaged citizen; this approach could miss opportunities for domestic energy savings through demand side management (Goulden *et al.*, 2018).

Examples of the first narrative include recent government documents that suggest smart technologies could empower consumers in relation to their energy use, in turn helping to lower bills (BEIS, 2017b; Ofgem, 2017). Similarly, the LCICG (2016) considers smart controls which will be "*predictive, intelligent householder-oriented building controls and diagnostic applications that optimise performance of building services (e.g. central heating*)", that will *"[assist] behavioural change by providing users with clear information, incentives and innovative tools with which to interact with buildings*". Prior to this, the EU Smart Grids Task Force (Smart Grids Task Force, 2011) similarly emphasised how smart grids and meters ought to be designed so as to empower consumers, including in gaining control of their energy consumption and allowing them to participate in energy markets.

In sum, this chapter revealed that for consumers at least here in Europe and the UK, the smart home revolution arrived. Certainly, during the site visits to retail stores the researcher was able to documented 267 SHTs options available to consumers today, provided by 113 different companies and available from a multitude of direct suppliers (e.g. PC Curry's), home improvement stores (e.g. HomeBase), general department stores (e.g. John Lewis), and electronics and appliance retail shops (Sovacool and Furszyfer Del Rio, 2020a). In addition to all the online outlets that due to lack of time and resources this PhD author was unable to further explored. This collection of options ranges from devices that can merely create isolated or bundled smart services, at lower levels of the smart spectrum, all the way towards more automated, intuitive, and sentiment options such as artificial intelligence, robots, and drones (Sovacool and Furszyfer Del Rio, 2020a).

Uncertainty around whether users will adopt and embrace this vast collection of devices, still remains. More, since adoption and domestication are complex processes that cuts across many of the dimensions previously examined in this study. For instance, the evidence here collected across expert interviews, site visits, and academic literature suggests that, among other things:

- Concerns regarding users', security, hacking, privacy and data ownership must be addressed;
- Smart home technology must operate on an easy-to-use basis, with strong warranties and built in longevity, where companies are accountable for the performance of these technologies;
- Efforts must be made to ensure markets for the technology remain open and transparent, allowing small developers to participate and to be integrated into this dynamic and growing market;

- Threats to democracy and surveillance capitalism urgently need to be identified and managed. If this issue is not attended, in the extreme, Kendall-Taylor et al. (2020) caution that a digital smart era can also empower authoritarian regimes (who are better able to track their citizens, co-opt critics and pre-empt protest and dissent);
- Interoperability needs assured across multiple levels, including between non-smart and smart devices, smart devices and each other, and smart devices and different systems across various suppliers and layered infrastructures (such as electricity, heat, internet, and so on) (Benjamin K. Sovacool and Furszyfer Del Rio, 2020);
- Energy rebounds and wasteful consumption must be reduced, perhaps through better standards and stronger regulation, so as to avoid information to users, or even built in excessive consumption or carbon emissions;
- Interventions need targeted to ensure a digital divide does not worsen and that poor, vulnerable, or otherwise excluded groups can benefit fully from emerging smart home options (Benjamin K. Sovacool and Furszyfer Del Rio, 2020).

Chapter 7 Exploring the gendered dynamics of smart home technology preferences in the United Kingdom

7.1 Summary and Introduction

This chapter based on a rigorous mixed methods research design including a nationally representative survey in the United Kingdom (n=1,032) as well as focus groups in London, Manchester, and Surrey (n=18 respondents) attempts to identify how people perceive the opportunities and drawbacks of smart homes and smart home technologies via the lens of gender. The author notes that although a similar study was conducted by Jensen and colleagues (2018), what makes this work unique is the novel classification across five thematics, namely: (1) knowledge, awareness, and adoption patterns; (2) housekeeping and daily domestic life; (3) environmental sustainability; (4) trust and risk tolerance; and (5) emotions and feelings. This chapter finally concludes with policy implications as well as how these findings point the way towards a future research agenda.

In this chapter the author answers the following research question:

- Are smart home technologies gendered?

Relevant findings presented in this chapter have been also submitted to an academic journal outlet under:

Furszyfer Del Rio, DD, BK Sovacool and M Martiskainen "Controllable, frightening, or fun? Exploring the gendered dynamics of smart home technology preferences in the United Kingdom", *Journal of Cleaner Production.*

7.2 Literature review

7.2.1 smart home technologies development and critiques: A brief glance

The world is becoming increasingly connected and digital. Internet use has experienced significant growth since the development of the World Wide Web in 1990 (OECD, 2018a). As such, broadband infrastructures are now installed in more than 104 countries with over 4.33 billion active users –56% of the global population— (Statista, 2019), where more than 80% of the world's youth (15-24 years old) are active internet users (ITU, 2017). The fast development of this service has also led to rapid advances in digital technologies which are reshaping economic and financial landscapes, creating new

opportunities and challenges not only for consumers, but also financial and nonfinancial firms, service providers and regulators (International Monetary Fund and World Bank, 2018).

In this sense, the use of interconnected digital technologies and data is offering new and perhaps profound opportunities across the world, whilst holding promises to enhanced productivity growth and improved citizens' well-being (OECD, 2018a). Indeed, Silicon Valley chips are present in almost everything we do, enabling environments in which on-demand services can thrive, from getting your groceries delivered to your house to finding a date through an app, to more challenging tasks, such as accounting (TASS, 2017), playing games (e.g. chess and checkers) (Gibbs, 2017) and music production (Huawei, 2019). But not only that, interactive technologies are giving rise to new learning methods, in which individuals perceive themselves as self-learning agents (OECD, 2018a). As with the introduction of these technologies, users can build their own multimedia content, update and refine their interests and learn more about themselves, others and the world (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). In sum, Kitchin and Dodge (2014) argue that the digital era is speeding up and automating certain practices, transforming social and economic relations, which in turn, are offering new forms of cultural activities, personal empowerment and modes of play.

Given the wide and rapid development of this digital transformation, it is important to consider its potential societal impact and how it may be perceived by and impact upon certain users. For instance, criticism has been levelled at the 'smart technology agenda', in relation to its vision and creators for being overwhelmingly male (Strengers and Nicholls, 2017). In these circumstances, this research argues that such imbalance affects other household members (mostly women) in which they may be non – or partial -users of home connected products. For the case of smart home technologies, this could lead to less control over the home, including but not limited to entertainment options, indoor temperatures, home security cameras and smart locks as domestic technologies become smarter (West, Kraut and Chew, 2019; Nicholls, Strengers and Sadowski, 2020) Moreover, smart technologies tend to focus on a 'masculine ideal consumer', suggesting that more consideration of the gendered roles in everyday life is necessary for a successful transition to a future of smart homes (Gram-Hanssen *et al.*, 2017). In addition, research suggests that when the adoption and use of smart home technologies is approached, homes are usually studied as a neutral, sterile and bland place, rather than a complex space of relationships (Richardson, 2009; Dankwa, 2018). The researcher, thus, argues that household dynamics should be further explored, as homes are one of the most gendered spaces (Tjørring *et al.*, 2018) as in most societies, what happens inside of homes is often culturally determined by gender (Cieraad, 2006). Along these lines is that Dankwa (2018) whom considers that the gender dimension and the ever changing notions of family and household dynamics in research ought to allow for a more in-depth understanding of how needs, behaviour and attitudes are gendered. Exploring

this notion, should enhance the societal relevance of knowledge (European Commission, 2016a), providing a better understanding of the use, adoption, services and markets linked to smart home technologies.

The previous analysis was presented in order to better contextualised the five core themes that emerged inductively from survey and focus group material and that are presented in the results of this chapter, these been: (1) knowledge, awareness and adoption; (2) housekeeping and daily domestic life; (3) environmental sustainability; (4) trust and risk tolerance; and (5) emotions and feelings.

7.3 Results

7.3.1 Are smart home technologies gendered? An introductory glance

The qualitative data obtained via this research strongly suggests that smart home technology dynamics are gendered. To give a few examples, in the open-ended questions on the survey, where respondents were permitted to enter statements directly, one participant, for example, commented that "*Alexa*[5] *never works. It's so much easier to just go turn the light on than repeatedly asking her. I hate it. But my Hubby loves it*." Another joked that, "*For some reason, our smart television cannot understand male voices, so only us females can use the voice control."* And, a female respondent from the focus group in London (FGLF) said that:

> *Smart home technologies are definitely gendered. Think about smart stereos and speakers. My friends or women never talk about stereos or speakers, it is always men. Plus, men have been allowed to be geeks, allowed to be eccentric, where women are seen as odd if they are techy. There is thus a natural affinity of men towards smart home tech, whereas women tend to get shot down if they express a preference for smart technology. I believe that society is telling us that women do the shopping, so they may use smart tech to order a clean pair of pants on Monday morning. These roles get built into smart technology.*

These statements were far from isolated; Table 12 draws from all three focus groups to qualitatively illustrate how expressions of favouritism, conceptualizations, awareness, and perceptions of benefits and drawbacks all differed by the gender of respondents (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a).

[5] Amazon Alexa, known as 'Alexa', is a virtual assistant developed by the online retailer Amazon. It is a voice-controlled system which enables services such as connecting to digital applications and platforms for streaming music, receiving news, extracting information and connecting to other devices.

Table 12 Qualitative differences in smart home technologies by gender

Location	Theme	Common patterns
London	Favourite piece of technology	Females: Smart phones were mentioned three times. Other piece of technology was iPod shuffle Males: Smart phone, Sonos speaker bar and PC
	What comes to mind when you think about the term smart homes	Females: Energy efficient, technology, control from outside, connected with apps and to each other and electricity Males: Automation, more control, having to learn another piece of technology (helpdesk), energy control, isolation
	What SHT do you own	Females: Smart meter, Hive Home and Amazon Echo Males: smart meter Sonos, burglar alarms, Alexa
	What SHT are (For this activity males and females were divided into groups)	Group benefits: Products that save time and are efficient, things that are connected and give you feedback, homes that try to anticipate my requirements
	SHT you are aware of	Females: Alexa, Hive, iKettle, smart TV, smart fridge, vacuum cleaner, phone Males: Smart meters, Sonos speaker
	Benefits of SHT	Group benefits identified: Save money and energy, more control and be more

	(For this activity males and females were divided into groups)	efficient, more security, enhance connectivity and it is also fun
	Drawbacks (For this activity males and females were divided into groups)	Group drawbacks identified: Dependency on been connected and tech companies, privacy, pressure on children to have the latest devices, it makes life more complicated
Manchester	Favourite piece of technology	Females: Mobile phones Males: Laptop, computer, PC
	What comes to mind when you think about the term smart homes	Females: Hive to control my heating, appliances such as Google home and Alexa, electric sockets (smart plugs) Males: Security systems, doorbells, smart and water meters, things to control your lightning, outside weather stations , Artificial Intelligence, efficiency, voice activation, electricity
	What SHT do you own	Females: Google Home Hub, Alexa and Nest Males: Smart meter, Amazon Stick, Google Home, smart meter, amazon Echo
	Benefits (For this activity males and females were divided into groups)	Group benefits identified: Enhanced control, remote control, enhance security and voice control
	Drawbacks	Group drawbacks identified: Reliability, possible costs and tends to deskill people, hacking, loss of privacy

	(For this activity males and females were divided into groups)	and personal information given away, encourage laziness as well
Surrey	Favourite piece of technology	Females: Sonos, Nest and mobile phones Males: iPad, computer, Ring Doorbell
	What comes to mind when you think about the term smart homes	Females: Enable, efficiency, connected, sophisticated Males: Automation, compatibility, cost, monitoring, convenience, intelligent
	What SHT do you own	Females: Hive, Nest Hue, Reolik cameras and Hive lights Males: Yale, two Alexas
	What SHT are	Females: A smart house is something where you can control everything Males: Smart home means something you can control remotely, or maybe monitor. So, the system making decisions itself, and this is what probably smart involves M: All related to AI, so it learns what you do
	SHT you are aware of	Females: Nest, Sonos Males: Alexa, smart fridges, kettles, robot vacuums
	Benefits	Group benefits identified: Remote control, energy efficiency, cost

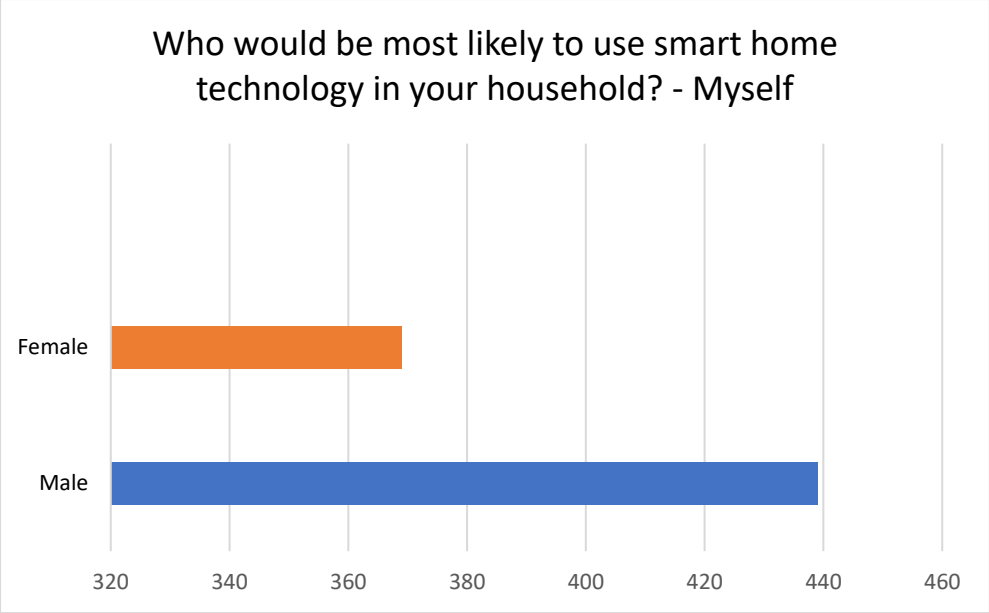
	(For this activity males and females were divided into groups)	efficiency, control, security and monitoring
	Drawbacks (For this activity males and females were divided into groups)	Group drawbacks identified: Data breaches, privacy, initial cost and setting technologies up

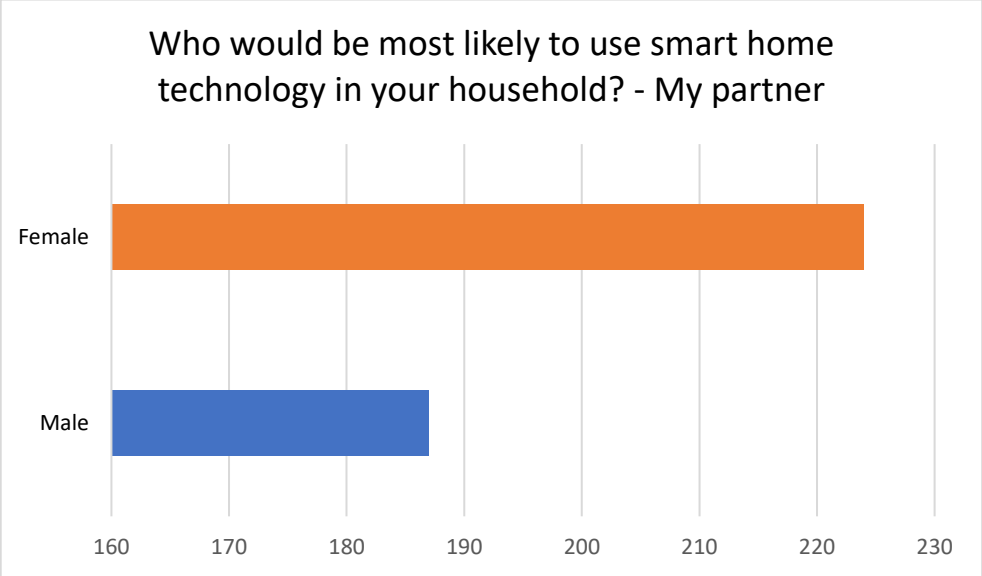
Source: Author, Benjamin K Sovacool and Mari Martiskainen (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a)

7.3.2 Knowledge, awareness and adoption

The results from the survey suggest that men state they are more likely to use smart home technology themselves, by a considerable margin, 84.9% of men compared to only 71.7% of women (see Figure 18). Similarly, men are less likely to say that their partner uses the technology, with 63.8% of men saying so compared to 56.5% of women (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). This corresponds with a female focus group participant who elaborated that she not only noted the dominant male role on usage, but also how this was linked to income: "*Males like my husband. He is the typical targeted customer and user as it's somebody with disposable income* [laughs]. *Joking aside, he is always been an early adopter. I would say it's a gadgety type person. So, he's not necessarily somebody that's looking for efficiencies or looking for savings but looking at technology itself."* (FGSF). A female participant corroborated the income aspect when she mentioned: "*People with money*" (FGLF). However, another participant agreed that although he was the one who bought smart home equipment, it was his girlfriend who used it*: "I buy it, she uses it"* (FGSM).

Figure 18 Gendered dynamics of who would be most likely to use smart home technologies
(Furszyfer Del Rio, Sovacool and Martiskainen, 2020a)

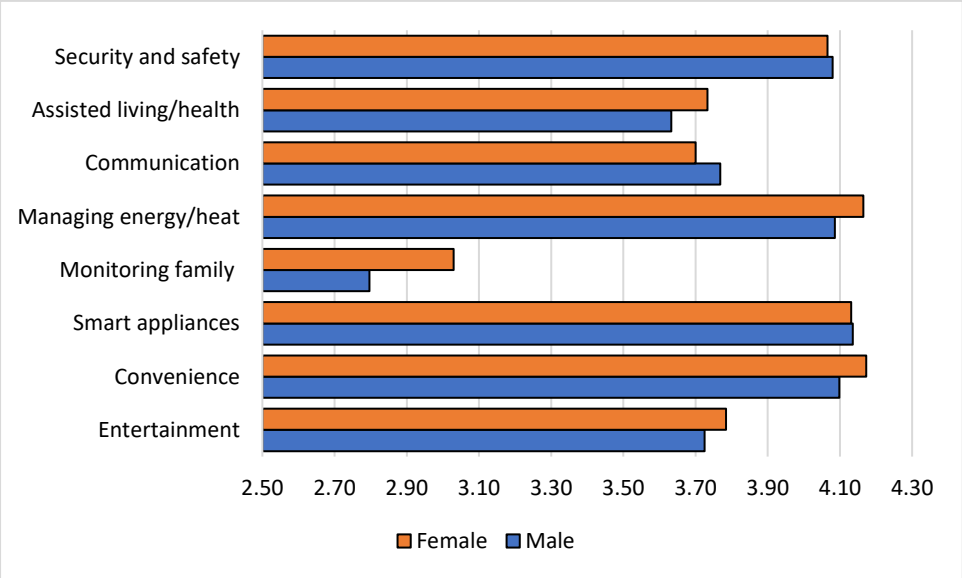




Moreover, the results show, in Figure 18, that males more highly prioritize convenience, are more likely to prioritize managing home security and safety, and are more likely to prioritize communication as the purpose of smart home technologies (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). Certainly, participants in the focus groups validated what the sample indicates when they respectively mentioned: "*Smart home technology is generally positive once you can get it working… As long as you're willing to sacrifice a bit of privacy for a bit of convenience, it's all about that"* (FGSM). Or a survey participant that commented: "*Make everyday living a lot easier"* (M885). On security, a participant stated: "*Security cameras are quite useful. I live in a farm where you get many dodgy visitors"* (FGSM). In a similar vein, FGMM corroborated: "[enhanced] *security, would be the only reason for me to buy any smart gadgets, I've heard these are quite useful to avoid intruders getting into your home".*

Women, however, state a greater priority for controlling smart appliances, for managing energy and heat, and for prioritizing the use of smart home technologies for health and assisted living (see Figure 19). To illustrate these preferences, participants noted: "*if your home is not occupied 100% of the time, to have control of it remotely is a necessity nowadays. You know, to be able to nip in, have a quick look, have look at the front door, and have a look in the sitting room. It's piece of mind*" (FGSF). On energy, FGSF commented*: "I think the biggest benefits are monitoring and efficiency. With Nest, for example, you're meant to be more efficient in terms of energy. The same with Hue".* Whilst on health and assisted living a female participant commented on her own experience: "*My friend is paralysed but he uses voice control for all sorts of things. It could definitely make a difference*" (FGLF).

Figure 19: Differences in mean scores for the "main purpose of smart home technologies" (Likert type response of 1 to 5, with 5 = strongly agree) (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a)



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

These findings show that males have a stronger preference for smart home technologies compared to women, and that men will prioritize security, safety, and communication, are partially explained in the literature. It may be reflected in the fact that the overall lack of women participating in the digital arena has resulted, according to the UN, (2019) in women and girls being 25% less likely than men and boys to know how to leverage digital technology for basic purposes, four times less likely to program computers and thirteen times less likely to file for a technology patent. Regarding technology use, women are less likely to know how to operate a smartphone, use social media, navigate the internet and understand how to protect digitalized information (West, Kraut and Chew, 2019). An explanation of women's lack of participation in the technology dimension is provided by

Lerman et al., (2003) who suggest that men are those who control access to most capital and, therefore, to capital-intensive production. Based on this premise, they infer that the process is one-sided and coercive, usually through economic and institutional means.

Such a gender divide in digital and smart technology is further explored by Borgonovi et al. (2018). They identify that root causes of it include hurdles to access, affordability, education, lack of technological literacy and training. But also these could entail inherent biases and socio-cultural norms that lead to the gender-based digital exclusion (Computer Science and the Artificial Intelligence Laboratory at MIT, 1983; Britton, 2019). Where affordability, according to (BMZ, 2017), disproportionally affects women and girls and remains one of the main challenges in tackling access to digital technologies. Under these circumstances, Lerman and colleagues (2003), argue that the links between technology and gender are complex and should not be studied in silos. Their analysis explains that the relation between both is reciprocal and closely related; one shapes the other and neither is static or stable. Thus, at all layers we can find connections, where technology analysis illuminates our understanding of gender and the other way around, gender illuminates our understanding of technology (Lerman, Oldenziel and Mohun, 2003)

For Strengers and team (2019), the uptake of smart home technologies has been lower than anticipated, but this low interest is more prominent among women. The low uptake, from the technical perspective has been attributed to issues related to interoperability and compatibility issues, price, usefulness and desirability. Another challenge identified by (Hargreaves and Wilson, 2017; Tirado Herrero, Nicholls and Strengers, 2018; Strengers *et al.*, 2019) and closer to the social domain, is that there has tended to be a technical "czar" within households, commonly a man, who brings smart technologies into the home. The same czar is then usually responsible for setting up, maintaining and introducing technologies to other householders. Participants in our focus groups supported this idea when they mentioned: "*I do enjoy doing setting these things up… I sort all tech related things at home"*. A similar point was mentioned by FGMM when she expressed: *I would install everything myself… so it's mainly me using everything, so I make the decision, I buy it, install it and configure everything".* Or FGSM, who commented that men will intrinsically desire such technologies: "*I think the new toys appeal to men. They really do. We love trinkets and things like that. Maybe it's an old-fashioned view, but I genuinely believe that" (FGSM).*

In this sense, the stereotype of males only allowed to be "geeks" might affect girls' confidence and their digital skills. Rode and Poole (2018) outlined that presenting as technically sophisticated could often be challenging for some women, mainly as interests in technology is often connected with negative stereotypes. Turkle's (1988) research pointed out this before, where she characterized geeks

as comfortable with technology, but also as being avoidant of personal relationships, which could result in raising issues of gender inauthenticity. These perspectives where corroborated by FGLM who commented on the stereotype of men being geekier than women: "*We've been allowed to be geeks, we've been allowed to be eccentric and we're eccentric, where women, we say it all the time to women, 'You're interested in speakers? You're odd.".* Indeed, this could be further validated by a study conducted by the OECD which found that 0.5 % of girls aspire towards ICT-related careers at the age of 15 in comparison to 5% of boys (OECD, 2018a).

This has, however, not always been the case as women have been working in technology for over century[6] (Perez, 2019). Yet, many of their stories have been hidden, and given the secrecy of their work, many of their insights remain invisible. For example, during WWII the US employed 10,000 women as coders to decipher encrypted messages sent from the Japanese and Germans (Poster, 2018). During that time, software programming in western countries was considered "women's work." Mostly, as industries working on technology considered women appropriate for programming, since stereotypes at the time characterized them as meticulous and good at following step-by-step directions (Thompson, 2019). During the 1960s, according to government statistics revised by Thompson (*ibid*), more than one in four programmers were women. The UK implemented a similar approach, where they employed 7,000 women to work at Bletchley Park for cryptanalysis. In this period, Hedy Lamar patented an encryption method for signalling torpedoes, the same that founded the basis of Wi-Fi and Bluetooth technologies (Poster, 2018). Another example is Elizabeth Smith Friedman, who helped to invent the science of cryptography for the FBI (Fagone, 2017). However, various men took credit for her work and her unit was dismantled. Women were also the first programmers calculating weapons trajectories (Poster, 2018). In fact, a 'computer' originally referred not to the machine but to the women who programmed it (Lerman, Oldenziel and Mohun, 2003; Shumba *et al.*, 2013). These examples help illustrate how women's technological contributions have been largely invisible throughout history, in part reflecting perhaps the continuing invisibility of women in many areas of society (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). In fact, some argue that the omission from women from the history of computer science has generated misconceptions of women as uninterested and incapable of working in this field (Perez, 2019).

Margolis and Fisher (2003) investigated the reasons that led to the decrease of women enrolling in computer science programs, for them, this trend started in the 1980s. Their findings reveal that boys

[6] Almost 200 hundred years ago, the first person to be what we would considered a coder was an English mathematician woman named Lady Ada Lovelace (Biography newsletter, 2020).

were more than twice as likely to be given computers as a gift by their parents. In other cases, if households owned a computer, they most often put it in the boys' room. Other influencing factors were that learning basic computer languages was deemed as a "father and son activity". Hence, men came with greater IT experience than women when they started college. This likely impacted on women's confidence and performance when attending lectures, as boys would have had previous experience in this area. The same research, however, proves that having previous coding experience is not a great predictor of academic success in the area (Fisher and Margolis, 2003). In addition, another study by MIT (1983) demonstrated that often women were ignored in academia. The study shows that women that raised their hands in class were often ignored by lecturers and talked over by other students. In fact, some of the things that were said to women during lectures reinforced certain stereotypes, such as: "they were not aggressive enough" whilst, if they challenged or contradicted other students, women were told that: "you are bitchy today –must be your period" and accused of incompetence: "I really don't think the woman students around here are as good as the men (Computer Science and the Artificial Intelligence Laboratory at MIT, 1983)". Regardless of this study having been conducted in 1983, to date, across all academic disciplines in the UK, women are still being ignored, as they account for 58% of postgraduate students but only 25% of professors (Britton, 2019). Furthermore, Vitores and Gil-Juarez (2015) highlight that while the number of women has increased in many other science fields, the number of women in computing has, in fact, been declining. Indeed, these stereotypes are felt and supported by women nowadays (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). For instance, FGLF firmly stated when talking about men allowed to be 'techier' than women: "*My point is that, we, women, tend to get shut down".*

Another reason for women being excluded in the technology field is provided by Lerman and team (2003), who explain that at least in the USA, engineering sciences have been deeply entangled with military service, an institution always regarded as a masculine political identity. However, results from our focus groups seem to indicate that the perceptions on what the role of women is in this area is changing (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). For example, FGLM mentioned: "*I don't think smart home technology is gendered at this point. I ended up doing Alexa and Hive through my girlfriends' recommendations".* Or FGSM who noted how technologies could be useful in breaking the gender divide: "*I think the element of boys wanting toys is real, but as smart home technology has become more embedded into society, I don't think that there will be much gender difference… It's just useful for everyone."*

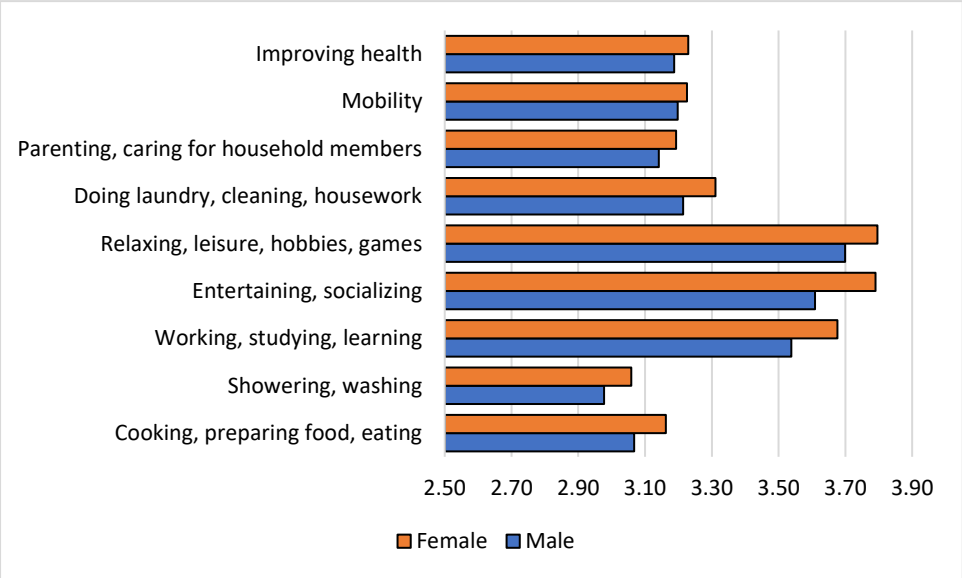
To further encourage women's participation in this arena, Poster (2018), for example, suggests that the way forward could be through programmes that promote technology specifically for young women and girls. Such programmes include for instance *girls who code,* which aims to increase female

participation in computer science and engineering. In addition, Poster argues that job advertisements should use more inclusive language and seek candidates not only with a background in computer science or the military, but also in social sciences, arts and law.

7.3.3 Housekeeping and daily domestic life

The material collected in this research also helped confirming a second theme, namely that of the gendered nature of (smart) domestic work and housekeeping (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). As Figure 20 indicates, when comparing responses across men and women from our survey, women more strongly mentioned that they would prefer to use smart home technologies for cooking, preparing food, and eating as well as doing laundry, learning, and studying.

Figure 20: Differences in mean scores for "smart home technologies are relevant for activities such as" (Likert scale of 1 to 5, with 5 = strongly agree)



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

Further studies support this PhD's findings, for instance, Rode and Poole (2018) coined the term "digital housekeeping", which consists of the activities one does in the smart home. In this sense, and to deepen the analysis of gender roles at households, they refer to Day's work (2001) on "chivalry" behaviours (e.g. males walking on the traffic side of the pavement to prevent any accident or carry heavy objects), which are commonly conducted by men to express their masculinity. Such behaviours could occur even when is unnecessary for non-functional purposes, which if applied to the smart home technology arena could present an interesting perspective. Working from this premise, Rode and Poole (2018) suggest that men could provide technological support (e.g. setting up a smart security system) and as a consequence, they could have an opportunity to demonstrate their masculinity in

the home. That is, having the chance to be the "technology czar" could for example be the equivalent of walking a woman home at night or opening a door to her. This provides an opportunity for men to demonstrate chivalry and thus allowing further assertion of masculinity (Rode and Poole, 2018). Although the language/conduct could explicitly not state "protect a partner", in the digital world it could instead focus on controlling technologies. Although this is changing with more women participating in decision making processes all over the world in terms of leadership and political participation, economic empowerment and access to services (UN Women, 2020), according to the World Economic Forum Gender Gap Report (World Economic Forum, 2019a) it will take a further 170 years to reach gender parity at current rates. Making this, in turn, an urgent call to encourage women to participate more actively in the digital arena and for men to give them the space and support to do this.

In this context, male attitudes towards technologies could focus on control and mastery (Landstrom., 2007) and as control is a mechanism to provide protection, it comes as no surprise that men would formulate their views of protection based on these terms. In this sense, by providing computer and digital assistance men reaffirm their masculinity, because women reaffirm and ground their feminine identities in allowing men to control technologies and protect them from any risk these devices could entail (Rode and Poole, 2018). Furthermore, as Day's work (2001) explains "*by calling on male protection, women reinforce traditional feminine identities that emphasise fragility and dependence*".

Strengers and Nicholls (2013) argue that despite the significant advancements in smart home technologies such as system integration, improved connectivity and the identification of challenges, smart technologies have failed to deliver the promises for effortless and easy living. Schwartz (2003) explored a similar area before and found that the introduction of science into housekeeping raised standards of nutrition and cleanliness, and has promoted modern cooking methods. This, in consequence, resulted in the cumulative effect of creating "more work for mothers". In fact, Schwartz's research indicates that women spent the same amount of time in 1970s doing housework as their grandmothers had in the 1920s, before the widespread use of most "labour-savings" appliances. During those times, women spent around 52 to 54 hours doing domestic chores.

In all likelihood, the same could happen with smart home technologies. For instance, a male participant from London focus groups doubted how efficient these technologies are when he mentioned: "*Like any new technology, it's about efficiency and time saving, but then it's like the vacuum cleaner and washing machine, it may make things easier for you to do. But does it save time? does it dryer things any quicker?"* (FGLM). FGSF, meanwhile, commented on how much time is spent to set these technologies up: "*The extra time it takes you to set up a more complex system. You know,*

we're talking about light systems. When you're talking about lightbulbs, you could just stick it in and run away. Here, you have to programme it with a name. So, it takes a lot of time… *By the time you've turned Hive on and off because it won't recognise a new light, it has driven you mad for a half hour".* Similarly, there could be time and effort linked to keeping smart home technologies updated with latest security and operating systems (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a).

7.3.4 Environmental sustainability

A third gendered dimension concerns environmental awareness and preferences about sustainability. As this research has previously presented, one of the selling points for smart home technologies is their ability to potentially be more efficient compared to standard equipment, and thus to save energy, save money, or reduce carbon emissions. These points were reflected in the data, with one survey respondent stating that "*Smart heating controls are saving me 11% on my energy bills compared to previously, they paid for themselves in well under five months."* Another noted that "*My gas usage has gone down since getting new boiler controlled by Nest Thermostat*," with a third stating that "*Smart meter/ thermostat has reduced our heating spend and given us more control."*

However, the sustainability attributes of smart home technologies are not a given (e.g. these could increase energy consumption and even generate more e-waste) nor uniformly shared. In the focus groups, during the focus groups participants conducted a task —we gave them a list of factors that smart home technology developers shall take into consideration when developing smart technology products and asked them to rank them in order of most to least important (see Table 13). Note that "environment" was rated fairly poorly as a key concern when compared to other aspects such as cost, privacy, or even comfort.

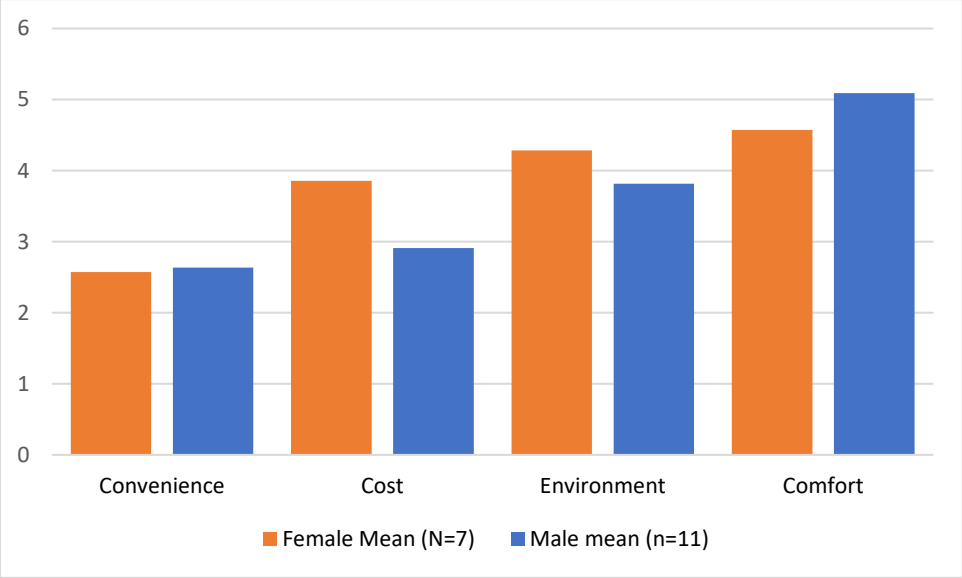
***Table 13*: Focus Group Ranking of the Prioritized Values for Smart Home Technologies (n=18)**

Value	R1 (F)	R2 (F)	R3 (F)	R4 (F)	R5 (M)	R6 (M)	R7 (M)	R8 (M)	R9 (M)	R10 (M)	R11 (F)	R12 (M)	R13 (M)	R14 (M)	R15 (F)	R16 (F)	R17 (M)	R18 (M)
Privacy	3	1	1	2	3	1	1	3	1	6	2	5	3	4	2	2	4	5
Control	4	3	5	1	2	4	2	1	2	2	5	3	4	6	4	5	6	6
Convenience	2	4	2	5	4	5	4	2	3	1	3	2	1	5	1	1	1	1
Cost	1	6	4	3	1	2	5	5	4	5	6	1	2	3	3	4	2	2
Environment	6	2	6	4	6	3	3	4	5	3	1	4	5	2	5	6	3	4
Comfort	5	5	3	6	5	6	6	6	6	4	4	6	6	1	6	3	5	5

Source: This table was built by YouGov and delivered to us as part of their analysis (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a)

Figure 21 replots these rankings based on gender, and it shows clear differences in the rankings for cost, the environment, and comfort. Where convenience was almost equally rated, women within the focus groups were much more concerned about both cost and the environment. Men were more concerned with comfort.

Figure 21: Mean scores from the focus group ranking of smart home attributes by gender (n=18)



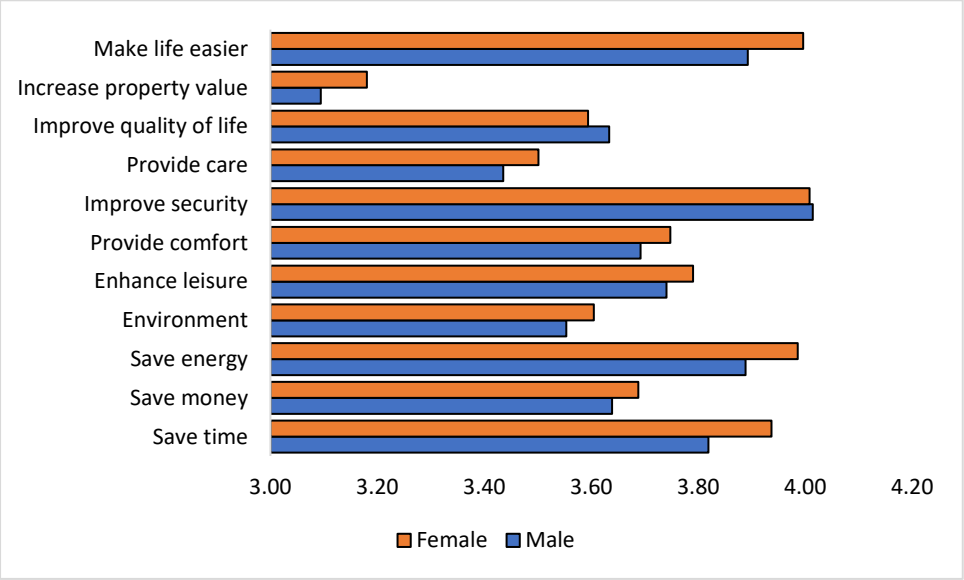
Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a)

The survey also supported this finding about women prioritizing environmental considerations more, although as Figure 21 indicates, environmental considerations rank lowly compared to other aspects among both genders—i.e., the environment is ranked behind issues such as convenience, security, saving money, saving energy, and saving time. An explanation on why smart home technologies ranked considerably low regarding environmental matters was brought by FGSM: "*I don't see how smart technologies could benefit the environment, because, you're actually generating more plastic and more crap that's going to go to landfill*". To this, FGSM added: "*I think there is an environmental damage done from the rare materials that go into the smart chips*". And FGLM pinpointed how these technologies are built in obsolesce and thus could affect the environment: "*Most of the items are designed to discourage you from repairing them, and most of the perceived wisdom is that you can't repair them, or you're told culturally that you're not to repair it".*

As Figure 21 also suggests, women more highly rate the ability for smart home technologies to save time; slightly more women positively rank saving energy, and more women rank environmental sustainability. Interestingly, women also rank more highly the ability for smart home technologies to

increase property values. The latter, for instance, was illustrated by FGMF when she explained: "*I see it as enhancing the value of your property. I do believe it is going to become the modern way".*

Figure 22: Differences in mean scores for "the potential benefits of smart home technologies are to" (Likert scale of 1 to 5, with 5 = strongly agree)



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a)

indeed, these findings advance some support of the idea that women have higher levels of environmental awareness. For example, in earlier research, "gender-based" disparity has been shown in regard to attitudes to and the perception of climate change (Viscusi and Zeckhasuer., 2006). Women have, for example, been shown to be "more fearful of the risks of climate change" and that "traditional divisions of labor account for higher levels of environmental concern among women." (Kellstedt et al. 2008). Research conducted, for example, in Finland, has found that men were more skeptical about climate change induced impacts (Upham *et al.*, 2015) while Denton (2002) has argued that women place greater importance on mitigating climate change as they would also be disproportionately affected by it. Women have, for example, been shown to be more likely than men to be aware of environmental concerns such as healthy food and sorting out waste (Kawgan-Kagan, 2015). Further evidence is provided by Dietz et al., (1998), who report that women tended to be more active on certain pro-environmental behaviors related to consumers' attitudes. In the same vein, Molina et al., (2018) confirms that gender does have an influence on environmental behaviors. In turn, women are more likely to conduct environmentally friendly activities in both advanced and emerging countries. Moreover, gender matters for pro-environmental behavior in

United States' legislatures (Fredriksson and Wang, 2011). A similar study was conducted by Ramstetter and Habersack, (2019) which shows that female representatives are more likely to hold pro-environmental attitudes than their male colleagues and adjust their legislative behavior accordingly. In other words, women in this experiment were significantly more likely to support environmental legislation than men even after controlling for not only political ideology but also nationality (Ramstetter and Habersack, 2019).

7.3.5 Trust and risk tolerance

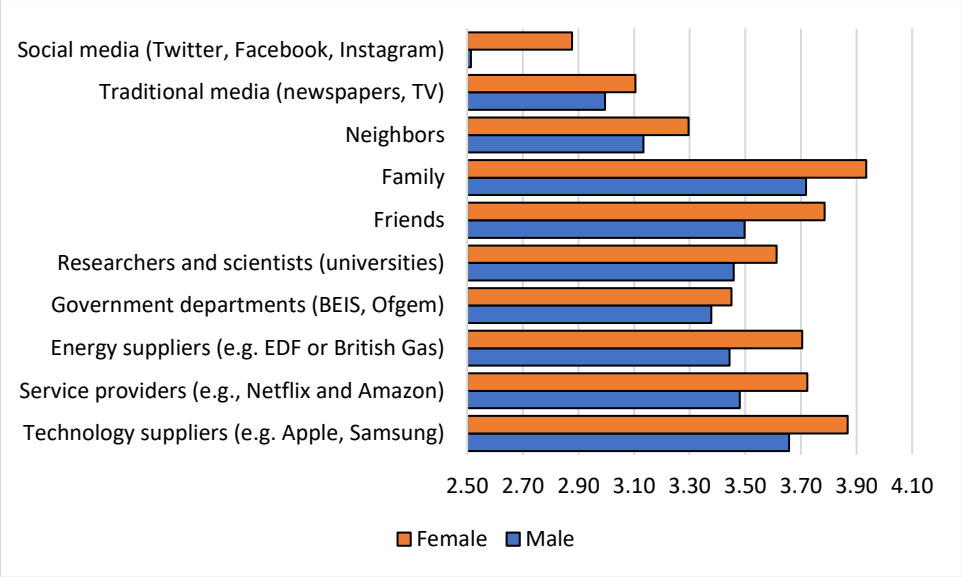
A fourth area that emerged from the data concerned were gendered notions of trust and tolerance of risks (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). These responses mainly featured in the qualitative aspects of the survey and the focus groups. As one respondent wrote in the open-ended question on the survey," *smart home technologies may be useful but are completely untrustworthy as it is not possible to know to where the data is transmitted. Manufacturer's claims cannot be guaranteed."* Another wrote that "*I worry when you hear stories such as Amazon Echo can listen to conversation in your home. People get spied on with this."* Others commented that with smart home technologies, "*it feels like someone is always listening"* and "*it just feels a bit Big Brother watching*" and "*It's like Big Brother watching all the time, which is potentially very dangerous."* One wrote an extended comment:

> *Smart home technologies are creepy. Not long after I got my first Alexa product myself and my wife were watching Guardians of the Galaxy 2 on DVD and the following day I received recommendations from Amazon via email on a range of products all branded in [Guardians of the Galaxy]. I don't like the idea of AI listening into my conversations. I have become aware of Facebook and Groupon email advertising arriving in my feed/inbox following conversations I have had with friends about specific issues, e.g. bio-resonance hair testing.*

These issues of trust also came up in the focus groups, with respondents from both genders articulating concerns about privacy, control, surveillance, and monitoring.

However, surprisingly, as Figure 23 summarizes, women seem to trust technology and service providers far more than men. Furthermore, women state to strongly trust social media platforms more than men. Women also state to trust family and energy suppliers more than men.

Figure 23: Differences in mean scores for "who is trustworthy in relation to smart home technologies" (Likert scale of 1 to 5, with 5 = strongly agree) (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a)



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

Yet, people have reasons to distrust industry. For example, a recent report indicates that Google have acknowledged its contractors are able to listen to recordings of what people say to the company's AI system (Paul, 2019). Amazon conducts similar practices as they have also recognised that when users talk to AI powered voice assistant Alexa, Amazon employees around the world regularly listen to recordings in order to develop new services, enhance customers' experience and improve the quality of the software (Hern, 2019). More recently, a study conducted by Imperial College London and North-eastern University (The Independent, 2020) revealed that smart speakers such as Amazon Echo, Apple HomePod and Google Home are being inadvertently triggered by popular TV shows to record users' private conversations. In the study, researchers played 125 hours of Netflix content to see if smart speakers were activated by dialogue that sounded like command words. The work showed that activations occurred up to 19 times per day, with HomePod and Cortana (Microsoft's assistant) being more susceptible to accidental recordings. The experiment also found that Gilmore Girls and The Office were responsible for the majority of activations (The Independent, 2020). Privacy issues take on more relevance, for instance, when Rick Osterloth (Senior VP of Google) contemplated whether homeowners should disclose the presence of smart home devices to guests. To this, he said "Gosh, I haven't thought about this before in quite this way… I would, and do, when someone enters into my home (Kelion, 2019)". Certainly, participants in our focus groups and survey commented on these issues when they expressed: "*I find it worrying that all the people who own smart speakers are delight[ing] that it can listen to them when they want it to. They don't seem to realise that it also listens to them when they don't want it to - a total invasion of privacy billed as a modern-day technology*" (F855). FGLM corroborated on that point: "*I'm struggling to understand why it's cool to have Alexa turn on my lights when the price I pay for that is Alexa is listening to everything that goes on in my*

house. Even when it's off". These notions where further supported when FGLF commented on her own experience: *I find Amazon Alexa so intrusive, the fact that they're listening to you, I just keep it off the whole time".* Or FGLF who expressed: "*not to put a downer on it but devices are always listening to you. Cameras are watching you. Who knows who is going to be listening to you or watching you, it could be anyone".* In fact, a male participant from London suggested that the learning aspects of *smart home technologies* are making it worse for users, instead, these devices *"should gather data to help make things work better for me, not for the tech companies".*

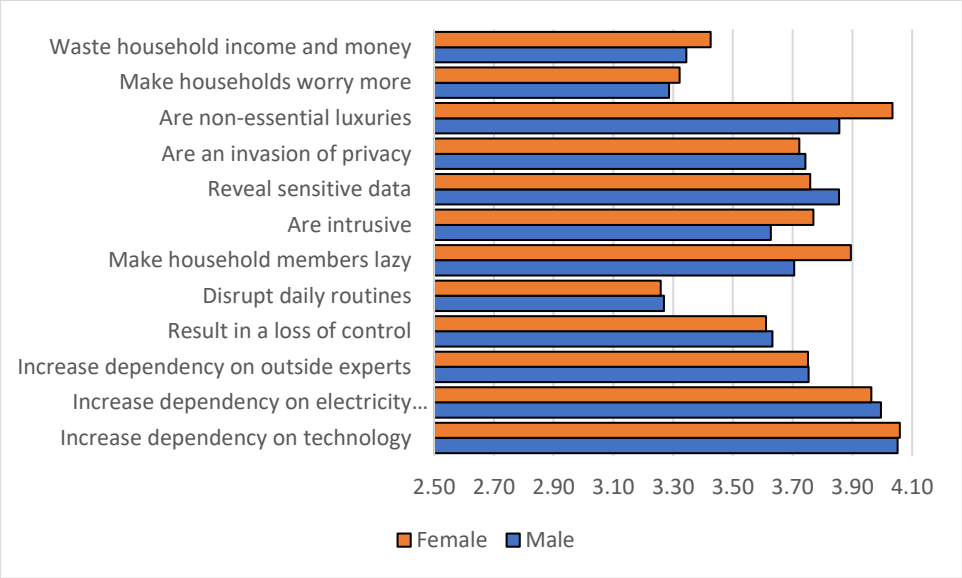
Further concerns are raised when Wyze Labs, company that makes smart cameras and connected home gadgets, confirmed that millions of customers' personal information was exposed to the public since it was hit with a customer data breach in 2019 (Isidore, 2019). Indeed, a recent study by Nicholls and team (2020) shows that vulnerabilities to smart home technologies are stressful and can undermine the essential sense of safety in users' homes. For them, industries also "contradict the intentions of smart home companies, which promise 'peace of mind' and improved privacy and security through smart technologies such as livestream cameras (Nicholls, Strengers and Sadowski, 2020)". Circumstances such as these, led M150 to comment bluntly: "*They may be useful but are completely untrustworthy".*

In addition, other reports have found industries allowing ethical breaches, such as storing employees and users' information in an insecure manner (Hern, 2016). Although users from our focus groups were aware of such risks, FGMM for example, commented the following concerns in relation to data security: "*There are always data breaches, all the time it's happening… and you're not just talking about one supplier, you're talking about many suppliers for different products*". Participants also mentioned what would it take to trust these technologies: "*if I read something on the news from a trusted website, and they say that these smart homes can be trusted, I would trust them. Like when the thing about Facebook came out, and my viewpoint of Facebook completely changed"* or FGLF who tied trust with transparency: "*I think the trust, when it comes to smart home technologies ties back into transparency. Because we all know that there is a trade-off. If you want more functionality you need to give them more details, but it's not very clear, and I think deliberately so, what exactly the trade-off is. Like, what piece of data is required for the functionality*?".

Ideas around risk and tolerance of risks also had gendered differences. As Figure 24 indicates, women in the survey stated to be more concerned about risks such as smart home technologies wasting money, causing anxiety, being unnecessary luxuries, being intrusive, and causing laziness. By contrast, men focused more on risks related to loss of privacy, revelation of sensitive data, disruption of

routines, loss of control, dependence on experts, and increased use of electricity (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a).

Figure 24: Differences in mean scores for "there is a risk that smart home technologies …" (Likert scale of 1 to 5, with 5 = strongly agree)



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

These gendered implications of trust and risk become less surprising when one discovers how gendered the design of smart homes (and other technologies) can be. Criado-Perez (2019), for instance, argues that with the current pace of technology, many women are living in a world designed by men and built around male data. She explains that AI, for example, has been trained on data sets riddled with data gaps on women. The problem relies on the fact that algorithms are often protected as proprietary software, hence, people are unable to examine if these gaps are taken into account. This, in consequence, has shown that algorithms trained with biased data have resulted in algorithmic discrimination (Buolamwini and Gebru, 2018). In these circumstances, if programmers are not aware on how these biases operate and are not collecting data to produce evidence-based processes, the model will continue to perpetuate old injustices (Perez, 2019).

The literature also suggests that discrimination gets worse when it comes to disabled (Loeb, 2016) and women of colour (Buolamwini, 2019). In these cases, data is almost non-existent, as most of these systems are often trained on images of predominantly light-skinned men as demonstrated by Buolamwini and Gebru (2018). In their research, they found that three commercial gender classifiers had near-perfect performance for lighter-skinned men while errors for darker-skinned women were as high as 33%. In this sense, Criado Perez (2019) identifies three key issues on the data gender gap

that need to be addressed: female body, women's unpaid care burden and male violence against women. She argues that if these differences go ignored and society and science proceed as "gender neutral", then the bias in AI can lead to higher levels of discrimination and exclusionary practices.

In their work, Strengers et al., (2019) also showed that women were less tolerant of technology than men, as they perceived smart home technologies as glitch or time consuming; "they just wanted the technology to work". While men also wanted the technology to work, they were nevertheless more likely to persist with technical difficulties and for some, these complications were identified as a pleasurable "hobby". Although participants in our survey held a different perspective, to this, M960 said: *"They are Incredibly complex to set up".*

Berg's (1994) previous research on this has suggested that while smart homes have prioritized technically enhanced security and entertainment, they have at the same time been underpinned by engineering concepts of control, efficiency and optimization where men have held, and are likely to continue to hold a leading role. Meanwhile, women that are not commonly associated with technology proficiency are likely to have less tolerance and time to set-up, use and maintain technology (Jensen et al., 2018). This premise, however, was dismissed when FGSM and FGMM commented on their own experience respectively*: "I suspect the early adopters are more likely to correlate with men, but the users, certainly in my experience are, and at home with my parents, it's my Mum who uses it".* And **"***I think, perhaps two or three years back, these things were only for men. But I think now that Smart Technology is hitting primary schools. I mean, both my grandchildren, male and female, can work things that I can't".*

7.3.6 Emotions and feelings

A final dimension where smart home technology preferences differ relates to statements about emotion and feelings. FGLM went so far as to comment:

> *The Internet of All Things fills me with dread. At the end of the day, it becomes sentient and takes over. You know what, I don't like being used, I will use you. I will be equal. I am afraid of all of the systems going wrong at the same time. It's fear.*

Another noted that smart home technologies *not working* filled them with panic and anxiety. FGLM remarked that:

> *When the internet goes down, you panic. And it is, it is a panic, I've felt it before. We have Hive, and it went down, and it was a case of, how do I turn it on? I'm at home, how do I turn my heating on at home? That was a moment of real panic.*

A third stated:

> *What I am afraid of is a cyber-attack from a terrorist, or, you know, an enemy nation, or a flare from the sun, that suddenly puts all the electronics out of business, we could be in trouble there. I think you are probably fairly safe with a smart home, but if you've got smart buildings, what happens then? Where, physically your whole environment is controlled by a third digital partner… Hospitals are going that way and it will move down to individuals, like block of flats.*

These were not isolated statements. Within the survey, respondents stated that smart home technologies made them feel *"insecure*," "*anxious*," "*afraid,*" and "*it just worries me, because I don't know what it will make the future look like*."

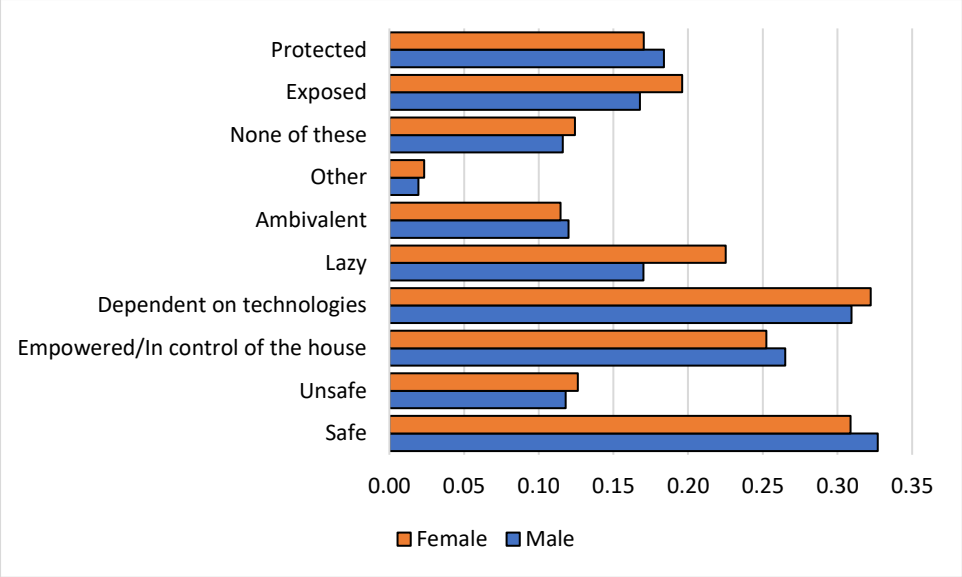
These dark and hopeless emotions were countered by almost equally positive emotions among respondents. FGLM remarked that:

> *Despite my nightmare scenarios, I'm positive about smart homes and a smart tech future. It may seem really odd, but I am. I hope, that we're going to get the built in, we're going to get to a point where we start to legislate more personally, I like smart home technology, I save up for it, wait for the money to buy it, anticipate it, and am totally excited about it.*

In the survey, respondents mentioned how smart home technologies made them feel reassured, safe, and protected, with one noting "*smart home technologies are very useful to me, they help me to feel safe and protected*", another stating "A*ll I have to say on this matter is that I would be lost without this technology"* and F618 *commenting: having such a technology makes you cool because you can live your best life by making things faster and more efficient and more fun ."* Others talked about how they "*enjoy*" having "*smart cameras to monitor my house*" and "*I enjoy the information smart homes provide to me*."

As Figure 25 summarizes, the results reveal that both men and women state to have a range of emotions in relation to smart home technologies. The results from this work also suggests that smart homes make many women reportedly feel lazier, exposed, dependent on technology, and unsafe. But results also suggest that smart homes make men feel more protected, empowered and in control, and safe (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a).

Figure 25 Differences in mean scores for "smart home technologies make me feel overall …" (Likert scale of 1 to 5, with 5 = strongly agree) (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a)



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

These results add context to earlier work suggesting that women unilaterally view smart home technologies with enthusiasm. Raptis' et al. (2017) findings highlight the importance of "coolness" in user experiences in the digital arena; not only by generating fun, but also other sensory experiences and more relaxing home environments. In this area, they reported that women expressed more enthusiasm, where they reflected some opportunities to express the feminine side as homemakers, partners and hosts (Strengers *et al.*, 2019). For men, on the other hand, setting up, tinkering and playing with the devices was where they found pleasure. These results are similar to those found by Mennicken et al. (2014) where they showed that (most likely and often men) technologically-competent users experienced a "joy of hacking". A female focus group participant commented on her own experience: "*I have a few friends who all happen to be male who have the bots and things like that, because they want it to programme and they think it's fun. I think both genders can find it fun, but it tends to be men"* (FGLF).

This PhD thesis results further deepen the lexicon of emotions reported in the literature about anxiety and wariness about smart homes. Despite some celebrated inventions such as driverless cars and robot carers for the elderly, this enthusiasm is not necessarily reflected in the population as a whole. For instance, more than 70% of Americans express wariness and concerns about a world where machines perform many tasks done by humans (Smith and Anderson, 2017). Most ordinary Americans are worried about the growing trend that automation of jobs will exacerbate economic inequality. Indeed, the word robot popularized in 1921 by Czech playwright Karel Capek (Gates, 2008), was used to designate work *robota,* to stress that these machines could replace labour in different forms (Djankov and Saliola, 2019). In the UK, for instance, an investigation conducted by The Guardian

(2019), reveals how millions of pounds are being spent developing a new generation of welfare robots to replace humans. This process has generated a whole new jargon such as "virtual workforce", "augmented decision-making" and "robot process automation" to name a few. As a result, fears are growing that the human element of the welfare state is being diminished and in consequence, discrimination and inequality against those who are less technology literate or with no access to internet will likely worsen.

This vision was shared in the focus groups when FGMF expressed: *"So smart meters, it reads your meter automatically, doesn't it? So, what about the poor man who's going around now and that's his job?...I must admit, even now if I'm at a supermarket, I prefer to go to a checkout, rather than an automatic checkout because I want people to still have jobs"*. A survey respondent remarked, in all caps, "*NO – I WOULD NOT HAVE THESE SMART HOME DEVICES IN MY HOUSE! TECHNOLOGY WILL BE THE RUINATION OF MANKIND IN THE END, NO ONE WILL KNOW WHAT TO DO IF IT ALL CRASHES!"* The idea of "machines are coming to take our jobs" or will spiral out of control has been a concern for hundreds of years, at least since the early nineteenth century, when Karl Marx stated: "*machinery does not just act as a superior competitor to the worker, always on the point of making him superfluous. It is the most powerful weapon for supressing strikes* (Marx, 1867)". Another example refers to when the Luddites resisted and tried to destroy machines that reduced their weaving skills obsolete (Clancy, 2017), even though, machines themselves helped building new skills and jobs (International Monetary Fund, 2019), a theme also picked up by Keynes in the twentieth century (Keynes, 2013). More recently, Gaia theorist James Lovelock (Poole, 2019) has envisioned that super intelligent machines will need humans to help them keep cool, and save the planet, in a warming climate.

However, not all respondents were able to explain a clear emotional reaction—positive or negative—with smart home technology, and instead stated to have uncertain, contradictory, or ambiguous emotions (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). One survey respondent stated that "*smart home technologies are meant to be helpful and save you time but most of the time you are wasting time setting them up and adjusting them… but hey they are fun."* FGLM stated that "*I have some reservations about smart home technology, which we've discussed, but I think it's healthy to question things and not just to accept them blindly, but yes, on the whole, I feel positive towards smart technology. Alongside the reservations."* FGLF said that "*despite nightmare scenarios in my head about smart home technologies, I am still filled with hope*." Another stated they did not know how they ought to feel, remarking that "*I think if there was that definition of smart technology it might help with understanding it better. Now it feels quite broad and vague."*

One emotional aspect of smart home technology that the researcher found outstanding was smart home technologies' ability to make people laugh—to make them revel in humorous or funny situations. One survey respondent (M27) wrote that "*Alexa has interrupted a conversation with fart noises, and then wouldn't stop;"* another (F370) stated that "*Sometimes Alexa will interrupt our conversation about the cats and start meowing*. A third (M392) state that "*I have an Alexa and when doing my shopping list, it misunderstood my item. So, I said you're a piece of junk! Alexa replied I've added you're a piece of junk to your shopping list!"* A fourth (F997) that "*My friend has Alexa. She tried to get it to repeat a Chinese recipe she had used and all it did was try to teach her how to say recipe in Chinese!."* While probably unintentional, and limited currently to one device (Alexa), these encounters do reveal the ability for smart homes to also amuse and bemuse their adopters. This idea is further explored more in detail the next chapter

7.4 Discussion and future research

What this chapter helps illustrating is a prominent association between self-identified gender and knowledge, practices, sustainability implications, trust, and emotions surrounding the smart home. Ultimately, this analysis suggests that homes and domestic spaces are undergoing significant technological transitions, and these are affected by, gendered knowledge, practices, risks, and emotions. Indeed, all these aspects are later explored in chapter 9. However, what this section further helped building is that these changes could continue to erode so-called "traditional" gender norms—such as men wanting to control or pay for energy services (a finding these results dispute), men not being emotional (findings here dispute), and women having less trust in technology and energy suppliers (findings here dispute)—and the gender roles associated with them (Furszyfer Del Rio, Sovacool and Martiskainen, 2020a). Despite these findings, the results here presented points the way towards fruitful future research. Topically, more attention to gendering vs. use value would generate practical information for marketing efforts on behalf of designers, manufacturers, and retailers. Furthermore, the focus of the PhD author and colleagues was on the "demand side," on users, but a focus on the "supply side," on industry and manufacturers, could also be fruitful to explore. A more in-depth analysis discussing the results from chapter 7 is found in the conclusion section.

Chapter 8 Inhibiting or inciting digital violence? Control, surveillance, and domestic abuse in the smart home of the future

8.1 Summary and introduction

This chapter based on a rigorous mixed methods research design including a nationally representative survey in the United Kingdom (n=1,032), focus groups in London, Manchester, and Surrey (n=18 respondents) and an extensive revision of the literature explores a still unattended area, that related with how smart home tecnologies can act as potential enablers of domestic abuse and/or violence. To do this, the author first presents a literature review section that encompasses four themes: the current digital revolution, the rise of surveillance, gender biases in the digital economy and smart home technologies and the thematic around cyber abuse. This is meant to offer background and context to the results and discussion to come, where the researcher explores the use of smart home technologies as possible deterrents and mechanisms to reduce and address domestic violence and provide victim protection and recovery. In doing so, it is explored user perceptions and preferences of smart home technologies, in relation to trust, monitoring, tracking, and surveillance. At the end of this chapter, conclusions on this regard are provided.

In this chapter the researcher answers the following PhD research questions:

- In what ways do smart home technologies promote domestic violence and abuse?
- In what ways do smart home technologies could aid in the prevention of cyber abuse and domestic violence?

Similar to the previous chapters, the work presented here has been submitted to an academic journal under:

Furszyfer Del Rio, DD, BK Sovacool and M Martiskainen "Inhibiting or inciting digital violence? Control, surveillance, and domestic abuse in the smart home of the future", (under review) in *Science Technology and Human Values*.

8.2 Literature review

The literature review presented below encompasses five themes that help providing better context to the reader. In this sense, the author of this PhD first introduces how the digital society may offer new means to promote violence towards women. Later, this section touches base on some the risks and benefits of the so-called 'fourth revolution', this nicely eases the path to further discuss the rise

of surveillance in the digital era. The author then covers how the digital economy is not gendered neutral but instead is negatively biased towards women, generating in turn, power imbalances. Finally, the author briefly introduces how these technologies may enable new means of violence and abuse.

8.2.1 The cusp of the digital transformation: offering a quick look of cyber violence towards women

Access to the Internet in our everyday lives is perceived by many as a key service to gaining efficient access to information (Butler and Abrahart, 1997), sharing information (Downes, 2007), guaranteeing economic well-being (Adikari, 2016), advancing social conditions (e.g. delivering educational outcomes and social networking) (Caridade, Braga and Borrajo, 2019) and achieving convenience (Bhatnagar and Ghose, 2004). In this sense, the Internet is increasingly perceived as a fundamental human right (Sandle, 2016). Based on this, the researcher argues that human civilization is on the cusp of a possible new era of digital transformation, where people, and their homes and vehicles, have the possibility to remain constantly connected to a multitude of different smart technological devices.

As IoT in tandem with smart home technologies become more deeply woven into all aspects of our lives, the discussion around the benefits of such technologies has often focused on values such as comfort, convenience and control (Chen *et al.*, 2017; Strengers and Nicholls, 2017; Marikyan, Papagiannidis and Alamanos, 2019). Previous research on the risks of SHTs has mostly explored users' privacy (Véliz and Grunewald, 2018; Wachter, 2019). However, a still unattended area is the increasing number of threats resulting from technology related abuse and their potential role in facilitating domestic abuse, particularly against women and girls (Chatterjee *et al.*, 2018; Freed *et al.*, 2018; Henry and Powell, 2018).

Although self-evident to the researcher, the importance of further exploring this issue centres on the fact that violence against women and girls is one of the most widespread, persistent and devastating human rights violations around the world (United Nations, 2018). In this regard, research shows (World Health Organization *et al.*, 2013) that 35% of women worldwide have experienced either physical and/or sexual intimate violence (not including sexual harassment) (UN Women, 2018). For example, in 2017, the United Nations Office of Drugs and Crime (UNODC, 2018) reported that 87,000 women were intentionally murdered, of which around 50,000 were killed by intimate partners or family members. That means that more than 137 women across the world are killed by a family

member every day (UNODC, 2018). The same study shows that 30,000 women were murdered by their current or former partner. In comparison, research indicates that domestic violence against men is present in smaller numbers, as one in every six men will experience domestic abuse at some point in their lives (BBC, 2018). Giving this growing crisis, the inventor of the World Wide Web (Sir Berners Lee) stated that this represents a "dangerous trend" and that online abuse "was forcing women out of jobs, causing girls to skip school, damaging relationships and silencing female opinions". He later commented that that he was "seriously concerned that online harms facing women and girls –especially those of colour, from LGBTQ + communities and other marginalised groups threaten[ing] [social] progress" leading him to conclude that "the web is not working for women and girls" (Sample, 2020).

In the UK alone, domestic violence is a prevalent issue. Refuge (2018) estimates that one in four women experience domestic violence in her lifetime. According to the Crime Survey for England and Wales, 8.2% of women and 4% of men reported experiencing any type of domestic abuse in 2018. This is equivalent to an estimated 1.3 million female victims and 600,000 male victims (Office for National Statistics, 2019). Cyber violence has the potential to increase these numbers, given that more than 70% of women globally, according to the UN, have already been exposed to or have experienced some form of online violence (UN Broadband Commission for Digital Development, 2015). Indeed, in England and Wales, from the ~2 million cases of domestic abuse reported in 2018, about 48% included technology-facilitated forms of abuse (Chayn, 2017).

In this sense, Van der Put and Assink (2019) identify a collection of terms that are often interchangeably used for describing domestic violence, including intimate partner violence, spousal violence, spousal assault, family violence, spouse assault and wife abuse. Although the researcher considers these concepts throughout this chapter, he uses the following definition of domestic violence as '*Any incident or pattern of incidents of controlling, coercive or threatening behaviour, violence or abuse between those aged 16 or over who are or have been intimate partners or family members regardless of gender or sexuality* (Home Office, 2013b)'. This could entail, but is not limited to, any form psychological, physical, sexual, financial or emotional abuse (Leitão, 2018). Moreover, in this research the author recognizes that domestic violence impacts across all social, economic, ethnicity, educational and cultural boundaries (Heise and Garcia-Moreno, 2002).

8.2.2 The Internet and resulting digital revolution

Fifty years ago, during October 1969, Leonard Kleinrock connected a computer to the interface message processor (IMP) which made contact with a second IMP attached to a second computer (Burkeman, 2009), producing what we now call the Internet and the World Wide Web. What has happened five decades since this event, is an undertaking that quickly exposes the limits of language, a radical change to our institutions, educational processes, work and research habits (Kleinrock, 2004).

For some, the importance of the digital revolution is compared with earlier industrial transformations propelled by general purpose technologies such as steam or electricity (OECD, 2019). Indeed, the so-called Fourth Revolution is permeating across different sectors, with some estimating that in the upcoming years, over 60 per cent of global GDP will be digitalized (International Monetary Fund and World Bank, 2018). In this sense, it is estimated that 70 per cent of new value created in the economy over the next decade will be based on digitally enabled platforms (World Economic Forum, 2019b). For example, the Internet is expected to account for 53% of retail sales in ten years' time, that is up from about a fifth from present (Retail Economics, 2019). On the banking arena, Arvidsson et al., (2017), notice that demand for cash has dropped over 50% in the last decade with more people owning debit cards and mobile phones apps. In addition, more than half of all bank branches no longer handle cash and 7 out of 10 consumers say they could manage without cash. In Sweden, for instance, cash transactions represented only 13% of payments habits in 2018 (RiksbankSveriges, 2018). Certainly, the digital transformation has had a global impact and its importance is underscored in the United Nations Sustainable Goals (SDG 9), where access to information and communication technologies and universal and affordable access to the internet represents one of its key targets (United Nations, 2017).

Internet access is growing with a global penetration rate increased from nearly 17% per cent in 2005 to over 53% in 2019 (~4 billion people) that means that around 50% of the world's population are still offline (ITU, 2019b). In developed countries most people have access to this service, with close to 87% of individuals using Internet. In least developed countries, only 19% of individuals are online, Africa being the region with the lowest internet access rates (ITU, 2019a). The same report indicates that over half of the global population (52%) is still not using this service compared to 42% of all men. The main barrier identified is lack of digital skills for the uptake and effective use of the internet (ITU, 2019c). Thus, having internet access is key for the IMF (2019) and World Bank (2019), given that this service could offer users *reach.* They argue (International Monetary Fund and World Bank, 2018) that physical infrastructure has been one of the most important barriers to access across a wide range of financial products. In this sense, digital channels deployed by banks and

telecom companies ought to enable millions of people with mobiles phones to access digital finance (International Monetary Fund and World Bank, 2018).

A key element of this transformation are smart home technologies, which amongst their main attributes consists in allowing users to control and monitor the physical world remotely (Carlos, Augusto and Shapiro, 2008). Others, highlight the relevance of wired and wireless sensors, along with enhanced communications networks, and distributed intelligence of smart objects as a mean of providing control mechanisms that are more effective than traditional methods (Atzori, Iera and Morabito, 2010; Chen and Jin, 2012; Brous, Janssen and Herder, 2019). Whist Darby (2006) and Buchanan and colleagues (2015) agreed that timely information, in the form of feedback from networked devices help users improve decision making with regards to tracking or situational awareness.

8.2.3 The rise of surveillance

There is a dividend in the digitalization debate. The first narrative perceives digitalization as a 'liberating technology' (Diamond, 2015) since it fosters transparency and accountability in nondemocratic governments and could help opposition movements to better manage collective action (Muzammil M. Hussain and Howard, 2013). However, as noted by (Cederman, Wimmer and Bria, 2010), in most developing countries governments are the major, if not the only provider of telecommunication services (e.g. North Korea, Cuba and Iran). This situation allows internet technology to be implemented in a way that benefits certain groups but neglects others (Gallie *et al.*, 2016). In consequence, vulnerable groups could be victims of invasion of privacy, denial of services and even destruction of property (Kleinrock, 2004).

In the extreme, Kendall-Taylor et al. (2020) warn that a digital smart era can also empower authoritarian regimes. These regimes are, in their words, embracing smart systems and technology "to refashion authoritarianism for the modern age" which can lead to "durable digital autocracies," "digital repression," and in some situations, real violence and repression via torture or murder. Moreover, Han (2020) notes how digital authoritarianism and infrastructure for surveillance have become even more prominent during the recent Covid-19 pandemic. Indeed, the philosopher mentions that in China, where the 'private sphere' does not exist, during the quarantine, drones fly over streets to stop anyone breaking the lockdown, surveillance cameras integrated with AI, measured body temperatures and notify, via mobile phones, people around them to be cautious. For Han, China, through big data and digital authoritarianism, achieved something unthinkable in other privacy-friendly countries; Chinese citizens not only submitted their will to corporate and

government control through their own social networks, but also, to watch over each other. Furthermore, the profound changes that the digital era entails, imply, among other things, that using online services carries privacy losses for users. And at the same time, it enhances surveillance practices that allow people, industries and governments to closely watch each other (Marwick, 2012) where the data of any individual can be can be used to infer its private attributes (Kosinski, Stillwell and Graepel, 2013).

However, the notion of a surveillant society is not new. In 1975, Foucault defended the idea that the French society has had reconfigure punishment through new "humane" practices of "discipline" and "surveillance", used in institutions such as but not limited to mental asylums and prisons (Foucault, 1975). For Foucault, such institutions ought to produce obedient individuals who comply with social norms, not only because of the fear or threat of physical punishment, but also, as a result of their behaviour being sculpted to ensure they completely internalise social beliefs and values (Galič, Timan and Koops, 2017). In this sense, Foucault inspired himself in Bentham's panopticon work, to envision a circular prison where the watcher cannot be seen but can watch everything, allowing the watcher to be almost 'omnipresent'. In this sense, the panopticon was "*designed to lay each inmate to the scrutiny of a central watchtower, which was positioned so that individual prisoners could never know when they are being watched* (Pollard, 2019)*".* Based on this premise, Foucault argued that prisoners felt and acted as if they were always being watched, which resulted in people adopting docile and obedient behaviours. In this sense and with the emergence of ICTs, Galic and team (2017) argue that the term surveillance has been spreading both in meaning and substance and has been theorised from a large range of disciplines. Lyon (2007) goes beyond and argues that the act of surveilliance, for instace, with the deployment of CCTV cameras possess a simoultaneous dual purpose. First, the aim of surveilliance is being watched to generate controlling and disciplining individuals so as they follow certain behaviour or specific sets of norms. And second, the act of surveilliance may be as well to protect and care for the same subject.

For McMullan (2015) however, unlike the panopticon where prisoners knew they were been watched, in the digital era, societies do not know and for this researcher, that is the whole point. Unlike CCTV cameras were people chose to avoid them and to avoid been monitored (Lyon, 2007), with the emergence of smart home technologies everything is invisible, thre are no towers, but they are communicating sensors in most of the digital devices tracking all users' behaviours, actions and collecting their data.

Certainly, as mentioned in chapters 5 and 6, data collection is at the heart of the digital society and this action is essential to deliver optimal services and thus, improving customers' experiences;

however, it could also be used for marketing purposes or to manipulate someone's behaviors (Jordan, 2019). For example, networks of sensors, can collect usage and behavioral data even in a private setting (e.g. in the home or when users are asleep) (Wachter, 2019). In this sense, certain computational techniques can identify people or trace their behavior by combining just a few snippets of data. In consequence, it is argued that privacy as we know it, is ending and we are only seeing the consequences (Of *et al.*, 2008).

Indeed, there are different

In this sense, for Zuboff (2019) '*nearly every product or service that begins with the word "smart" or "personalised", every internet-enabled device, every "digital assistant", is a simply supply-chain interface for the unobstructed flow of behavioural data on its way to predicting our futures in a surveillance economy*'. More specifically, Han (2017) holds a conception of [smart] technologies as part of the neoliberal era, where '*instead of making people compliant, it seeks to make them dependent*'. The smartphone as a key surveillance device, in Han's world it is comparable to a rosary '*both the rosary and the smartphone serve the purpose of self-monitoring and control*'. He later explains that '*power operates more effectively when it delegates surveillance to discrete individuals*. All in all, Han summarises the desire for individuals to own these technologies in the motto: 'protect me from what I want' (Jeffries, 2017)

8.2.4 Gender bias in the digital economy

In addition to these concerns, the smart tech industry has also been criticized for being gender biased pointing to a gender imbalance in smart homes. For instance, digital assistants such as Siri, Google Home and Alexa engrain harmful gender biases (Specia, 2019). For example, the speech of most voice assistants is female by default, thus sending a signal that women are obliging, docile and keen-to-please commands. UNESCO (West, Kraut and Chew, 2019) explains that since '*it honours commands and responds to queries regardless of their tone or hostility…this reinforces commonly held gender biases that women are subservient and tolerant of poor treatment*'. The report conducted by UNESCO titled *I'd Blush if I could*, refers to Apple's Siri assistant which offers the phrase: 'You're a slut'. Amazon's Alexa responds to this phrase: 'well, thanks for the feedback'. In fact, the study suggests that as most of AI staff is male '*feminised digital assistants…greet verbal abuse with catch-me-if-you-can-flirtation*'.

Not only that, Siri and Alexa's obsequiousness –and servility—provides a strong illustration of gender biases coded in technology products, prevalent in the technology industry and present in digital skills education (UNESCO, 2019) . This comes as no surprise as at least 5% of interactions with digital

assistants are ‘unambiguously sexually explicit’ and the numbers could be much higher but software have difficulties detecting sexually suggestive speech (Rawlinson, 2019).

Digital security technologies also disadvantage women and other groups (Poster, 2018). For example, biometric facial recognition systems as identified by (Buolamwini and Gebru, 2018) have trouble identifying women’s faces and faces of people of colour. Although, according to the US National Institute of Standards and Technology, the face recognition database improved 20-fold between 2014-2018 (Boutin, 2018). Airports’ security systems are also more likely to call women for strip searches relative to male passengers due to biometric matching algorithms (Browne, 2015).

Given that machine learning is a technique that finds patterns within data, voice recognition is another dimension that is male biased (Bajorek, 2019). Indeed, speech recognition is trained on large databases of voice recording called corpora and these are dominated by male voices (Perez, 2019). For instance, a study (Tatman, 2017) revealed that Google’s voice assistant was 70% more likely to accurately recognize male speech than female speech. The importance of voice recognition is relevant as voice commerce is estimated to be an $80 billion business by 2023 and around 50% for searches will be through this mean (Bajorek, 2019). In this sense, it could be argued that it is unfair that women are paying the same price as men for products that deliver an inferior product to them (Perez, 2019) or does not fairly and accurately represent them Voice recognition software on smart phones is not the only example of a universally applicable product that men have designed. Also, car voice controls are male designed and thus, biased towards recognizing women’s commands. Automakers in an attempt to address their error,, delivered the following remedy: ‘women could be taught to speak louder, and direct their voices to the microphones’ (McMillan, 2011).

In the ‘apps world’ biases against women persist. For example, Tinder, the highest grossing dating app on Apple’s store (Shead, 2017) generating more than 810 million dollars last year is not an exception to gender biased. Duportail’s (2019) research, revealed that Tinder machines operate using an algorithm which suggests younger, less educated and poorer women to advantage men in the digital dating world; however, the algorithm does not work the other way around. Her work also reports that the app is one-sided, designed by men for men. The gender bias is not surprising when two-thirds of the 4 million clients paying for Tinder Gold are men. Based on this, Duportail suggests that Tinder is a meticulously assembled machine which reproduces patriarchal dogma. Practices such as these help support Wajcman’s statements when she mentions that: “technology is an extension of patriarchal and capitalist domination…has been shaped by men to the exclusion of women” (Wajcman, 2004 pg 29). From Wajcman’s view, there is a tendency to reinforce gender

hierarchies within technological development where women benefit from technological advances than men.

Another good example is the app Absher, which is available in the Saudi version of Google and Apple in their online stores. This app allows men to update or withdraw permission for female relatives to travel abroad and to receive notifications via SMS if their passports are used. Saudi women have complained about this app, stating that: it is 'inhuman', 'it gives men control over women' and 'they need to remove it' (Reuters, 2019). Others stated: '*tech giants could help bring about change in Saudi Arabia if they pulled Absher or insisted that it allows women to organise travel independently – which would significantly hamper guardianship system…if [they] remove this application, maybe the government will do something* (Reuters, 2019)'. This is another case where technology is not offering progress but only invasive powers to users, generating damage and even inflicting violations to human rights.

Other forms of control are presented in period-tracking-apps as revealed by Privacy International (Privacy International, 2019). They found that menstruation apps, for example, have been sharing intimate personal details, including the last time the user had unprotected sex. These apps include Maya (more than 5m downloads) and Period Tracker MIA Fem Ovulation Calculator (over 2m users), that informs Facebook when a user is menstruating or intending to get pregnant. On a similar track, Mahdawi (2019b) shows that Activision Blizzard– a video game company—was encouraging their employees to use family-planning apps. Later, these apps, shared information with the company so they could track how many of their employees were trying to get pregnant. Given the rise of 'menstrual surveillance', Mahdawi (2019a) has coined the term 'digitalized vagina' as corporations are increasingly aware that female bodies could be lucrative information temples. In turn, industries are exploiting this data in new and ever-more-dystopian ways. She takes Ovia Health as an example, since this app has become a powerful tool for employers and health insurers to collect data about their workers' lives. This data includes intimate information about fertility, menstrual cycle and the progression of pregnancy. However, when it comes to consider women for 'healthier matters', such as when Apple launched their health-monitoring system, it could master most of the vital signs of the body, they forgot one crucial detail: a period tracker (Alba, 2015).

8.2.5 Smart technologies and cyber abuse

Involuntary monitoring and surveillance through connected devices entail another risk factor associated with sexual and domestic violence and abuse (Lopez-Neira *et al.*, 2019). The rapid development of smart technologies and digital communication services has resulted in an increasing

number of technology-related abuse (Freed, D., et al., 2018; Henry and Powell, 2018). Examples of this include: online harassment (Joshua Guberman, Carol Schmitz, 2016; Vitak et al., 2017), cyberstalking (Ellison and Akdeniz, 1998; Fraser *et al.*, 2010; Eterovic-Soric *et al.*, 2017; Tokunaga and Aune, 2017), virtual stalking (Bowles, 2018), doxing (Douglas, 2016), cyberbullying (Designing, 2016), technology-facilitated sexual abuse (TFSV) (Henry and Powell, 2018), sextortion (Poster, 2018), children's sexual exploitation (Mitchell *et al.*, 2012; Martin, J., & Alaggia, 2013), non-consensual pornography (revenge porn) (D. Freed *et al.*, 2018), deep fakes (Lyu Xin Yang, no date; Floridi, 2018), electronically enabled trafficking (Adikari, 2016), online behavioural control and the use of spywares (Chatterjee *et al.*, 2018) (see Appendix III for definitions).

Most sobering are cases of sexual abuse and exploitation, with Keller and Dance (2019) warning that the internet is 'overrun' with images of child sexual abuse or torture, with some victims as young as three to four years old. They report that in 2018, online tech companies reported more than 45 million online photos and videos of children being sexually abused, more than double what they found in 2017.

Furthermore, a recent study of nude image abuse in Australia, the UK and New Zealand revealed that more than one in three people have been victims of nude image abuse, that is, up from one in five in 2016. The researcher found –surprisingly—that the rates of abuse were similar across all three countries ranging from 35-39% (Cohen, 2020). This issue shall urgently grab serious public attention, since victims of revenge porn and other non-consensual image creation and distribution has reached alarming levels, where 8% of American women have been victims of this type of abuse (Ruvalcaba and Eaton, 2020). A similar trend is presented by Vinopal (2020), where she shows that one in 25 people in the U.S has had a sexual video or image of themselves shared on the internet without their consent and about 90% of them are women. More women too, are more likely to be victims of revenge porn with little successful attempts to remove the contents from the internet. For instance, a recent investigation by The Guardian (Mahdawi, 2020), revealed that PornHub's system can be easily circumvented, and she also notes that the same current website method for removing non-consensual porn "not only puts the onus of finding and flagging videos entirely on potentially traumatized victims—[but] those victims can't rely on the system to work (Mahdawi, 2020) ".

Other sources of abuse include unwanted sexual attention, image-based violence, emotional manipulation or coercive offences (Lopez-Neira *et al.*, 2019). According to Centre for Research & Education on Violence against Women & Children (Baker *et al.*, 2013), there are six broad themes that encompass forms of cyber violence: hacking, impersonation, surveillance/tracking, harassment, recruitment and malicious distribution (a definition of each is provided in Appendix IV). Poster

(2018) makes a call for more women to participate in the cyber security arena as a million more US women than men got their identities stolen in 2014. Moreover, women and girls are more likely than men to be targets of 'remote sexual abuse', that is, forced into posing nude online or being staked through the internet (Poster, 2018). Not only that, a recent report from the New York Times (2019) revealed that Facebook groups for single women and widows are full of targets where scammers can message hundreds of potential victims. In this area, the F.B.I has received nearly 18,500 complaints from victims of romantic fraud[7] in 2017 with reported losses estimated to be around $360 million USD. Given the number of scams through online outlets, associations such as Advocating Against Romance Scams (2019) has been lobbying for a law to hold social media sites responsible for such crimes.

In this sense, research has focused on 'conventional' cyber risks such as harassment and abuse on social media platforms, in addition to restrictions to devices such as laptops and phones (Lopez-Neira *et al.*, 2019). However, sources to perpetrate tech abuse keep rising. As noted by (Bowles, 2018) and (Lopez-Neira *et al.*, 2019) with the emergence of IoT devices such as smart locks, cameras, smart speakers and thermostats there are new means of coercion and manipulation opportunities against victims and survivors, an area that has received little attention in the academic and legal dimensions (Adikari, 2016; Freed *et al.*, 2017; Henry and Powell, 2018; Lopez-Neira *et al.*, 2019).

Although tech abuse is not taken as seriously as abuse perpetrated in person (Scott, Lloyd and Gavin, 2010; Nobles *et al.*, 2014; Elks, 2018), victims of technology-related abuse have described their experiences as 'jungle warfare' because they did not know where the attacks were coming from (Bowles, 2018). Others noted that: 'abusers were monitoring and controlling remotely through the smart home appliances and the smart home system' (Bowles, 2018). Tech abuse, thus, do not recognize borders and boundaries, victims of it often feel hounded, under constant surveillance, harassed and bullied by the abuse on their IoT devices and social media, particularly, since these provide instantaneous communication (Harris and Woodlock, 2019), allowing abusers with quicker access to methods to harass and abuse (Melander, 2010).

To this end, some of the most relevant work on SHTs and domestic abuse found the following:

1- Dimond et al., (2011) interviewed ten female victims. Their work indicates that victims of tech abuse struggled managing privacy settings and felt that they were less tech savvy than their abusers.

[7] Romance scammers create fake profiles to contact potential victims on dating sites and apps or through popular social media apps such as Facebook and Google. Once the scammers gain the victims' trust they make up a story and ask for money

2- Matthews and team (2017) interviewed 15 victims. They designed a three-stage model which consisted of: physical control, escape and life apart. Using this model, they investigated technology issues and how each stage of the model was different from the others.
3- Woodlock (2017) used a multiple-methods approach which included focus groups, two online surveys and interviews. Her results indicate that phones, tablets, computers and social networking websites are commonly used in intimate partner stalking.
4- The most comprehensive work was developed by Freed et al., (2017) who conducted interviews with 40 professionals and focus groups with 32 victims (all females). Their findings indicate that blocking abusers on social media or on the phone can escalate abuse from online harassment to physical violence. In addition, their work reveals that given the nature of intimate relationships, abusers can typically access the victim's digital accounts and devices and use them to control them.

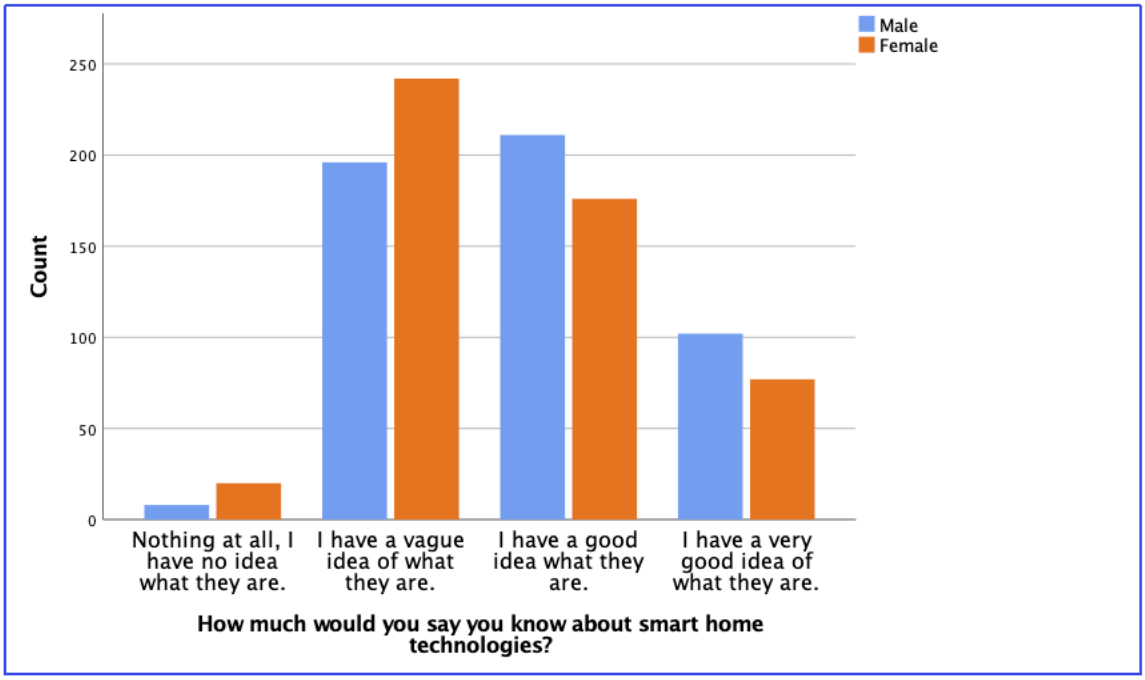
The author has presented in this previous analysis of the literature review a brief exploration of the following themes: past and current state of smart home technologies, in addition to some of the "dystopian" features smart home technologies possess to enhance surveillance practices conducted by governments and stalking practices conducted by individuals, as well as gender biases in the digital arena and cyber abuse. As the author has presented such themes, now it could more easily introduce to the reader the results in the sections below.

8.3 Results

8.3.1 Knowledge as enabler of domestic violence

The first question this section explores relates to knowledge, here, the researchers asked survey respondents: How much would you say you know about smart home technologies? Results indicate that most men 60.5% have a good idea to a very good idea of what SHT are, in contrast to 49.2% of women (see Figure 26). Indeed, the idea that males are better versed on these technologies could facilitate domestic violence, in fact, different studies situate this element as key enabler for domestic abuse (Dimond, Fiesler and Bruckman, 2011; Adikari, 2016; Diana Freed *et al.*, 2018b).

Figure 26: Differences in knowledge about smart home technologies



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

For instance, Dimond et al., (2011) indicates that victims of tech abuse struggled managing privacy settings and felt that they were less tech savvy than their abusers. Similar results were found by Freed et al (2018), who conducted interviews with 50 professionals that had collectively served hundreds of victims of intimate partner violence, as well as focus groups with 32 victims in the United States. Their work reveals that due to victims' lack of knowledge, abusers can typically access victim's digital accounts and devices and use them to control them. Furthermore, victims described themselves as lacking in technology expertise and in some cases, commented they had '*zero knowledge'* (pg.11) when it comes to technology. Others described how they had '*no idea*' (pg.11) how to manage privacy settings, turn off location services or set up new accounts (Freed, et al., 2017). Moreover, many social media platforms (e.g. WhatsApp, Facebook and Instagram) innocently aid abusers to propagate the abuse, since features such as location, 'last seen' and 'read receipts' are enabled by default and users do not know how to turn them off (Freed et al., 2018). Moreover, despite some platforms provide mechanisms by which people can report abuse, users do not have the technical knowledge to find and use reporting mechanisms (Freed, et al., 2017).

In this sense, to support this trend, female participants in our survey stated, for example mentioned that '*I have very little experience of smart home technologies*' (F288) and '*I haven't used any*' (F307). In one of our focus groups, a female participant for example stated that '*I don't use any smart stuff for anything'* FGSF when discussing smart home technologies used for energy monitoring (Furszyfer Del Rio, Sovacool and Martiskainen, 2020b). In a further discussion on whether smart home

technologies were gendered, one female participant noted that they were '*caveated with boys and toys'* (FGSF). More specifically, lack of knowledge was mentioned by one male focus group participant when discussing potential surveillance equipment such as cameras in the house*: 'I think there are issues that could arise especially in unhealthy relationships where one person is more tech savvy than the other. You don't know quite what monitoring equipment they might be putting on, let's say, the bedroom or even the bathrooms'* (FGSM).

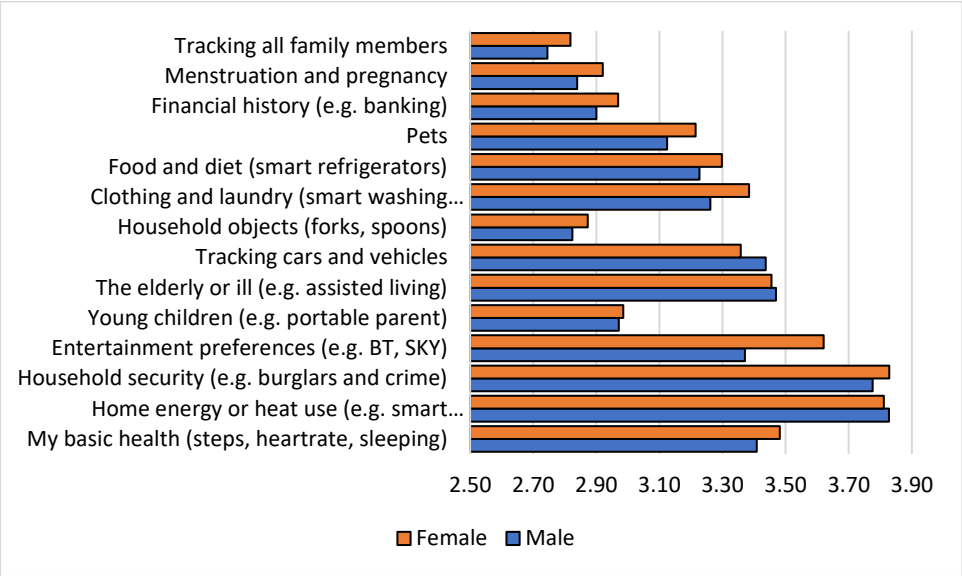
However, lack of knowledge not only remains on the victims' side. A growing body of research (Chayn, 2017; Raptis *et al.*, 2017; Bowles, 2018; Lopez-Neira *et al.*, 2019) suggests that another concern is the deficient expert knowledge needed to advise victims about safety and security along with the lack of resources in the legal framework. Due to the lack of expertise in this area, pressure is placed on victims to resolve issues, many of whom feel that they do not possess the knowledge to either identify, cope or manage technology abuse. Victims, in consequence, may not realize the role technology is playing in their abuse and fail to bring it to the advisors attention, hence the issue remains undetected and unaddressed (Freed et al., 2017). In these circumstances, others demands shall be addressed to manufactures, calling for security and privacy to be prioritised for victims and other vulnerable groups, whilst taking into consideration gendered concerns (Arief *et al.*, 2014; Matthews *et al.*, 2017; Strengers *et al.*, 2019).

Indeed, several times participants, both male and female, in the focus groups and survey, commented on how these technologies are not easy-to-use, hard to set-up and how lack of expertise from manufacturers could lead to trouble. On these subjects, focus group participants for example stated: '*frankly, none of them are easy to set up. I am a geek, and none of them work in the way that they promise they will'* (FGSM) and *'it is too complex for some people to contemplate and set up'* (FGSM). In our survey, one respondent emphasised that smart home technologies were *'incredibly complex to set up'* (F977) (Furszyfer Del Rio, Sovacool and Martiskainen, 2020b).

8.3.2 Smart monitoring as enablers of stalking

As shown in Figure 26, there are differences between women and men in terms of their views regarding SHTs used for monitoring. The findings indicate that women have a stronger preference for smart home technologies compared to men to monitor aspects related to health, energy/heat use, household security, entertainment preferences, young children, elderly/ill, household objects, clothing/laundry, food/diet, pets, financial history, menstruation and pregnancy and family members. Men, in contrast, would only have preferences to monitor cars/vehicles (Furszyfer Del Rio, Sovacool and Martiskainen, 2020b).

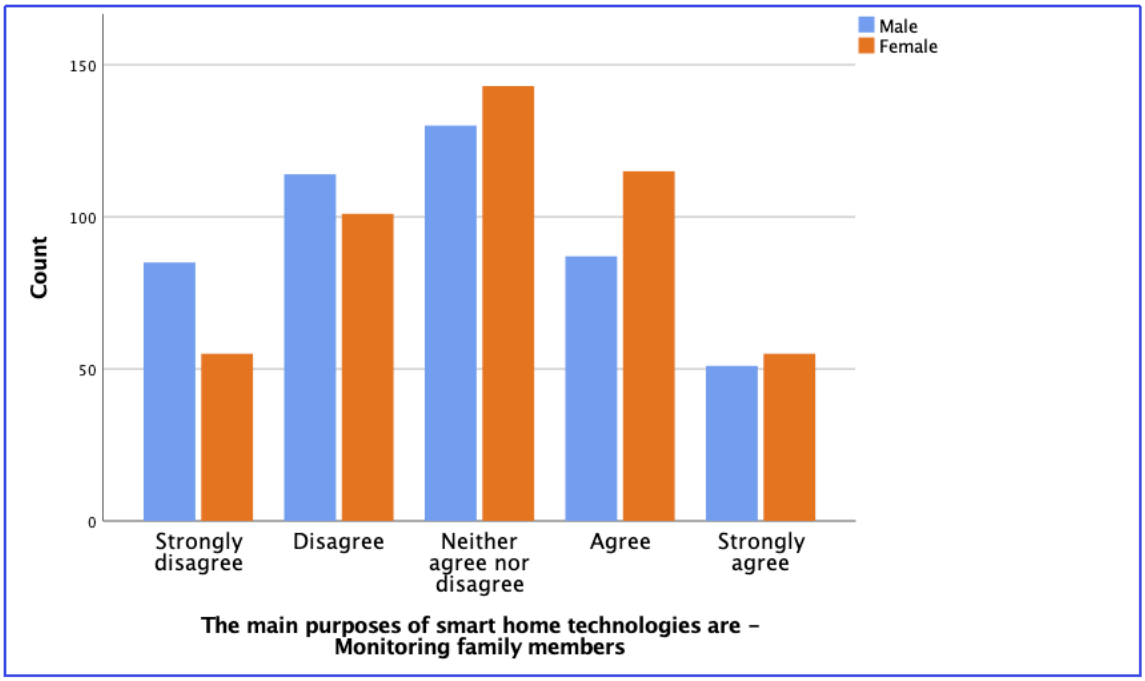
Figure 27: Differences in mean scores for the 'I am comfortable with smart home technologies monitoring' (Likert scale of 1 to 5, with 5 = strongly agree)



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

For instance, the results from the survey indicate that 33% of women and 29.5% of men agreed that one of the purposes for smart home technologies could be to monitor family members (see Figure 28).

Figure 28: Differences in survey counts for 'The main purpose of smart home technologies to monitor family members'



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

Indeed, in the cyber domestic violence dimension, strangers are not the primary culprits but partners or family members often are the ones that initiate security breaches, look to enhance control and stalk partners (Refuge, 2018; Leitão, 2019). Observations on this matter were brought by survey respondent F996 and focus group participant FGMF, respectively, as they expressed: '*Sometimes couples use it to spy on each other'* and '*I don't know if you watch Coronation Street… a gentleman and his partner have split up and he left a camera in her house, so he's been watching her from his house, so that goes on'.* Research in this area has explored how certain technologies could facilitate constant surveillance on partners (Harris and Woodlock, 2019) and simultaneously, provide perpetrators with quicker access and methods to harass and abuse (Melander, 2010).

For Stark, (2012) stalking is '*the most dramatic form of surveillance used in coercive control…fall in a continuum with a range of surveillance tactics whose aim is to convey the abuser's omnipotence and omnipresence*'. Therefore, digital technologies can provide the sense of being ever-present in the victim's life. Fraser et al. (2010) corroborates that '*one of the most terrifying tactics used by stalkers is to make the victim feel that she has no privacy, security, or safety and that the stalker knows and sees everything*'. In this sense, although a victim might be separated from his/her partner, they have not been able to completely escape their presence in their lives (Dimond et al, 2011). Participants in our focus groups mentioned how these technologies could facilitate being stalked. For example, FGMM said: '*[Nest camera] You could use it when somebody doesn't really know is been watched. I'm following you and you don't know that I'm following you'* and FGMF: '*Stalking is the only use I can see in Ring Cameras*'.

However, cameras are not the only way to stalk victims, Interval House (2019) found common means to carry-out stalking through technology. For instance, perpetrators could slip small tracking devices into their victim's clothes or use smart security locks to either lockout or lock-in their victims. Abusers could use location-based services (such as find my iPhone), parental tracking or other safety services (e.g. Find my Friends) to track their victims, which could result in potentially dangerous physical stalking (Freed *et al.*, 2018). Other forms of stalking are facilitated by apps, for example, abusers could use the geolocation posts on Facebook, Instagram or Snapchat to track their victims' activities and show-up in person or let their victims know where they are (Woodlock, 2017).

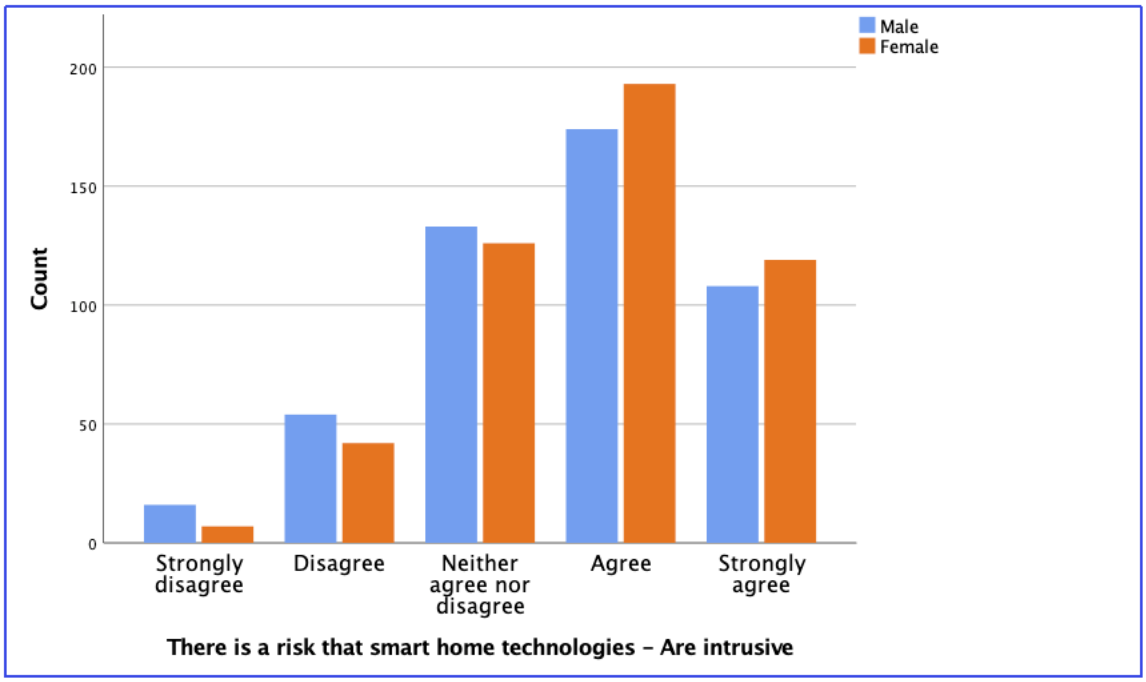
For example, the *Washington Post* (2019) reported that an Australian woman's ex-boyfriend stalked her for months by using smartphone apps linked to her Land Rover. With this, the perpetrator was able to control her windows and stop the car remotely. Indeed, in an interview, Freed (2019) mentioned that such apps are '*dual-use apps, applications that have a legitimate use case, but then are misused in cases of intimate partner violence*' As a result of recurrent attacks, victims have

reported to feel constantly unsafe as they are unable to truly escape from their abusers, regardless of their physical location (Dimond et al., 2011). Indeed, results from the National Network to End Domestic Violence found that 50% of victim service providers report that offenders constantly use digital platforms and mobile apps to stalk victims and another 41% reported abusers use GPS tracking devices (Young and Saxena, 2019b).

Based on this, the *New York Times* reported that these threats are part of a new pattern of domestic behaviour cases in which: '*the newest conveniences are now also being used as a means for harassment, monitoring, revenge and control* (Bowles, 2018)'. Indeed, centres for domestic violence note that abusers were monitoring victims' activities or remotely controlling smart home appliances and smart home systems. Whilst other victims report that they had their '*thermostats kicked up to up to 100 degrees*' or their '*smart speakers turned on in the middle of the night*'

Certainly, participants in the survey noted that '*smart home technologies are invading privacy and over-monitoring users'* (M18) and that they are an '*invasion of privacy as they are listening all the time'* (F582). Another survey respondent felt uncomfortable around such technology: '*I don't like the idea of AI listening into my conversations*' (F995). Overall, 54.5% of male and 60.6% of female respondents agreed that there is a risk of SHTs of being intrusive (see Figure 29). Pertaining one of our themes on domestic violence, features of digital communications such as storage, synchronicity, replicability and mobility (Baym, 2011) enhance abusers' ability to persist intruding on their targets regardless of their location. In turn, perpetrators' dimension of control goes beyond previous spatial boundaries and become more intrusive (Furszyfer Del Rio, Sovacool and Martiskainen, 2020b). According to FGLF, '*the smart home is intrusive, it's full of cameras or devices always watching you, microphones that are always listening to you.'*

Figure 29 Differences in survey counts for 'There is a risk that smart home technologies are intrusive'



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

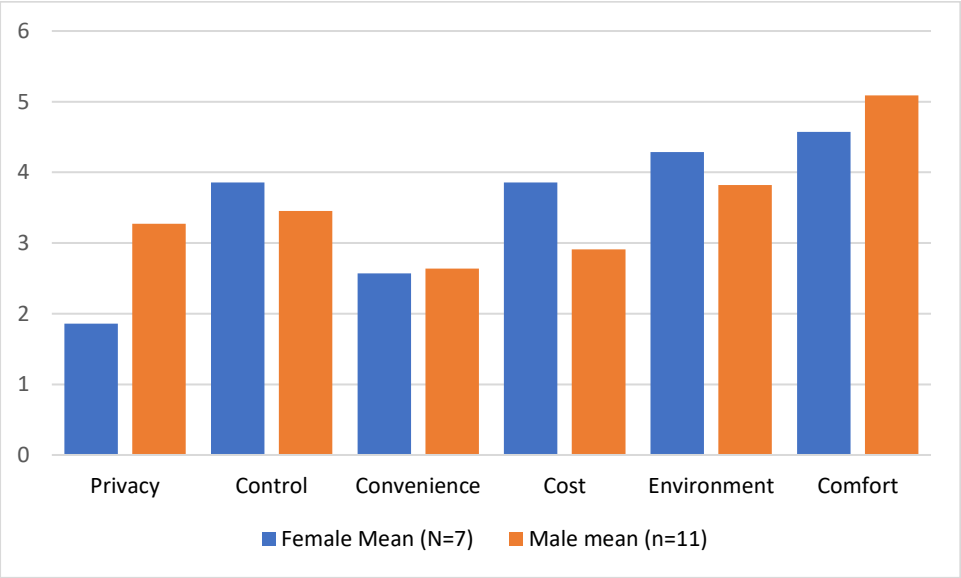
In sum, smart home devices could facilitate domestic abuse to occur 24 hours a day, and regardless of the location of both victim and the perpetrator (Woodlock, 2017). Some have therefore argued that the notion of violence can be 'escaped' is further weakened because of the concept 'feeling safe' from an abuser as geographic and spatial boundaries have changed (Hand and Peters, 2009; Harris and Woodlock, 2019). Indeed, Stark's findings (2012) identified that victims in this situation felt a condition of *unfreedom entrapment,* which key feature was to micro-regulate victims' everyday behaviours in private and public spheres, restricting access to both (Stark, 2007; Woodlock, 2017).

Confirming these implications, the researcher found in the literature that smart home technologies as enablers of intrusiveness has led domestic violence victims to state: '*Why does my partner always know where I am and what I'm doing*' (Blunden, 2018). whilst other felt their freedom threaten*: 'I would get over 100 abusive texts a day – I never felt free of him'* (Woodlock, 2017). Young women interviewed about abusive text messages from violent partners have mentioned: '*it goes into your head*' as victims carry their phone all the time, they have declared the abuse '*stays with you*' (Stonard *et al.*, 2017). Intrusiveness has also led victims to feel unsafe; *'I don't feel safe anywhere, I feel like he is able to contact me at any time at any place* (Harris and Woodlock, 2019).

8.3.3 Parental control and children surveillance

Figure 30 illustrate visible differences in SHT attributes, for instance, men value privacy and comfort more than women. However, females were more concerned on aspects related to control, trust and the environment. Convenience, however, was almost equally rated (Furszyfer Del Rio, Sovacool and Martiskainen, 2020b).

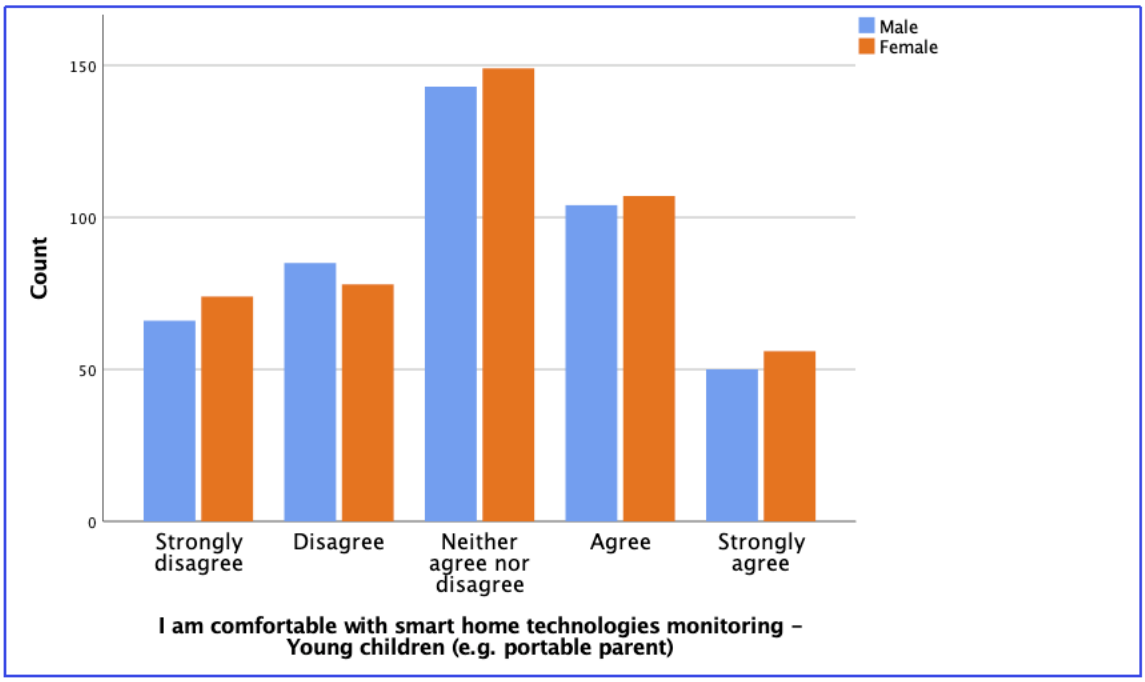
Figure 30: Different in mean scores from the focus group of smart home attributes by gender (n=18)



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

A tension in the survey and focus groups was found on using smart home technologies to monitor young children. As represented in detail in figure 31, results from the survey indicate that only 29.8% of men and 31.7% of women agree to use these technologies with this end.

Figure 31: Difference in survey counts for 'Comfortableness of using smart home technologies to monitor children'



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

However, most participants in the focus participants felt comfortable monitoring young children. To illustrate this point, FGMM said**:** *Baby monitors, when they're sleeping. Definitely not a problem with that…That would be the only camera I would have inside my house'.* On this, FGLM expressed: '*if you have children, you may want to be watching what they're up to'.* For some, invading baby's privacy was not an issue, as elaborated by FGLM: '*It's a very helpful baby monitor. And if somebody wants to track the behaviour of my two-year-old grandson, they're welcome to it'.* Another FGLM stated that it was *'completely acceptable to monitor a young child upstairs while you are downstairs'* and that *'SHTs have great potential to stop kidnappers and alert the police or others about kidnapping from a remote location.'* Indeed, the researcher will return to this point about SHTs possibly stopping abuse in chapter later in this chapter.

Nonetheless, reasons to distrust technologies designed for children should be on parents' radars since technology companies, estimate that there are around 45 million online photos and videos of children been sexually abused and, in some cases, tortured. Keller and Dance (2019) found an insatiable criminal underworld that has exploited the flawed and insufficient efforts to contain these horrific imaginaries, given that criminals are using advanced technologies like encryption to stay ahead of the police. Similar experiences are note by Chiu (2019), who recently reported that through a Ring camera, an eight years old girl not only was subject to racial slurs, she was also told to break her television by a hacker—he continued pestering and harassing the little girl until the parents disconnected the device. Or how, as the vulnerability of some smart devices a baby monitor was

hacked (Domonoske, 2018). On this, FGSF commented: '*there are some horrible people out there…absolutely vile people, they will definitely take advantage of some of these things'.* FGLF added that '*I want to trust SHTs more, I would love to trust them more. But I don't.*'

Ironically, in some cases children themselves ask for SHTs that could be used to monitor them. Focus group participant FGLM said

> *It's so I can keep in contact with my children, our kids said we needed them [smart home technologies]. Children's schools they wanted to have constant contact with parents and having a reliable way they could be contacted.*

FGSF noted that:

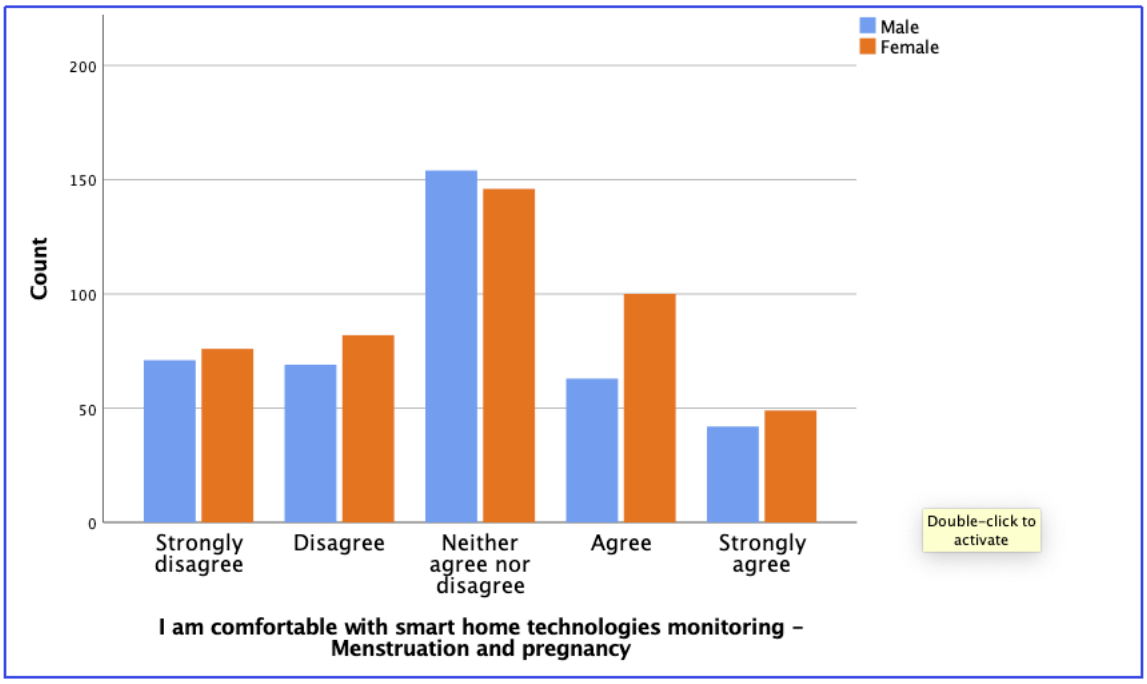
> *When you join school now, you're generally expected to do some element of your homework using Google or exploring online. So, children are encouraged from an early age to use digital technologies. Because if they do not, they are going to be excluded from the world*.

Parents observations on this matter were apt, given that the UK government, through the Education Technology (EdTech) program, seeks to tackle day-to-day challenges faced in the education sector, including reducing teacher workload, increasing efficiency, improving accessibility and inclusion and improving teaching and students' outcomes. The program seeks to tackle these challenges through the use of tablets, laptops and/or other digital devices (Department of Education, 2019). Demonstrating how much the industry has grown so far, investments in EdTech have reached £90.9 million –a 140% increase on the amount invested in 2016 (Robins, 2019).

8.3.4 Menstruation and pregnancy

A final set of concerns could arise through the monitoring of smart home technologies are those related with menstruation and pregnancy. In this sense, in the survey, as figure 32 illustrates 28.9% of women and 20.3% of men agreed to use these technologies for that purpose (see Figure 32). Yet people could have reasons to distrust technologies accessing personal data to monitor menstruation and pregnancy cycles.

Figure 32: Survey counts for 'Comfortableness of using smart home technologies to monitor menstruation or pregnancy



Source: Author, Professor Benjamin K Sovacool and Dr Mari Martiskainen

Given these potential scenarios, focus group participant FGSM even expressed being distressed on where their data was going: '*For me, the biggest fear, it's the data that they're colleting that I don't know about. I think it's the analytic data that they're generating on you. They can tell what you like, what you don't like, they even can tell what your personality is'.* These concerns were not far from reality, as many manufacturers of smart devices base their primary business model on of collecting household data (Naughton, 2018). Not only that, Zuboff (2019) notes that consumers are unaware of the value of the data they are giving away, which is not only extremely valuable, but also can be profitable to generate predictions about preferences and future behaviours. Focus group participant FGLM shared a similar perspective when he stated: '*The people who are benefiting now, and will do so more in the future, are the people who own the data that's generated by smart technology, and then use that data to influence others' behaviour'.*

In this way, although participants seemed to be aware of some of the instruments that regulate SHTs, many still did not know what sort of personal information they were giving away when accepting terms and conditions. To this, focus group participant FGMF stated: '*all these are signed up to GDPR, aren't they? but it concerns me that maybe there are hidden ways of, I'm not saying that there's any subterfuge going on, but sometimes you might not have ticked a box, so that inherently gives them permission to use your data in certain ways. I find myself checking more carefully now*'. Indeed, most participants were unaware of what information users are giving away when agreeing to terms and conditions (Furszyfer Del Rio, Sovacool and Martiskainen, 2020b). Focus group

participant FGMM concurred and asked in the room*: 'how many of us actually read all the documentations and terms and conditions?'* Certainly, most consumers are not reading them properly, as for example, Amazon states that users have given permission for human verification and allows to use data '*to train our speech recognition and natural understanding systems* (Hern, 2019).

Focus group participant FGLF explained in her experience why this could happen: '*Basically, they designed the interface to make you just click through and ignore and just give them all they need'.* This vision could be accurate given that study conducted by McDonald and Cranor (2009) calculated that users would take up to 76 working days to read through all the privacy polices encountered in a year. In this sense, LifeHacker provides internet users with the criteria they should look out when skimming through privacy policies. They advise users to look at statements related to data sharing, storage and collection or phrases such as 'store' and encrypt'. Additionally, they advise users to search for terms such as 'deletion' or 'retention' to learn about how long platforms keep their information (Grauer, 2019).

8.4 Perceptible examples and means for smart home technologies to inhibit and deter violence

Starting from a level 3 of smartness, if hacked, inhabitants of a smart home may encounter themselves in a vulnerable position. Since a home with these characteristics (e.g. integrated systems, automation and sentient) and with interconnected devices featuring the following smart devices: fire alarms emitting loud noise and water, smart speakers playing disturbing music at the loudest volume, showers turning to boiling hot temperature, Amazon Alexa requesting expensive products and air conditioning turning icy cold, when all of these operating at the same time, smart home technologies could become a temple to harass people[8].

Although this example was not provided by the participants from the focus groups nor the survey, the author notes that tech abuse could be conducted, for example, through smart indoor security cameras installed throughout the victim's home, so that the abuser could constantly surveil and overwatch the victim's conversations with friends and family. Such scenarios have been reported to the police department in Palo Alto (Bowles, 2018) and by Refuge UK, where one of the victims stated: "*He regularly turned up where I worked…After reporting him to the police the online harassment stopped. But the paranoia stayed for a long time* (Refuge, 2020)".

[8] The author was inspired in providing such scenario based on Mr Robot's episode https://vimeo.com/178324074

More specifically, Webb (2020) illustrates how tech abuse could be carried out through the use of stalkware and spyware devices, indeed, such software enables someone to monitor activities on another person without their consent. Her work reports that stalkerware infections grew by 40% in 2019 with more than 67,000 users having stalkware apps installed in their phones. Moreover, in her work, Webb notes how easy is to download such apps which can gain access to everything on a victim's phone within minutes, such is the case of Xnspy app, which in their own website they portray messages such as: "*XNSPY is the easiest and safest mobile app to monitor cell phones and tablets. So get to know what your children and employees are talking about and who they are in contact with*" or more apt to this chapter, where XNSPY claim the following: "*You can remotely track what your loved ones and staff are up to by reading their SMS, iMessage's and IM chats like WhatsApp, Viber, Line and Skype. You can also monitor the shared multimedia from five other social media apps* (XNSPY, 2020)".

It is under this context where the author argues the need for a counterbalance and as previously stated, this research now briefly covers how the use of these technologies could prevent tech abuse and cyber violence. Indeed, in other cases, SHTs have helped prevent domestic violence. For example, in New Mexico a man was arrested for beating his girlfriend and threatening to kill her. During the assault he asked: '*did you call the sheriffs*?' The question was picked up by Amazon Alexa and recognized as a command, prompting to call 911 (Miller, 2017). In addition, many smart speakers have unobtrusive recording features that could provide evidence of abuse.

Other app-based bottoms or Bluetooth trackers can allow victims to send silent messages calling for help or record dangerous situations. In order to prevent domestic violence, Brignone and Edleson (2019) review quality and potential use of smartphone apps to intervene in intimate partner violence either in domestic settings or through an app. Research has shown that meeting online had finally overtaken meeting through friends, with around 40% of US couples first connecting through an app. And second, only in England and Wales, dating apps have been linked to more than 500 crimes, whilst the majority are sex offenses, others range from murder and rape to child abuse (Kjellsson, 2016). In their work (Brignone and Edleson, 2019), found that higher rating apps such as Tech Safety, Over the Line and Youth Pages often had accessible user interface, updated and functional links to keep victims informed. In addition, such apps possessed technical capabilities that were mindful to the victim's safety, such as turning off location tracking and the safe and secure storage of user data and developers.

A similar approach is taken by Freed and team (2017), they refer to the works of (Arief *et al.*, 2014) and (Emms et al., 2012) to better design platforms to help victims. The first lays out a vision for

'sensible privacy'. Their app would erase information about visits to victims-relevant websites by a user and at the same record potential abuse associated with the device. The second suggests tools to help survivors erase their browsing history. Other digital platforms, such as GuardDV (2019) aim to protect victims of domestic violence with real-time information about the safety of their environments through the use of smart monitoring and facial recognition technology. Other apps for victims of domestic violence have been developed, including BrightSky developed by Vodafone and Hestia (Vodafone, 2019) TechSafety app (Safe Chat Silicon Valley, 2019) and others.

The prevention of domestic violence is not limited to SHT apps. Ogilvy for instance, is developing an e-textile technology that keeps a record of events. The smart clothing device is known as 'The Dress for Respect' and for some it will bring sexual harassment into the limelight. These dresses have sensors sewn into them that record contact and pressure. In this sense, when contact happens, the same area lights up on the dress on the control unit's computer screen. This technology can also keep track of events (e.g. time and location) and even notes the intensity of the touch, as the sensors record presence of touch and pressure as well (Murphy, 2018). Further, the Sexual Assault Kit ,designed by nurses and survivors, is intended to create a trauma-focused approach that ensures that legal evidence is not invalidated for victims of sexual assaults, in addition to promoting safety, well-being and healing for victims (Morley, 2020).

Moreover, other online outlets, for instance, ProPublica has recently published a guide to aid victims of sexual assault associated with dating apps. Specifically, they provide users with a step by step guide of the most popular dating apps, such as but not limited to Tinder, plentyoffish, OkCupid, Match Spark Network, Gridr, etc (Propublica, 2020). This website provides step-by-step guides on who to approach, what to write dating app companies and how to block and report users with an abusive conducts. Other security measures are provided by governments. For instance, the Australian Office of the eSafety Commissioner (2019) provides useful advice to users on what to look for when purchasing smart devices. The guides contents explain how to be safe when using these technologies in a clear and friendly format in addition to age recommendations. Or the FBI, who recently warned users about features that come with enhanced televisions and guard questionable data collection, could be used for monitoring purposes and as a gateway for hackers to come into users' homes. The FBI warns about the range of threats smart devices could entail, from changing channels and showing children inappropriate content, to turning the bedroom TV's camera and microphone and silently cyberstalk users (FBI, 2019).

8.5 Conclusions

In sum and at the simplest level, SHTs are gendered, with men being more aware of them, and men also often the perpetrators of domestic violence and abuse. Women report or state within the data to have less knowledge about how the technologies operate, or even that they may exist, and seem to lack the knowledge that they can track and monitor things as intimate as personal movements, clothing, menstrual cycles, and pregnancy (Furszyfer Del Rio, Sovacool and Martiskainen, 2020b). The findings lastly suggest that because of this lack of knowledge and awareness, fewer women may be able to utilize SHTs to prevent domestic violence and abuse, or cope with it should it occur.

The results also reveal some interesting findings concerning the acceptability of surveillance and monitoring. Almost one-third of all survey respondents, or 33% of women and 29.5% of men when broken down by gender, agreed that one of the purposes for smart home technologies should be to monitor family members. Many discussed monitoring children, a concern not only if those parents abuse their children (the most often perpetrator of abuse is a family member or relative), but also opening up vulnerabilities to hackers and third parties with remote access that can facilitate cyber stalking.

Contrary to the optimistic views of SHTs in its promotional material, results suggest such technologies have just as much potential to be '*sinister, malicious and intrusive*,' as one respondent put it. Moreover, unlike conventional forms of abuse, the constant presence of digital technologies and our online environment may make it difficult to ever truly escape such abuse, once it begins, with SHTs making possible abuse 24 hours of the day and independent of the physical location of the perpetrator. It may create future hostile digital environments that track, control, and abuse people—especially women and children—from the earliest stages of their life, from inception and pregnancy in some circumstances.

Nonetheless, the findings were not entirely negative. Like many tools, SHTs possess a duality to them, there are configurations and options where they can prevent and inhibit abuse, via smart clothing that automatically detects a physical assault, to cameras or systems that offer real time assistance to the police for catching criminals and documenting abuse, to apps and devices that help victims recover from abuse, too. Which pathways SHTs proceed down will depend greatly on how the technology is governed in the next few critical years shaping its evolution (Furszyfer Del Rio, Sovacool and Martiskainen, 2020b).

Moreover, the data collected in the study was not uniformly negative of smart home technologies. For example, in some instances, smart surveillance has fulfilled its purpose. Survey respondent F898 avoided having been robbed through monitoring his/her property: '*Caught a burglar in my home on Canary camera but police still don't have arrested any one as yet'.* Monitoring has also helped

avoiding food waste as noted by survey respondent M350: '*As by-product, we noticed while on holiday our hive wasn't active - we asked a family member to check, and there had been a power-cut which tripped the breakers. Saved us at least £300 in freezer food'.* FGMF said that smart home technologies helped her to keep in touch with their loved ones: *'I use technology for a range of applications… but mainly to keep in touch with younger members of my family*'. Whereas survey respondent M703 perceived SHTs as a mean of enhancing relationships: '*They can provide a way of aiding relationships'.*

Chapter 9. Smart but unfriendly: smart home connected products as a source of conflict within households

9.1 Summary and introduction

Some of the findings presented in this last chapter have also been submitted to an academic journal under: **DD Furszyfer Del Rio**. "Smart but unfriendly: smart home technologies as enablers of conflict" Submitted to *Technology in Society.* In this chapter, the reader will encounter quotes from experts, survey and focus groups participants found in previous chapters; however, the author decided to re-use them in this chapter since it helps illustrating some of the points presented below.

This chapter, moreover, aims to put together all empirical data collected from smart home technologies, that is, data that has been presented from chapter 5-8 to explore a still unattended issue; that related with smart home technologies as enablers of conflicts. Indeed, in chapter 9, the author explores SHT from the position of how they could generate conflict within homes and their inhabitants. This, since most previous academic research has focused on the challenges of delivering smart domestic environments (Cook, 2012; Wilson, Hargreaves and Hauxwell-Baldwin, 2017), whilst research that has explored how people use SHTs, often focus around social character without including the notion of conflict. In this sense, drawing from a rich empirical dataset consisting of a literature review, semi-structured research interviews with experts, three focus groups across the UK (Manchester, London and Surrey) and a national representative survey (n=1032), the researcher explores how these technologies can enable conflicts with couples and partners, children and parents, landlords and tenants, neighbours and hosts and guests.

9.2 Literature review

This section offers a brief review of four different streams of scholarship relevant to the study: 1. defining what homes are and how the concept has evolved throughout time, 2. two typologies of conflict (human and computer science), 3. understanding the links between human computer interaction and conflict and finally, 4. conflict resolution. This is meant to offer background and context to the results and discussion to come.

9.2.1 A historic glimpse to what a home is

Homes have always been recognised as a protected space for families (Mallett, 2004). Nevertheless, as a site of care, socialisation and consumption, the home has drawn consideration from outside

institutions, attentions which has often faced with resistance (Goulden, 2019). In this sense, for Couldry and Mejias (2019) smart home technologies are facilitating the possibility of colonising a relatively untouched domain of the social life. In consequence, the deployment of these technologies are changing the very meaning of the home and domestic life in subtle but important ways.

Historically, Mallet, in her literature review refers to Rykwert's (1991) work to explore the conception of a house. He found that in 17th century, Sir Edward Coke, declared, 'The house of everyman is to him as his castle and fortress, as well as his defence against injury and violence, as for his repose'. In this sense, Witold (2001) adds that during the same time, ideas of what a house was, conflate around privacy, domesticity, intimacy and comfort as organizing principles for the design and use of domestic spaces. Such themes are still recurrent in contemporary conceptions as presented by Chapman and Hockey (1999), where users draw their attention to the same elements as in the 17th century. These valuations are not made in vacuum: Dovey (1985) argues that home represents the 'inside' from the outside world, where the latter is perceived as imposing, threatening and a dangerous space; for Mallet, this world it less more defused and less defined that the 'inside' (Mallett, 2004). Contradictorily, homes could also create a sense of oppression, tyranny and persecution (Mallett, 2004). In this way, contemporary conceptions of what a home is, rather than reductively presenting it as an unidimensional structure (e.g. house, flat, institution or caravan) is a multi-layered and multidimensional concept where cultural and historical contexts are stablished (Bowlby, Gregory and McKie, 1997).

9.2.2 Defining what a home is

Other studies differentiate between house, home and household. The first is defined by Giddens (1986) as "*simultaneously and indivisibly a spatial and a social unit of interaction*" he continues "*setting through which basic forms of social relations and social institutions are constituted and reproduced* (pg. 82)". Regarding households as a concept, Saunders and Williams (1988) work from the premise that rather than the individual, a household is the most basic economic unit through which the relationships of production and consumption can be analysed. Together with geographic location, along with issues around class, ethnicity and housing tenure, they (Peter Saunders, Peter and Williams, 1988) explain some of the variations in the meaning of home that exists between households.

House and home then are different between each other, Gram-Hanssen and Darby (2018), suggest that a house –is a building—and a home could be considered as a place, feeling or practice. Others, nevertheless, argue that without a family, a home is only a house (Gilman, 1980). Certainly, thus, a

key component of a home relies on the interactions between place and social relationships. Based on this, some could argue that homes are complex places (Hargreaves, Wilson and Hauxwell-Baldwin, 2018). Indeed, they are meaning and emotion-laden places in which, often, there are multiple interactions among household members, each one with different roles and relationships with technology (Mennicken and Huang, 2012; Nyborg, 2015). Fox (2002) concurs and adds that the concept of home is difficult to pin down, for her, '*home represents a complex and multi-dimensional amalgam of financial, practical, social, psychological, cultural, politic-economic and emotional interest for the occupiers* (39 pg. 21)'.

Moving forward to smart homes, in recent times, smart technologies have challenged or expanded the very meaning of a home (Caroline, 1991; Steward, 2000; Hazel, 2004; Aune, 2007). Sovacool and Furszyfer Del Rio (2020) review Gram-Hanssen and Darby (2018) and distinguish four very different conceptions of a home: home a security and control place, as a site of activity, a space for relationships and continuity and home as identity and values. Later, Gram-Hanssen and Darby illustrates how this maps onto four very different schools of conceptual, technical, prospective, and evaluative smart home research (2018). Whilst, Hargreaves, Wilson and Baldwin (2018) differentiate between functional, instrumental, and socio-technical views of a smart home, with each leading to different views of what a smart home is and does.

In this PhD thesis, the author considers the previous elements and envisions a home as a compound place with complex interactions. In this sense, a home does not only represent a tangible structure but escapes beyond the physicality. As such, not only householders interact with each other and with at-hand-technology, but also, technologies themselves must communicate between them to satisfy users' needs, where users and technology are embedded and belong to one system only; the home. In this sense, and going back to our results in chapter 6, the smartness of a home will depend on how integrated technologies are, their learning capabilities and their skills to retrieve information, not only from the home's ecosystem but also, from the outside. In turn, the home ought to automatically communicate with services past the home's ecosystem (e.g. energy suppliers, health providers or even mobility services) to guarantee the users' wellbeing whilst satisfying their needs.

9.2.3 human conflict

Human conflict can be traced back to our two genetically closest relatives, *Pan troglodytes* and *Pan paniscus* (Boehm, 2012). Certainly, for Kinzey (1986), all three live in bounded social and fight with conspecifics, along with a significant amount of interactive dominance-and-submission behaviour that

can result in conflict. Indeed, competition and conflict among and within species, for food, mate or for a place to live, are all implicit features in the process of evolution and in consequence, to human biology (Jasny, Roberts and Vignieri, 2003) . However, different to our ancestors, although humans are conflictive species, we have developed intergroup conflict management (Boehm, 2012). Mainly, since as social beings, we have evolved behaviours to avoid the detrimental effects of intraspecies violence (Jasny, Roberts and Vignieri, 2003).

In this sense, conflict for Diez et al., (2006) is a struggle between people with opposing ideas, needs, beliefs, values or goals. They add that conflict denotes the incompatibility of subject positions. For Deutsch (1973) conflicts are classified based on their cause, namely: inequality of control over resources, difference in preferences and nuisance, difference in values and the nature of the relationship between values. Others (Pia and Diez, 2007), emphasise that at the heart of conflict, relies opposition and incompatibility and is not always characterised by violence. However, this research agrees with Easterbrook's et al., (1993) definition of conflict: '*the interaction of interdependent people who perceive opposition of goals*…[This] *definition highlights three general characteristics of conflict: interaction, interdependence, and incompatible goals*.' Easterbrook et al., (1993), further explores this issue and reports different stages of conflict. First, it starts as a *latent conflict*, where the conflict is there but the parties are not aware of their existence. *Perceived conflict* is noticed by some or all parties but is not explicated like a manifest of conflict is. Furthermore, Resendes and team (2014) refer to Furlong's (2010) work to look at the origins of conflict. In its work, five categories are identified:

Table 14 origins of conflict by category and components

Category	Components
Values	All values, morals, ethics and beliefs
Relationships	Negative past history or experiences
External/moods	External factors not directly related to the situation; however, they still have an impact and contribute to the conflict
Data	When parties have incorrect data or the interpretation of it is incorrect
Structure	System structure problems, such as but not limited to resources, authority problems and organizational structures

Source: adapted from: Resendes and team and Furlong (2010; 2014)

In this sense, for Sandole et al., (2009), conflict occurs in all kinds of human relationships and is neither good or bad, the matter in which is approached or how it is responded to, is what ought to determine whether it is constructive or destructive. Indeed, Deutsch (1973) and Niemantsverdriet et al., (2017) corroborate this point and suggest that conflict does not necessarily lead to a negative outcome, as in some cases, it could stimulate curiosity, prevent stagnation and lead to social change. In addition, conflict could be beneficial in establishing social norms and gaining an understanding of each other's needs and wishes. In fact, for Fisher (2000), lack of conflict usually signals the absence of meaningful interactions. Moreover, he argues that interpersonal conflicts arise when incompatible goals develop between persons or groups, the origins of these, however, are not stable and often vary. Although Harris and Looney (1999) do not deny this, they remark that conflict should always be considered as a serious issue since it makes behaviour less effective, thus, creating a serious impediment for performance.

Based on the previous conception of what conflict entails, the researchers conceives such concept around the notion of people's incompatibility and opposing ideas, needs, beliefs, values, goals and opposition of goals. Certainly, the researcher agrees with Deutch and Diez (1973; 2007) that incompatibility resulting in conflict is not always characterised by violence and under certain circumstances, may indeed lead to positive social change.

9.2.4 conflict in the computers' domain

Conflicts in computer science, yet, are different in relation to human conflict but still somehow alike (Furszyfer Del Rio, 2020). In the computer science dimension, conflicts could be the result of different users having different preferences, from multiple applications within one system compatible over a resource or from conflicting interests within one user, among others (Niemantsverdriet, van Essen and Eggen, 2017). On a similar vein, Shin and Woo (2005) report that the origin of conflicts occurs when applications share limited resources in the environment. Tuttlies et al., (2007) offers other narrative and identify conflict, with respect to a user application as "*a context that change that leads to a state of the environment which is considered inadmissible by the application of the user*". Within the smart home dimension, this research recognises that conflict could be mainly caused when two or more users access the same application. Nonetheless, they have different preferences, where, if preferences are strong, conflicts are more likely to manifest (Deutsch, 1973). In this sense, Al-Bin Ali (2004) reveals two categories of conflict based in their technical recognizability and Thomas and

Kilmann (1978) cover interpersonal conflict through a two dimensional approach. While, Coombs (1988) suggests three types of conflicts

Table 15 Categories and dimensions of conflicts

Categories and conflict dimensions	
Technical recognizability	**Interpersonal conflict**
Explicit conflicts: those that are directly identifiable by a system by a system by examining behaviours	Assertiveness: the extent to which a person attempts to satisfy his own concerns
Implicit conflicts: these are consequence of "hidden factors" such as moods and human intentions.	Cooperativeness: the extent to which the person attempts to satisfy the other person's concerns

Source: Adapted from Ali-bin Ali (2004)

Table 16 three different types of conflicts

Types of conflict		
Type I	**Type II**	**Type III**
Conflict within a user, who must take an option	Conflict between users who must settle for the same thing	Conflict between users who want the same thing but must settle for different ones

Source: adapted from Coombes (1988)

Resendes and team (2014), provides different classifications, grouped in four categories: 1. source, 2. time of detection, 3. solvability or 4. intervenient. Key for this research is the last category from Resendes et al., (2014) work, same that can be divided into three subthemes. First, single user, in which one user has conflicting intentions (e.g. comfort and energy savings); second, user vs user, when more than one user coincide over a certain device/service and finally, user vs space, when user actions conflict with any established space policies. A deeper analysis is provided by Niemantsverdriet et al., (2017), when they Identify three types of conflict: 1. preference conflicts, 2. activity conflicts and 3. attitude conflicts. Where the preference conflicts (the most prevalent) are situations where users are engaged in the same activity but prefer different settings for the same activity. Activity conflicts arise because people simultaneously engage in different activities that have different requirements. In this sense, they conclude that multi-user interaction should be built upon natural ways in which people

handle conflicts in their everyday routines. This, with the expected outcome of fitting interactions within the social context.

Moreover, conflict could arise as a consequence of lack of resources. For instance, service conflicts occur when multiple users access services and then services have to choose one user to provide a customized response (Shin and Woo., 2005). On a similar way, resource conflicts could also be consequence of several services attempting to share the limited resources simultaneously. As a result, applications commence operating without possessing all needed resources and users receive incomplete services (Shin and Woo, 2005). Sorensen (1994) stresses that indeed, technologies' domestication rarely is a "harmonious process". But rather, conflict is a natural step on the domestication method since it involves negotiations between householders. In turn, conflict can arise as smart home technology users become main, partial or even non-users.

The nature of conflicts is reported by Niemantsverdriet et al., (2018). For them, IoT designers do not always recognize shared use of technologies as it is often emphasizing the individual, with personal pre-sets and profiles in mobile phone applications. Indeed, Lucero et al., (2016) Illustrates this, in their study, they argue that smart lighting allow highly individual interaction which could bring issues in the multi-user home context. As with other smart home technologies behaviours and pre-sets rules are most likely to be identified individually, with often one main user which defines the interactions for others (Niemantsverdriet, van Essen and Eggen, 2017). Certainly, this results unsurprising given that the shared nature of IoT devices can be difficult to recognize. Based on this, Bernheim et al., (2007) suggest that is paramount that "*developers need to consider whether or not technology they are developing should support sharing* (Pg. 125)". This is further corroborated by Rodden et al., (2004) when they conclude that interactive devices should be reconfigurable in terms of placement and assembly, to not only support but also enable users to share information.

9.2.5 Human computer interaction and conflict

Different to a common system where users can directly interact with systems through explicit orders (Resendes, Carreira and Santos, 2014). In a smart environment, as noted by Cook and Das (2004), the system possess the ability to autonomously acquire and apply knowledge about an environment and to adapt to its inhabitants. However, context changes frequently since users' preferences change over time and are influenced by mood, motivations, goals and needs (Hasan *et al.*, 2006). In this sense, cognitive psychology's perspective could help complementing this thought, since it shows that preferences are constructed in the moment rather of elicited memory (2006). This, within the context of smart home technologies, makes preferences less static than the preference rating in user profiles.

Since in many instances, behaviours are subjective and inconsistent, thus, inaccessible by common-non intrusive sensors (Hasan *et al.*, 2006). In this context, technologies must possess the abilities to obtain information about the user and ongoing activities to infer context, whilst allowing users to stablish their preferences that tailor to the systems' needs. Hence, technologies would be capable to anticipate users' needs based on past behaviours and incorporate implicit and explicit feedback to tailor its services (Resendes, Carreira and Santos, 2014).

In this sense, most smart home systems are controlled through mobile phones which makes this interaction highly individual (Lucero, Lashina and Terken, 2006). A similar approach is found in interfaces, since are often designed from the perspective of individual users; however, these are often shared (Bernheim and Inkpen, 2007) . In contrast, as noted by Niemantsverdriet et al., (2017), homes are often presented as a social environment, inhabited by families, housemates or couples. In this way, the actions of one user may affect others, that is, during a precise moment, each user's intentions can be different. As a result, each user will want a different scenario setup. However, as shown by Resendes and colleagues (2014), given that these scenarios cannot be activated simultaneously on the same space, then it is safe to say there is a conflict situation.

Moreover, the link between conflict and smart home products is further explored by Markopoulos (2005). In his work, he notes how technologies are often built to go beyond problem solving and system adaptation, but also, entail the ability of a system to interact socially with people and thus becoming a socially competent agent in the group interactions it supports. This thought is supported to what Vernon (1933) defines social intelligence as a person's ability to "… *get along with people in general, social technique or ease in society, knowledge of social matters, susceptibility to stimuli from other members of the group, as well as insight into the temporary moods or underlying personality traits of strangers*".

Indeed, a key area in smart homes is shared technology, a theme early approached by Randall (2003), where he identifies two settings of personalisation (adjusted to the users' needs) and integration (open for all family members). Based on this, Bernheim and Inkpen (2007) go further and discuss two other approaches. The first, is the appliance model, where devices can be used by anyone and rely on social protocols to mediate sharing (refrigerators, kettles, toasters, shared TVs etc). Whereas devices that use the profile approach, ask users for their credentials to login. Moreover, in their research, they suggest that profiles are not made for privacy but rather as a mean for personalization of features in the home. In order to be non-intrusive, smart technologies often act based on the state of devices, objects, places and people. This notion of state is frequently referred as context (Dey, 2001). When devices detect a change in context, systems thus react based on a set of previously defined policies

and rules. In this sense, the system's behaviour is based on context-awareness and results in an automated response to context changes (Resendes, Carreira and Santos, 2014). However, in a smart home, the possibilities of having multiple contexts interacting with each other is beyond likeable. Which in turn, can generate conflict with other users.

Indeed, the intersection of HCI resembles similarities with human conflict, as in this situation, struggles may also emerge due to incompatibilities. In this context, the actions of a particular user upon certain device may affect other individuals' preferences, modifying, in turn, specific technologies' setups which cannot be operated simultaneously by different users; situation that may lead to conflict, not only amid technologies but also between users.

9.2.6 Conflict resolution

Working from the premise that conflicts in smart homes often occur upon systems keeping track of users profiles and then storing user ratings, setting and preference (Niemantsverdriet, van Essen and Eggen, 2017), research suggests (Shin and Woo, 2005) that a strategy to mediate conflicts between users could be through profile merging. Other approach is taken by Shin et al., (2010), when they suggest two means for conflicting resolution. First, weighted alternative, where is weighted the importance of each preference and second, majority rule, where votes are counted. Another alternative is leaving conflict resolution to technology itself for explicit conflicts and those related to implicit conflict (been more difficult to recognize) could be solved through user control (Shin and Woo, 2005; Niemantsverdriet, van Essen and Eggen, 2017). The latter has already proved successful, by Lucero and team (Lucero *et al.*, 2007) exploring lighting system for the bathroom environment. They found that people prefer to deal with conflicts themselves, rather than having a system to mediate preferences for them. In turn, the interaction with lighting systems becomes less complex. Or Niemantsverdriet et al., (2018), who explore three lightning varying in type of social information and different interaction styles. The team found that, in general, people preferred to make small adjustments to the current settings themselves, in order to minimise the impacts on others.

Moreover, Shin and colleagues (2010) conclude that to resolve conflicts of multiple occupants of a smart space, two approaches must be implemented. First, automatic resolution, that is when the decision is simple or close to what all users expect and leverages the relative priority of users. And second, social mediation, which involves negotiating a resolution and it acts by suggesting possible candidates. This approach is often used when decisions are complex of different from at least one of the users expects. Moreover, social mediation, allows users to select their preferred settings in consultation with other people. This approach works based on information and decisions from a group

of people sharing an application in a determinate space (Dey and Mankoff, 2005). In social mediation, however, Shin et al., (2010) add that the final decision can be classified in two steps: face-to-face discussion, to debate recommendations and selections and voting, which results convenient when users are unable to directly communicate with each other. Thus, without assistance of technology, people are usually aware of other users and hence, it is often to resolve conflicts by discussing or yielding their privilege to use the technologies. Meerbeek et al (2014) experiment could help illustrating this, in their work, they tested 40 offices controlled venetian blind systems and found that in three out of four, users were not satisfied with automatic mode and due to poor communication users, switched it off completely.

Now that the author has introduced conceptualizations and its own conceptions of the themes that are next explored, the reader may more easily contextualise the results presented below along with the discussion and conclusions sections

9. 3 Results

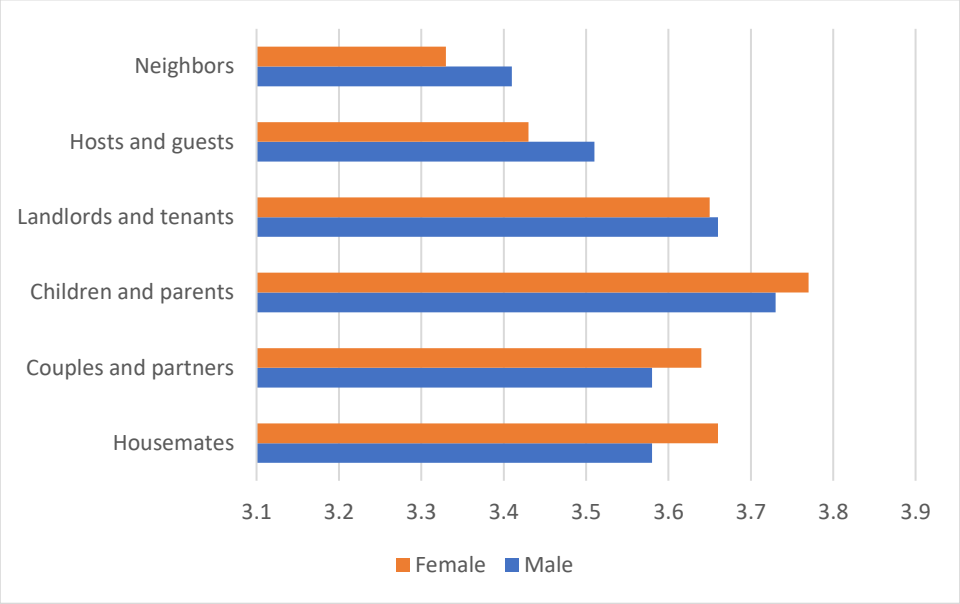
9.3.1 Presenting conflict within households

The qualitative data collected for this study, strongly suggests that smart home technology enable conflicts within households and neighbourhoods (Furszyfer Del Rio, 2020). To give a few examples, in the open-ended questions on the survey, where respondents were permitted to enter statements directly, one participant, for instance, commented that "*I have nothing positive to say about smart technology. Woke up my whole neighbourhood at midnight".* Another female participant on the survey comedically expressed*: "My children stopped asking me questions and kept asking Alexa.... they would change my music and I'd end up listening to baby shark over and over, Alexa now lives with my sister as she wouldn't take the kids".* And, a female respondent from the focus group in London, commented that:

> "*My sons from time to time would disappear upstairs. I think technology is taking away our family time, that makes me angry and we usually argue about that. To avoid fighting, I had to resort to things like switching off the router and then pretending I hadn't*".

In this sense, the six emerging themes that this research explores are conflict with (1) housemates, (2) couples and partners, (3) children and parents, (4) landlords and tenants, (5) hosts and guests and (6) neighbours (Furszyfer Del Rio, 2020).

Figure 33: Differences in mean scores for the 'Smart home technologies could lead to conflict in the home related to' (Likert scale of 1 to 5, with 5 = strongly agree)

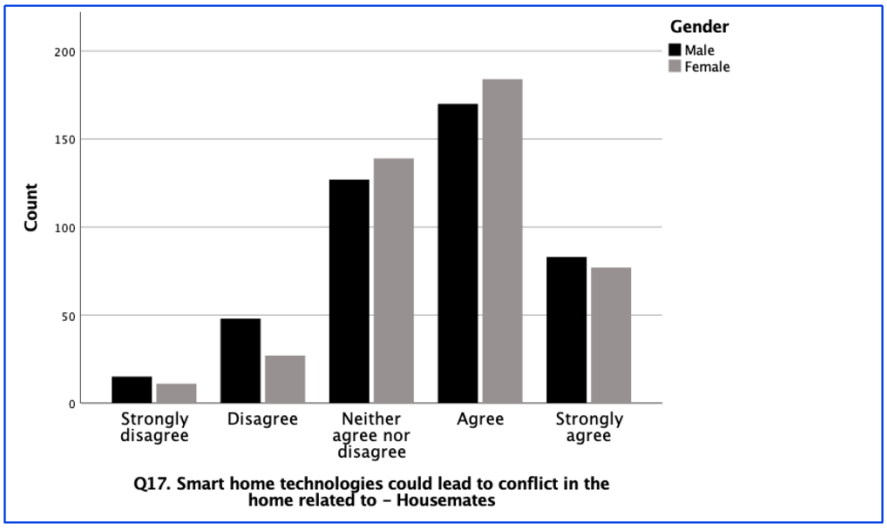


Source: author

These findings show that that both male and female respondents agree that smart home technologies could enhance conflict particularly between children and parents. The second source of conflict were both mostly agreed, was between hosts and guests. This was then followed by conflict among housemates, couples and partners, hosts and guests and at the end, conflict among neighbours (Furszyfer Del Rio, 2020).

9.3.2 Smart home technologies as enablers of conflict with housemates

Figure 34 Differences in survey counts for 'Smart home technologies could lead to conflict in the home related to housemates'



Source: author

The results indicate that most participants agree that smart home technologies could lead to conflict in the home related to housemates. Indeed, in its work, Anderson (2014) reports common reasons why flatmates fight with each other. Anderson identifies money issues as a key source of disputes between flatmates and within that, splitting bills comes first. A female participant from London clearly expressed how her concerns could be addressed through the use of smart home technologies when she mentioned: "*I am tired of paying after my flatmates' mistakes. Bills come unbelievably expensive because they leave the heating on during the night and throughout the day"*. She continued "*Remote control, ultimately that's what we want from smart tech. For example, I could limit the use of electricity by my housemates if I'm not there. We could actually stop arguing about bills and cut on unnecessary expenses*".

Anderson (2014) further identifies antisocial noise and lifestyle differences as key reasons of conflict. Regarding how smart home technologies could originate disputes within households in this area, R29 commented: *"The most promising aspect of smart home technologies is to have automation devices that understand, what I like to call, rhythm of life, which basically means consumption needs; so when do I need to drive and when do I need to turn my heating on. I don't think technologies reached the point where they understand households' dynamics that well to keep everyone in the house satisfied"*. Although, Taylor and colleagues (2007) argue that this would be able since people use information clues to coordinate behaviour among each other. In this sense, they contend that "*is people that induce their homes with intelligence by continually weaving together things in their physical worlds with their everyday routines and distinct social arrangement*s" (15 p. 383). Thus, for them (Taylor *et al.*, 2007), the smartness of devices is found in the way individuals use and arrange the objects in the physical world, allowing, in turn, to understand users' rhythm of life.

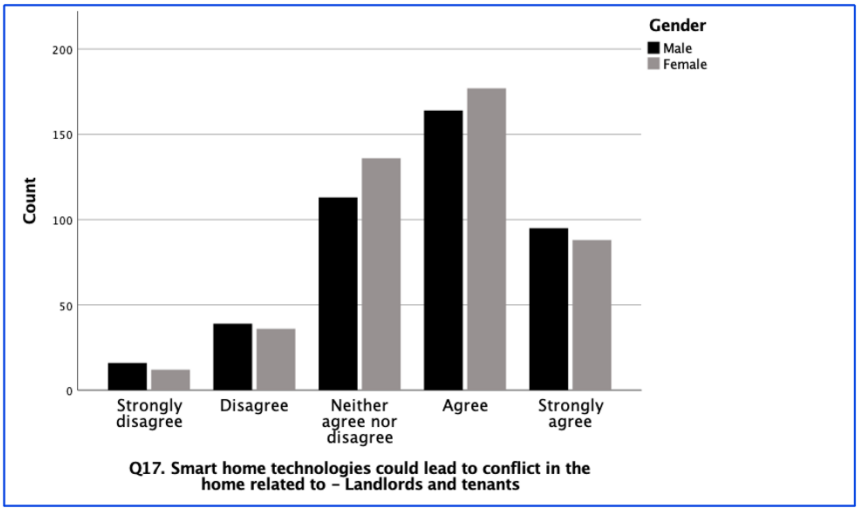
Others highlight the kitchen as a prime area to fight given the utilisation of appliances, time spent in the area, space distribution and not respecting other people's belongings (Ah-Kin, 2011). To this, FGMM mentioned: "*I came across a camera you put in your fridge. I imagine you can use it to stop others from stealing*". Certainly, Vanus et al., (2017) argue that monitor indoor environments is among the main uses for smart home technologies; however, issues around intrusiveness and privacy as highlighted by Hern (2018), could lead users to stop using smart devices in its totality. To this, FGLM commented: "*I first bought [SHT] because I thought it was cool, but I don't want to use it now that I've learnt more about the intrusiveness and the interconnectedness… I don't want to be surveyed in my own house by someone else"* Or M592 who wrote all in capitals: "*[SHT] are an invasion to our privacy. DONT USE THEM!"*. A more in-depth answer was provided by R24 when they explained:

> "*So, a bit of my work is on surveillance with a lot focus on the user and whoever is spying on them. And now you see things like the internet of things or any other stuff within your home, suddenly is not necessarily about your relation with some external frat, but about people you live with, because it's their nature as well and the systems cannot tell between who's dangerous for you and who you present your data to*"

Other reasons why flatmates fight is due to lack of space to socialise. Saner (2019) reports that that landlords are converting communal spaces into bedrooms, depriving tenants of areas where they can socialise. In turn, this has negative repercussions for the health and happiness of the 'Generation Rent'. These results are corroborated when a research conducted by The Times, reveals that 90% of advertised rooms in London had no separate room, with communal spaces turned into bedrooms.

9.3.3 Smart home technologies as mediators or means for conflict between tenants and landlords

Figure 35 Differences in survey counts for 'conflict in the home related to tenant and landlord'



These findings illustrate that both females and males agree with the idea that smart home technologies can enable conflict in the home between landlords and tenants. In fact, according to participants, this was the second most rated source of conflict, just after parents and children (Furszyfer Del Rio, 2020). In its work, Crosby et al., (2003) identifies that a source of fight between both concerns pressures in leasing. Other reason why tenants and landlords fight is adequate notice for inspections (Anderson, 2017). Property Rescue's (2018) study shows that almost half of UK tenants interviewed have had a fall out with their landlord during their tenancy. The main reasons described in their study are: landlords were unapproachable, damages in the property and/or broken appliances, denning tenants to decorate the property and property's cleanliness. Belvoir (2013) identified similar issues but adds unclear communications between parties. Upad, on the other hand, notes that boiler breakdowns are the main source of conflict, followed by drain issues and white good repairs (Upad, 2020).

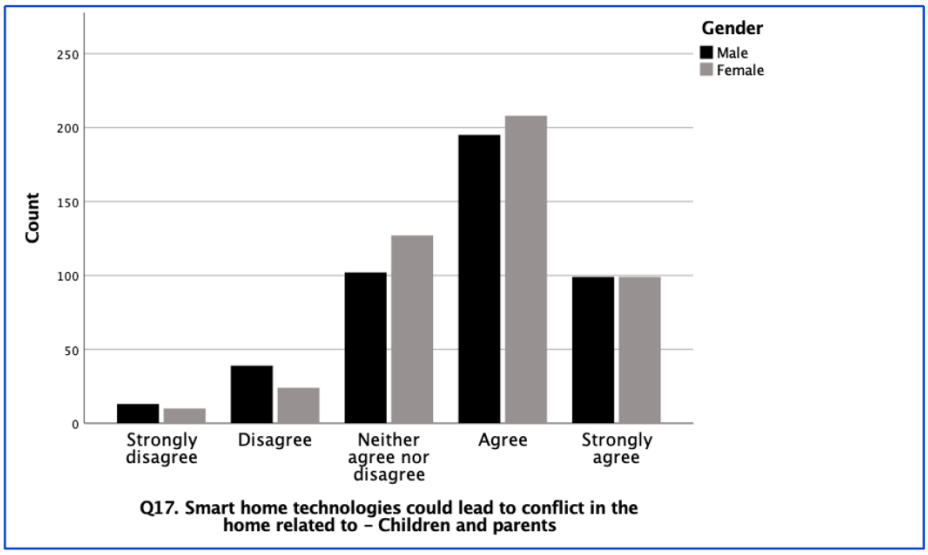
In this research, experts and focus groups participants identified not allowing tenants to decorate or bring their own technology to the property as main source of conflict between parties. Indeed, in this work, government, industry groups and international organisations, highlighted the importance of consenting tenants to install smart technologies to facilitate a low carbon transition and thus, enabling services such as demand side response (Furszyfer Del Rio, 2020). To this, R16 mentioned: "*only around 20 to 30 percent of people actually own their apartments, the rest they just pay the rent. So, I'm wondering whether the owners would be interested in investing in these technologies*". R17 corroborated this point and added: *"Many people live in rented properties, neither them [tenants] nor the landlords have any incentives to install and invest in more efficient technologies or insulation*". Finally, R31 further explored this issue in her own experience:

"*I mean there is a lot of people who aren't going to be incentivise to buy this sort of technologies and landlords are not incentivised to give it to them either. I think property ownership it's been a huge barrier for us with the smart meters and I think it's been a huge barrier for any other areas. So, one of the things that we found is that tenants are really keen to take up on smart meters, but the landlord-tenant relationship is a massive blocker for that. In many cases, we have heard this could lead to a fight or could be a reason for leaving the property. More, since they have the right to have it install but they are too worried in case the landlord says no. We have seen it in other areas, so if you look at the rollout of super-fast broadband, governments now they have to intervened because landlords didn't give it access to broadband fibres to go and install superfast connections*"

Aubry, on the other hand, (2015) reports that most complaints from landlords are related with tenants are disruptive visitors, conflict with other tenants, constant presence in their apartments and poor upkeep to units, in addition to conflict with neighbours and provocative behaviours.

9.3.4 Smart technologies as enhancers of conflict within families

Figure 36: Differences in survey counts for 'conflict in the home related to children and parents'



Source: Author

This was the source of conflict where the majority of participants agreed: technologies as facilitators of conflict between children and parents. Indeed, circa 200 males and 200 females agreed with this idea and around 200 strongly agreed on smart devices as facilitators of conflict. In this sense, the most frequent source of family conflict, at least in Canada, Spain and the United States is between siblings (Desir and Karatekin, 2018). Indeed, Doherty (2010) reveals that four out of five siblings will 'torment' one another at some point during their childhood. Felson (1983) identifies that sibling aggression is almost always explained in terms of jealousy or sibling rivalry from the elder towards the younger due to lack of attention from their parents. Felson (1983) further argues that households themselves promote conflict between siblings given that they will compete for property, space and other tangible goods. Since children, often share these goods, conflicts may arise when they desire access to goods at the same time. As mentioned above, a similar dynamic is presented in smart home technologies, as reported by Shin and Woo (2005), the origin of conflicts occurs when applications share limited resources in the environment.

This same issue was brought by a mother from Surrey, when she explained that: "*They [SHT] do not all work together. Specially, when everyone is home. I have God knows how many apps in my phone to control things. Now, we don't use it them longer because it's just too annoying."* In this sense, Goulden (2019) recognizes practices concerning domestic organisation in the form of controlling other households members and households objects. Goulden uses Google Assistant as an example since it can recognise up to six individual voices and assign them to their correct account. Hughes et al., (1998) further supports this issue and shows that family members used other members' routines to avoid simultaneous use of appliances and thus avoiding conflict.

Further sources of conflict are identified by Yu (2019), who shows that family income represents another source of parental-child fights, since economic pressure leads to parents' depressed mood, which as a result, disrupts both, marital relationships and parenting. Indeed, A dad from London explained that children wanting the newest gadgets create pressures on them. He later commented that children in school usually contribute a lot to this issue since recurrent conversations from children are around having the latest technology, he said that "*This generally makes life more complicated and more expensive. It is impossible to always be on-trend with children's demands".*

Further research has explored the use of how technology affects household dynamics. For instance, mobiles phones, according to the University of Southern California (USC Anneberg, 2018) are a cause of conflict in a fifth of Britain's families. Parents in the study rated screen time as one of the top sources of regular conflict between them and their children, since these devices interrupted conversations and disrupted meals. This dynamic was clearly expressed by FGLF when she expressed: "*myself, I really*

tried to stay away from that [mobile phones] as long as possible, but our kids said, 'we needed them'. Now, instead of saying: 'children come home, is getting late' is more like a feeling of 'go out and meet people'. Like when I was a teenager, the way to meet somebody was to go to a bar with your friends and now it's all online through phone dating apps and stuff".

However, despite a sense of anxiety and conflict, parents and teens felt largely optimistic about the benefits these devices bring (USC Anneberg, 2018). This emotion was nicely captured by FGLM when he expressed*: "Despite my nightmare scenarios, I'm positive about it [SHT]. It may seem really odd, but I am. I hope, that we're going to a point where we start to legislate more personally, and people are going to legislate for us, so we can get more control over these things".*

Other source of conflict is related to monitoring children (Furszyfer Del Rio, 2020). As shown by Hawk and team (2009), this could lead to negative outcomes as they reveal that if parents engage in highly intrusive behaviours over their children, it may backfire on them and children may adopt more secretive conducts, enabling parents to know less about their children's activities and whereabouts (Hawk *et al.*, 2009). A similar case was mentioned by a male participant from Surrey and how the use of smart monitoring systems led to conflict in his house: "*I have discussed this with my family, but my son absolutely hates being monitored. He hates it. I have tried convincing him that I am not monitoring his whereabouts, I just want to know he is safe and the place he is, is safe too. But he's not happy with it*". Indeed, research (Weir, 2016) suggests that the technology of parental control has evolved so rapidly there are not yet clear norms of what is acceptable or even healthy in terms of demarcating the boundaries of monitoring.

Goulden in his work (2019) helps illustrate the previous point. For instance, Amazon's Adults accounts can control what media and apps a Child's account can have access to, allows the controlling adult to view their child's browsing history, set time limits on account use and set educational goals. Google's Families operate under a similar basis. Parent and Family Manager enables the registered adult(s) to view purchases made by Family Members and exercise control over other users' purchases. That could happen with a parent too, although, in Adult's Accounts, the purchaser can vanish any family member. In the digital world, separating a family member from an account does not require much effort. For Goulden (2019), the ejection from a digital service will only depend by whichever account manager clicks first; within Families, whichever individual created the original Family Manager account is invested with the ultimate power.

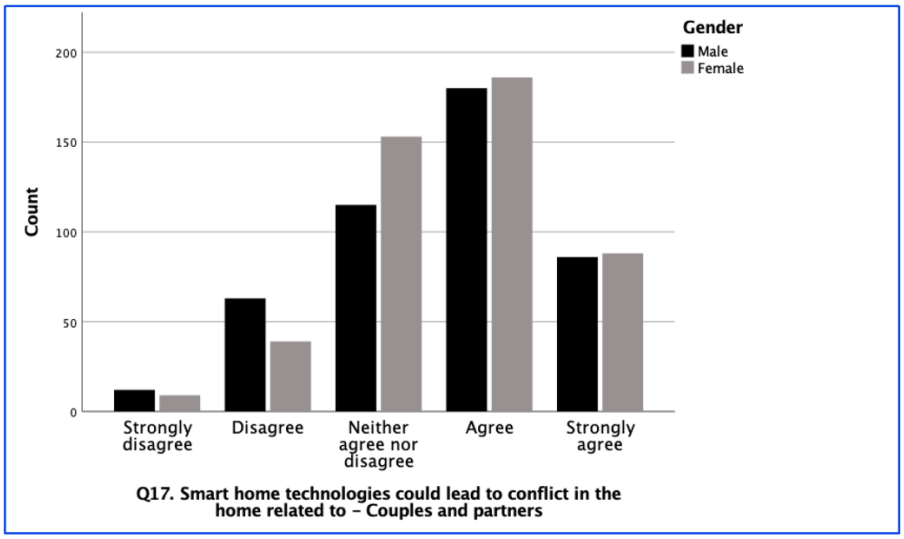
Another source of conflict is noted in the report from The Enemy Within from BBC (2012). The report shows that out of the 1,018 families surveyed, four in ten said family conflicts involved making another person feel stupid (BBC, 2012). Indeed, one male participant from Surrey confirmed such

practice when he mentioned: "*My parents and my boyfriend, they're useless. They can't do anything. I end up sorting out all their electricity bills, switching their contracts and setting up all technologies. Sometimes it is quite frustrating explaining to them how to operate certain devices*".

Finally, research conducted by Quinlan (2020), revealed that children have expressed feelings of loneliness or of not belonging in a family where use of technology is high; lack of communication within family members could, in consequence, have negative impacts on the social and emotional development of children. Quinlan (2020) further warns that: "*Devices are used to pacify small children of three or four years of age… where once a toddler would have learned to manage difficult emotions through interacting with a parent who would help them regulate their feelings, now they're being handed a tech device. The interaction with the parent is not happening."* This idea should certainly raise concerns as to the long-term impacts as children could lose negotiations skills. Possibly, one female participant from Surrey anticipated a similar scenario, as she expressed**: "***A lot of my friends and myself who have got kids have Alexa. And we have to be very careful how we speak to her. We say please and thank you to our Alexa, so that you don't just say: 'Turn the lights on!', you say: 'Please, can you turn the lights on, Alexa,'. Because kids can't just bark at somebody".*

9.3.5 Smart home technologies and conflict between couples

Figure 37 : Differences in survey counts for 'conflict in the home related to Couples and partners'



Conflict between couples and partners came fourth and surprisingly, not all perceptions were negative, in fact, a female survey participant commented that: "[SHT] *they can provide a way of aiding relationships".*

A report from the Council of Contemporary Families (2018) reviewed a variety of different households tasks such as shopping, laundry and housecleaning, and found that women reported that doing the dishes was the main source of conflict. In fact, the research shows that couples who share dishwashing responsibilities seem to have a better relationship (Carlson, Miller and Sassler, 2018) Faulkner and colleagues (2005) found that equity, measured as an index of fairness, including domestic chores, spending money and working for pay did not affect couples' satisfaction; however, when wives reported higher levels of inequity, husbands reported greater marital conflict. Similar results are found in Dew and Wilcox's (2011) research, when they reveal that decline in marital satisfaction for new moms was linked to both increased domestic chores and to increased perceptions of housework inequity.

The previous academic studies seem to indicate that among the main reasons of conflict between couples is housekeeping and equity. Smart home technologies, however, could help in alleviating this, since its promise is to make users' lives easier by acting as 'proverbial butlers' and anticipating users' behaviours and needs (Chen *et al.*, 2017). From this narrative, certainly, SHTs through learning algorithms can allow the automation of certain household chores and it turn, this ought to result in enhanced convenience to users. R20 illustrated this idea when he said: *"you've got people trying to sell the robot vacuum cleaner model because who the hell wants to vacuum. So, the robot does it for you".* On a similar vein, R18 reflected that: "*these devices ask very little from the consumer in terms of how active they need to be, they don't require changes in behaviour, they just make existing behaviour more effortless or easier*."

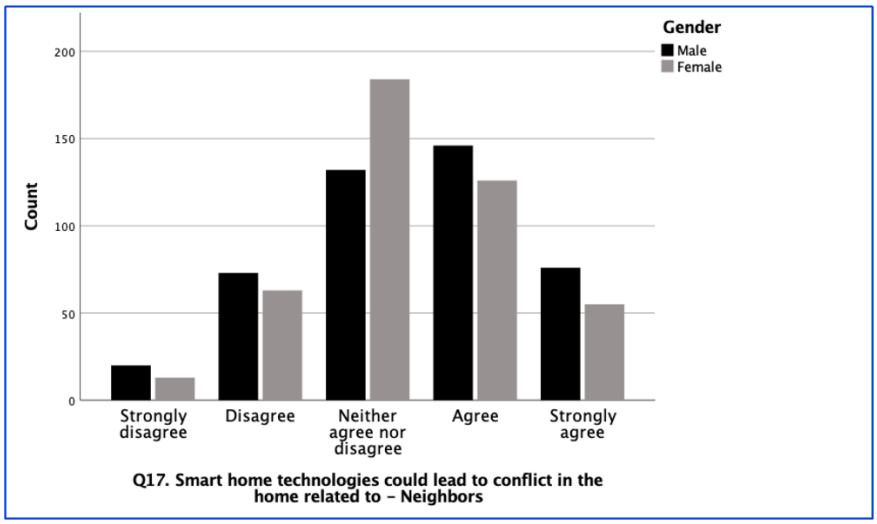
Another source of conflict is presented by Deloitte. In their study (2018) they show that the use of technology, particularly that the 'overuse'[9] of smart phones, is causing conflicts between co-habiting partners (Deloitte, 2018). Another study amongst teenagers found similar results: teenagers who were more dependent on their phones reported being less certain about their partnerships and felt less satisfied in their relationships (Lapierre and Lewis, 2018). On this matter, Lapierre commented in an interview (2016) " *I don't want to say it's uniformly negative [smart phones], but definitely hints in that direction*". Beyond smart phones, IoT devices pose a specific set of challenges in domestic violence contexts, challenges which are just recently being recognised by (Bowles, 2018; Diana Freed *et al.*, 2018b; Lopez-Neira *et al.*, 2019) and in this research. In the focus groups, issues around cyber abuse perpetrated by partner or ex-partners were also presented. To this, FGSM expressed: "*I think there*

[9] According to the Deloitte's study, more than 33% of UK adults look at their phones within five minutes of waking up and over 50% do the same within a quarter of an hour. A recent report from The Guardian reveals that people generally spend an average of 3:15 minutes on their phones every day, with the top 20% of smart phone users spending upwards of 4:30 hours. Users on average will also pick up their phones 58 times a day (Mattei, 2019)

are issues that could arise especially in unhealthy relationship where one person is more tech savvy than the other. You don't know quite what monitoring equipment they might be putting on, let's say, the bedroom, the bathrooms". Or FGLF who concurred: "*I don't know if you watch Coronation Street… a gentleman and his partner have split up and he left a camera in her house, so he's been watching her from his house, so that goes on".*

9.3.6 Neighbours fights

Figure 38 Differences in survey counts for 'conflict in the home related to neighbours'



Results from the survey indicate that conflict between neighbours is the least likely means of smart home technology as an enabler of conflict (Furszyfer Del Rio, 2020). Literature in this area identifies that among the main reasons why neighbours fight is because they fail to behave responsibly, noisy and are troublesome (Laurier, Whyte and Buckner, 2002). Where in lower income suburbs in Australia, neighbour interactions are reported to be more intense as residents rely more heavily on their neighbours for social support (Boyce, 2006). In turn, prosperous suburbs retain a culture of privatism and moral minimalism that creates trouble-free-environments (Laurier, Whyte and Buckner, 2002; Cheshire and Buglar, 2016). Based on these premises, then we could argue that privacy, allows a conflict-free space and in contrast, proximity creates an environment for gossip, dispute and social conflict (Percival, 2000). In this research, participants' experience described different situations where their privacy was violated by SHT. For example, F366 commented: "*Not to my own, but my neighbour's Alexa picked up my voice through the walls once*". R24, brought a recurrent violation of privacy that affected both theirs and its neighbour's activities. They said that:

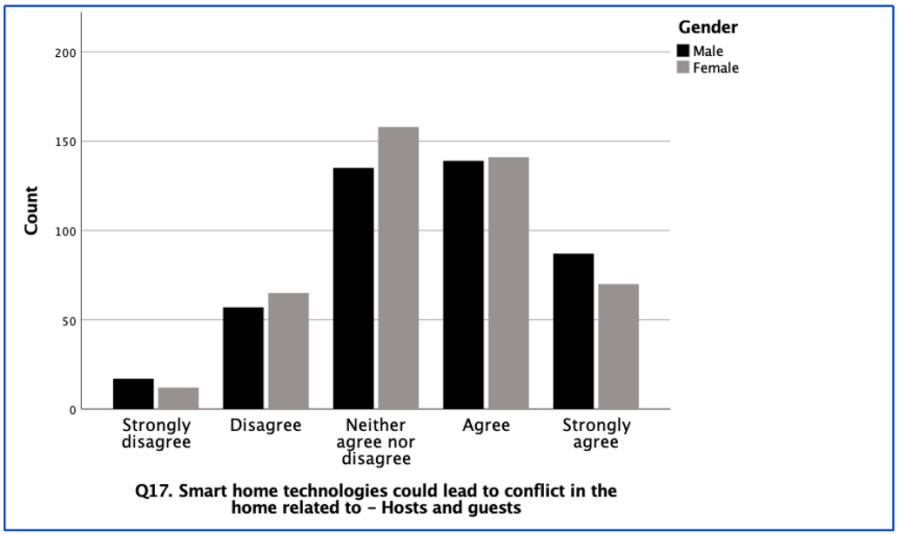
"On a personal experience, once I took over my neighbours' TV. Then, their daughter was watching TV and my YouTube streamed a first-person shooter video game. Video game not really programmed for your child. It happened because I had their Wi-Fi password when I babysitted for them, even though, it wasn't connected to their Wi-Fi at the time. But Google, obviously got it wrong because I have a smart TV, so they still have a Chrome Cast on a TV. So, Google is adding all this up and decided it was my TV. And it is still nowadays worst. Recently, because when they use Chrome Cast I get a notification pop up on my screen which gives me controls over it. So, the fact that they're my neighbours, it has no means of addressing, it just has to make a kind of inference about intimacy, which is you've got the Wi-Fi password. The other thing is like how complicated it is domestic life in terms of where the boundaries lines are. So, they're not even in my family and now, my technology overlaps with theirs. So now we run into problems with where you get agency over one user to another."

Citizens Advice notes that anti-social behaviour such as making a lot of noise, dumping rubbish, pets and using someone else's garden without permission are common sources of conflict amongst neighbours. The Metropolitan Police (Metropolitan Police, 2020) corroborates such types of conflicts but adds overgrowing trees and children playing in the street. Indeed, 500,000 complaints were made to local councils in the UK by individuals concerning their neighbours, pets and property (Smithers, 2014).

However, it is not all negative! Smart home technologies could also offer a service to enhance relations among neighbourhoods, for example, R27 explained that: "*In the energy dimension there are possibilities to trade energy services directly with neighbours and so forth. There are certain sectors of the population that distrust energy providers but trust their neighbours. However, if something goes wrong in this business model, I can see lot of issues arising from it*".

9.3.7 Conflict around guests and hosts

Figure 39: Differences in survey counts for 'conflict in the home related to hosts and guests'



The author did not find academic literature in this area and the thin evidence found in non-academic literature, namely blogs and webpages were not helpful in situating the findings from the survey, focus group and expert interviews. Airbnb (2018), for instance, notes that a common source of conflict between guests and hosts is the conditions in which amenities are found and any damage that guests could do to the property (from breaking a plate to a smart home auto-temperature regulation). To further explore common sources of conflict between hosts and guests and link these to the results, the researcher searched in Airbnb blogs and common complaints websites, however, the researcher only found that common themes were around hosts behaving unresponsively towards guest(s), the property was not safe or clean upon arrival and appliances did not work well (Airbnb, 2017). Results from this research link issues related to privacy and conflicts between guests and hosts (Furszyfer Del Rio, 2020). In fact, a tension was found in the focus groups on this matter when FGSF expressed: "*I'm a self-employed cleaner. You never know when you go in somebody's house and I mean, I'm reliable. I'm fine and I really don't care if they had surveillance cameras installed. But in theory, I think you must tell some-body that they're being viewed."* FGSF concurred and mentioned: "*you should be made aware of that, because that's a bit weird if they don't. If you know you're being recorded, wherever you are, you should then have a choice*. *However, I'd find it quite hard to tell someone there are cameras in my house".*

9.4 Avoiding conflict within households: Tangible examples and a way forward

As this chapter presented, the majority of conflicts within households emerged from the use of voice control systems, such as Amazon Alexa and Google Home. Although in fewer numbers, other

conflicts arose regarding the use of security systems, smart TVs and smart heating systems (see for example quotes from R24, FGLF and FGFM). The author of this PhD argues that conflict within households should take more relevance given that smart home technologies work based on the premise of constant personalization and integration. In this research, identified as levels of smartness three (automation) and four (learning).

A technology that did not arise as a mean of conflict in this research but has previously been explored is lighting. For instance, Offerman and colleagues (2014) studied motivations, needs and wishes of people when interacting with lighting in home environments. Their study shows that users possess different levels of lighting needs and these are highly dependent on context, state, the author argues that requires control at different levels of smartness. Offerman's et al., study (2014), aligns to the results of Lucero at al., (2006) which show that people will prefer to solve conflicts with themselves, rather than having a system mediating the preferences for them. Users, under these circumstances, decide to change their focus to reduce complexity of interaction with lighting systems (Lucero, Lashina and Terken, 2006; Offermans, Essen and Eggen, 2014; Niemantsverdriet, van Essen and Eggen, 2017). It is under this context where Niemantsverdriet et al., (2017) determine that multi-user interaction in lighting ecosystems is rather challenging and claim that answers on how to tackle these challenges are scarce. In their work, attempting through different means (voice recognition, graphical user interfaces and automatic behaviour) found that speech-controlled integration would be the most suitable to avoid conflicts. Other example that support the previous finding is provided by Magielse et al (2013). In their work, they explore how three different control structures (individual, shared and hierarchical) in lighting interfaces influenced how users behave in a discussion. Their results were translated into the design of a light controller device which not only work for the office environment but allow both, individual and shared control over certain luminaries.

The researcher in this context acknowledges that conflict resulting from smart home technologies would be prevail unless these technologies move to greater levels of smartness, better integrate into the system and adapt to different users' needs. The author, in this sense, proposes a mixed model in which technologies support awareness (identifies who is using the technology) and permits users quick interaction with technologies, but always minding individual personalization through learning algorithms, automation and service integration.

9.5 Conclusions

This study investigated how smart home technologies could enable conflict within households by drawing original data from a nationally representative survey in the United Kingdom (n=1,032), 31 expert interviews in the UK and Europe, as well as, focus groups in London, Manchester, and Surrey (n=18 respondents). The results show a prominent association between the use of SHT and conflicts within households. Particularly, looking at results from the survey, how these technologies could enhance conflict between parents and children (Furszyfer Del Rio, 2020).

Moreover, contrary to the optimistic marketing perspective of smart home technologies as a mean to ease users' lives and connect consumers with their loved ones, the results from this research suggest that these devices also have the potential not only to disrupt families' routines but also invade neighbors' privacy. In addition, people in the focus groups showed concerns about how these technologies could not only lead to conflict, but also, how in the 'wrong hands', smart devices could facilitate control, stalking and other means to perpetrate domestic violence and cyber abuse (Furszyfer Del Rio, 2020).

From another perspective, the data collected aligns to findings in the literature, which suggest that smart home technologies are changing dynamics and the very meaning of what a home is. As R2 nicely put it: "*Technology changes and adapts to understand users and we are not aware of that happening. Homes should remain a stable place in our world, but now, if all gets digital it could all change with a flip of a switch*". In this way, not only users need to have a better understanding of how these technologies operate in the real world, but industry as well as regulators, need to build smart devices with the idea that users will share information and that are going to be used simultaneously by multiple users.

Chapter 10. Discussion and conclusion

In this chapter, first, the overarching questions and sub-questions of this PhD are answered. The author, moreover, reminds the reader why a sociotechnical approach was used and notes five sociotechnical approaches to better understand smart homes. The researcher, later in this section makes a stronger case regarding the interaction of smart energy technology and actual energy use. This, in order to contest how sustainable these technologies really are. This is followed by the researcher presenting lessons to be learnt from behavioural change interventions in the improved cookstove field transferred to the smart home technologies dimension. Here, the author also discusses some similarities between both technologies and how their adoption and use may affect energy behaviours and household dynamics. Finally, the researcher presents the overall conclusions of this PhD and suggests areas for future research.

As mentioned above, the first part of this section centres its focus in answering the questions this thesis posed. Thus, to answer the first question of this PhD: In what ways do behaviour and behavioural interventions shape cookstove adoption? The researcher, based on the literature review analysis, indicates that for users to uptake improved cookstoves, households must have the opportunity (e.g. means), ability (e.g. knowledge) and motivation to first adopt these technologies and with time, learn how to use them correctly (e.g. without stacking) and continue with this practice steadily over time, not only during certain seasons. Indeed, from a sociotechnical perspective and as noted by Jürisoo, Lambe and Osborne (2018), this involves a series of elements that go beyond fuel options, but also, entails a series of choices, such as but not limited to purchasing the stove, use it to prepare each meal and to establish a new routine.

In addition, literature in the behavioural change field, indicates that people are more likely to change their behaviours if these require little effort (C. Sunstein, 2008; Kahneman D, 2011). In this sense, cookstove implementers ought to be skilful enough to persuade customers that these technologies are going to improve their lives without significant effort. Although, this is not an easy task, behaviour change techniques such as social support/social norms, through peer pressure, seem to have positive impacts at a very low cost and without much effort from policy makers and energy users to reduce household energy consumption (Mullainathan and Allcott, 2010; Allcott, 2011). Similar approaches could also be implemented at the community level for the sustained use of improved cookstoves.

Moving forward, to answer the first sub-question that emanated from this thesis: how do rewards (e.g. financial incentives and subsidies) influence in the adoption of improved cookstoves? This research found that although economic incentives are core drivers for the initial adoption of improved cookstoves, if the incentives are not maintained over time, the use of improved cookstoves may decline in some cases. Hence, although economic incentives increase adoption and use, which results in clear improvements in environmental quality and users' health, future and maintained use is not guaranteed through these policies.

To answer the second sub-question: do demographic factors shape decision-making regarding the adoption of these technologies? This research found that education, specially, women's education, as well as education beyond secondary school, played a role as a significant determinant to increase adoption and maintained use of improved cookstoves. Furthermore, this research also found that having a stable income influences in the adoption of maintained use, perhaps, since with higher family income, household members are able to pay for repairs. Moreover, household characteristics play a significant role too, mainly, in terms women's decision-making power, as female-headed households, since when women hold this position, households tend to adopt cleaner fuels and technologies. Therefore, it is vital to have broader understanding regarding gender dynamics as with this, it will be easier to advance future uptake of ICS.

To answer the third and last sub-question correspondent to chapter 4: How does social support impacts on users' perspectives of improved cookstoves? This PhD revealed that social relations have great influence on the diffusion and adoption of new innovations. Higher adoption rates can be achieved if, for example, organizations promoting improved cookstoves use in their marketing campaigns trusted individuals or leader groups to make improved cookstoves more desirable and thus, encouraging people to follow their example (Goodwin *et al.*, 2014). Moreover, this research through its literature review analysis, found that community engagement can help enhancing clean cooking practices and at the same time, programme implementers can rely on these social networks to promote local entrepreneurship and behaviour change practices that favour clean cooking methods.

Before answering the second main question of this PhD, the researcher makes this transition, linking back to the sociotechnical systems framework in the smart home dimension. In this sense, this research notes five sociotechnical approaches to better understand smart homes. Indeed, as reported in the publication (Sovacool and Furszyfer Del Rio, 2020a) resulting from this PhD, author and co-supervisor remarks the relevance of the following theories. First, Multi-Level Perspective

(MLP) approach which analyses socio-technical transitions by emphasizing regimes, dominant routines, and alternative spaces or niches. Second, Actor Network Theory (ANT) raises concepts such as “network assemblages” and “sociotechnical imbroglios” to focus on agency or politics, especially at the micro level. Third, the researcher presents the Social Construction of Technology (SCOT) same that stresses closure, frames, and the meaning groups of stakeholders give to technology. Fourth, Technological Innovation Systems (TIS) is the method that assess complexity and variation in large systems, however, it prioritizes the functional aspects of innovation (Sovacool and Furszyfer Del Rio, 2020a).

Moreover, this research signifies the importance of regarding smart home technologies and systems as more than a hardware, but also, as possible mechanisms for resource extraction; transferring wealth from developing countries to developed ones or even as systems of segregation (Sovacool and Furszyfer Del Rio, 2020a) . For the latter, the author suggest that this digital transition must work in tandem with democratic and socioeconomic objectives, especially those related with tackling exclusion and marginalization. As by 2019, according to International Telecommunications Union (2019), half of the population lacked internet access. To bridge this gap, the Alliance for Affordable Internet (2018) suggests governments to reduce costs to no more than 2% of average monthly income for one gigabyte of data. Others suggest to support local digital businesses and to reduce taxes on telecoms equipment (International Telecommunication Union and United Nations Educational Scientific and Cultural Organization, 2019). Whilst the researcher agrees with the previous suggestions, it also recognizes that connectivity alone is not enough, but also, issues around technological literacy (NCAL, 1999; OECD, 2000) and linguistics through the domination of the English language in software must be addressed (Montaner, 2018) . Further, policies to promote equal educational opportunities and access to hardware and software ought to be implemented in addition to investments in new roles of teachers and learners.

In this sense and to answer the overarching question in the smart home technologies dimension: What are the benefits, barriers, and polices for making smart home technologies more sustainable? The researcher first recognizes that lack of data to draw conclusions about how sustainable smart home technologies are, remains as a key issue to provide policy recommendations and enhance current regulation. However, the author of this PhD recognises that to improve the sustainability of smart homes, issues in the four following areas need to be addressed:

1- Social: policies need to focus in enhancing regulation from data control and restrictions, to encryption, to clear guidelines for ownership of data, as well as safeguards against hacking and piracy. The author of this PhD thesis emphasises that consumers’ protection

is a must for the successful deployment for smart home technologies. However, the author recognises that the European General Data Protection Regulation constitutes a first good scheme to enhance trustworthiness, to treat users fairly and protect them from harm (Véliz and Grunewald, 2018), by making data protection by design and by default a mandatory requirement (Information Commissioner's Centre, 2018). The researcher, thus suggest the amendment of two points of GDPRs in order to enhanced social protection:

- Paragraph 26 of the GDPR (The European Parliament and The Council of the European Union, 2016) ignores the fact that risks to privacy could arise after data collection due to inferential analytics (Wachter, 2019). The researcher, thus, suggests this legislation to be expanded to focus on data during and after analysis.
- Article 9 of the GDPR focuses on what constitutes sensitive data. However, the researcher proposes that sensitive data could be anything that is detrimental to users' privacy, even if revealed indirectly through inferential analysis.

2- Technical: In the technical domain, there is a need for both; innovation and technical learning, as well as the necessity of setting standards, especially to address obsolescence (guarantee longer product lifetimes and warranties) and interoperability (between devices but also technology providers). On the latter, this research indicates that when technology systems communicate with each other, their value increases, which makes interoperability key for maximizing benefits to users and the energy system. This evidence is further supported by a study conducted by McKinsey (2015), which shows that interoperability among systems is required to capture 40% of the potential value within the Internet of Things. The researcher, in this context, suggest two policy recommendations to enhance current European legislation and in consequence, improve technical sustainability:

- The European Commission should modify its standards on electronic communications networks (2007/176/EC) (European Commission, 2002) to include in the list of standards and/or specifications, a de-facto communication standard. This, should be similar to those performed by the Internet Engineering Task Force (IETF), the European Telecommunications Standards Institute (ETSI) and Machine to Machine (M2M) for low end devices (Mckinsey, 2019b) to achieve a feasible solution for the interoperability of smart homes.

- To mitigate planned obsolescence, we recommend the European Commission should adopt the European Parliament resolution 2016/2272 (INI) (The European Parliament and The Council of the European Union, 2017) which emphasizes the case of obsolescence caused by software updates.

3- Politically: data collected from the expert interviews, for instance, indicate the need for a more open market as well as protections in place to minimize vulnerability and "smart poverty", with the end of "leaving no one behind". Certainly, this issue has been previously highlighted in the study by Marikyan et al (2019) when they warned that regulation and legal stipulations have fallen behind of innovation, with many gaps in national policy and legislation. The researcher in order to procure customer and potential users suggest the following modification:

- Modify the Product Liability Directive (Council of the European Union, 1985). Given that liability only apply to products and providing data through an IoT system is considered a service. We suggest adding services to the Directive and extend liability to developers.

4- Environmentally: although smart home technologies hold the promise to deliver energy savings, by helping consumers changing their behaviour and use resources more efficiently, it is unclear whether these savings outweigh the production footprint and rebound effects (Eric Hittinger and Paulina Jaramillo, 2019). Given the potential for energy rebounds and waste, this research highlights the importance of ensuring that smart home technologies deliver on improvements in efficiency, emissions reduction, energy consumption, and sustainability. In order to facilitate the pathway towards a low carbon transition, the researcher suggest two regulatory recommendations:

- The researcher suggests modifying Schedule 2 of the Waste Electrical and Electronic Equipment Regulations (WEEE) (UK Statutory Instrument, 2013)to explicitly list smart home technologies, either as an aspect of subsection 3) or 4), or as new class. The researcher, in this sense, similarly suggest adding to Annex IB of WEEE Directive 2012/19EU34 (The European Parliament and The Council of the European Union, 2003)in Category 3) interactive packaging and smart home technologies.

- There is no current regulation on data traffic and energy consumption. There is a need, thus, to implement one by Ofcom (in the UK) and the European Commission (across Europe).

Within the same context, the researcher moreover, would like to make a stronger case regarding the interaction of smart energy technology and actual energy consumption in order to better situate the sustainability of these devices. For smart energy technologies, Nicholls and team, foresee a future in which households can monitor their energy consumption and through automation processes and enhanced feedback, improve household's energy consumption. This, mostly through the use of smart energy technologies and IC (Nicholls, Strengers and Sadowski, 2020). This role of smart energy technology, in fact, is shared by other institutions. For instance, the European Commission's Strategy Energy Technology 2030, remarks in its institutional plan, to reduce 80% of energy consumption through the deployment of ICT in 80% of European households (European Commission, 2020).

Indeed, there are certain technologies that essentially, in their advisement campaigns, address preventing energy waste or achieve energy savings. A couple of examples, below:

- *"Saving energy starts with your thermostat**.** Putting in new light bulbs. Efficient appliances. Unplugging everything when you leave. It saves energy, sure. But it's a drop in the bucket compared to what a thermostat can do. Your thermostat controls half your energy bill. And it's wasting energy* (Google Nest, 2020)*"*
- *"Motion sensors have your back. They can turn off that light or television when the room is empty and prevent wasting energy (and money)* (Strengers et al., 2020)[10]*"*

However, this goal is far from been achieved, since smart home technologies has the potential of create new and enhanced forms of entertainment and ambience which may indeed lead to increments of energy consumption. In this context, there are other advertisement campaigns that, in fact, may lead to increasing energy consumption thought luxurious and –for this researcher—even mundane activities. For instance

- *"Setting the perfect mood in your home with the touch of a button"* users can find themselves in a *customizable* and *controllable* ecosystem according to their moods with lighting names such as " *"Relax, Deep Sea, Energise, Cherry Blossom, cosy Flame and Fairy Woods* (O'Boyle, 2015)*"*

[10] This quote was retrieved from Strengers et al., (2020), since the author was unable to find the website where the Australian team retrieved the quote from.

Strengers and team (2020) further explore smart lighting through personalized pre-schedules such as 'good night' mode, which can automatically turn off smart devices, including lighting. Certainly, such personalised features have space for energy-savings benefits; some, may even say that such savings are achieved effortless. However, in their study, Strengers et al., (2020) refer to (Window Dressings, 2014) to note that other smart features such as 'Vacation' mode can erode the sustainable aspect of these technologies, since with this feature "*a control system can evoke a lived-in look by randomly turning lights on/off and raising/lowering shade*s". Such features aim to deter potential intruders and could potentially provide peace of mind to the users[11].

In this sense, the implications of smart energy technologies such as lighting in energy demand remain unclear. As the IEA (2017) remarks, LEDs are typically more efficient than other forms of lighting; however, the cost of networked standby consumption for the smart lighting may well exceed the overall production of light. Moreover, and as this thesis has shown, many smart home technologies look to enhance security, provide aesthetic and pleasant experiences, others are to 'show off' or decorating, whilst other smart devices may facilitate sleeping, enhance health and provide new forms of entertainment. All these features may offset automation processes and the creation of more efficient behaviours; however, data to proof this claim is not yet available.

Moving forward and to answer the first sub-question of this PhD: how does one define smart home technologies? What are they? based on expert interviews and data collected from the literature, the author, in an attempt to cover all aspects of what smart home technologies entail, reminds the reader the following definition: *Smart home technologies are connected devices that can communicate with each other and react to internal or external signals to enhance the energy services delivered to consumers whilst generating benefits to the system, where the system could be local, national or international. These technologies must possess the ability to interpret available data through a learning algorithm that can predict behaviours and recognize those that are unusual to call for users' attention. These devices ought to automatically program themselves and act on predefined routes to provide the services that the user requires. Technologies could be controlled either by users or delegate it to the system and could be controlled in-site or remotely, so users can have access to the services delivered by the home regardless of their location* (Furszyfer Del Rio *et al.*, 2020) .

Given that the next sub-questions were widely covered in previous chapters and are later discussed in this section, in an attempt to summarize these findings, table 17 (see below), lists:

[11] In previous times, and from an anectodical perspective, such tasks were previously delegated to neighbours, friends and families, to let the householders know that their house was fine

- What are their biggest benefits?
- What are their biggest barriers?
- What business models have the most promise?

Table 17 lists of benefits, barriers and business models

Smart home technologies main benefits discussed by experts	
Energy savings	Social benefits including inclusion, networking, status
Convenience and controllability	Educational benefits and learning
Financial benefits and saving money	Entertainment including music, movies, streaming
System benefits for grids, networks, operators	Safety and security
Environmental benefits including carbon, pollution, waste	Other enhanced experiences (e.g., shopping)
Aesthetics including style, design, feel, and fashion	Free services or promotional gifts
Health benefits and assisted living	

Smart home technologies main barriers discussed by experts	
Privacy, security and hacking	Cultural differences to global diffusion
Technical reliability, warranties, and obsolescence	Poor connectivity, lack of standardization, and supply chains
Usability, user acceptance and learning	Corporate longevity, accountability, and consumer choice
Elitism, incumbency, barriers to market, and erosion of democracy	High cost
Uncertainty, lack of sharing, and difficulty monetizing benefits	Fear of new technology
Interoperability and resilience	Social isolation and loneliness
Energy rebounds and wasteful consumption	Resource intensity, materiality, and sustainability
Loss of personal control and autonomy	Health

Smart home technologies potential business models discussed by experts	
Energy services provision (electricity, heat)	Capturing savings (economic, energy, time, emissions)
Household data and surveillance capitalism	'Prosuming', peer-to-peer trading and/or Blockchain

Bundling and integration of services	Mobility, Electric Vehicles (EVs), and Vehicle-to-Grid (V2G)
Subscription models and digital platforms (e.g., Netflix, AirBnB)	New advertising channels
Health care	Pay as you go
Convenience or accessibility	Coupling with retrofits
Demand response	Insurance models
Security and safety	

Source: author

To answer the last question, which smart home technologies are available in the UK market? This research, based on the expert interviews and data collected from site visits to retail stores, found 267 technologies, same that were grouped in 13 categories of household appliances (already presented in figure 11, Chapter 6) which ranged from lighting, energy and utilities to gardening, baby monitors and smart clothes (Sovacool and Furszyfer Del Rio, 2020a)

Furthermore, and although cookstoves and smart homes are rather contrasting technologies, differing rural versus urban adoption and holding different levels of smartness. Despite the differences in smartness, and as the focus of this PhD remained in household dynamics and energy behaviour, this led to the researcher finding a number of similarities between them. To make these assessments, the researcher takes into consideration the eight behavioural change techniques (presented in the table below), along with the literature review conducted from the improved cookstoves analysis presented in chapter 4 and compares them with the data collected in chapters 5-9.

Table 18 Behaviour change techniques clustered in 8 themes

Behavioural Change Techniques	
Theme	**Explanation**
Reward and threat	This technique could come in the form of reward, value exchange or incentive; such as coupons, voucher or discounts. This could also entail negative reinforcement, punishment, sanctions and emotional consequences, such as fear and appeal.
Shaping knowledge	This technique could entail instructions, education, the replacements of habits, training, reinforcement practices and public relations.

Changing the physical environment	This approach entails not only practices related to environmental restructuring and logistics to deliver and access to services, but also defaults.
Social support	This technique includes the involvement of communities of practice, co-creation of messengers and outreach workers in order to disseminate values to support the adoption of new routines and habits. In this sense, social support could also come in the form of social norms (i.e. social influence and social pressure)
Goals, framing and monitoring	This technique focuses in themes around users' intentions and ambitions. It considers action planning as well, along with commitment contracts, feedback monitoring and self-monitoring.
Comparisons	This BCT includes evaluations such as those involving pros and cons and comparing future outcomes. In may as well include themes related with modelling and social comparisons
identity and belief	This technique gathers elements at the individual level that could boost behaviour change such as but not limited to: mental rehearsal and self-talk, self-efficacy, self-affirmation and health belief mode.
Regulation.	This approach tackles themes around restrictions and standards

Source: author

Financial incentives as part of BCT reward and threat, are consistently reported to be core drivers for sustained adoption of improved cookstoves, particularly, in poorer communities (Puzzolo et al., 2013; Thurber *et al.*, 2014; van der Kroon, Brouwer and van Beukering, 2014; World Bank, 2014; Hankey *et al.*, 2015; Ruiz-Mercado and Masera, 2015; Treiber, Grimsby and Aune, 2015; Cundale *et al.*, 2017). Certainly, in the studies above presented, it is often agreed that fuel costs are steadily reported to be core drivers for sustained use and adoption of improved cookstoves.

Participants in the focus groups also noted how financial incentives offered by smart home technology developers and industry play a key role, not only for their adoption, but also for their continued use. For instance, FGLM mentioned how industry approach users in terms of economic savings to promote smart thermostats' sustained usage: "*British Gas has the best marketing campaign, they say it {Hive} will save you money by saving energy. I think they are now offering it for free and customers will pay for it with the money they save in their bills*". Another participant from London also mentioned that he mainly uses Hive because of the financial rewards it provides: "*I install a Hive and I save £15 a month that I have to pay towards my Hive, it actually does save money*

and I can buy my Hive at £15 a month". He continued "*I've paid for it [Hive] in gas and utilities anyway. And you save it off my combining heat and electricity*". This point is also corroborated by LCICG (2016) when they highlight how innovations in domestic building operations could potentially save "the most carbon, most quickly, predominantly from the existing building stock", and highlights economic benefits of energy savings and global market potential of innovative products.

Results from the literature review analysis revealed that shaping knowledge is the most popular intervention for users to adopt ICS (van der Kroon, Brouwer and van Beukering, 2014; Goodwin *et al.*, 2014; Ramirez *et al.*, 2014; Thurber *et al.*, 2014; Hankey *et al.*, 2015; Lewis *et al.*, 2015; Namagembe *et al.*, 2015; Rosenbaum, Derby and Dutta, 2015; Jagger and Jumbe, 2016; Champion *et al.*, 2017; Cundale *et al.*, 2017; Tigabu, 2017). Indeed, these studies indicate that individuals are more likely to use ICS once they know the benefits these can provide, not only in terms of health and convenience, but also how these technologies can improve the environmental quality around them.

A lesson here, could thus be learnt for smart home technologies developers, since the empirical findings from this research indicate that not having a clear definition on what these technologies are, hinder further regulations (e.g. waste and energy consumption) and users' uptake. Certainly, participants in the focus groups mentioned how having a clearer definition of what these technologies are, might help in their adoption. For instance, FGMF illustrated this point when he said: "*I think if there was that definition of smart technology it might help with understanding it better. Now it feels quite broad and vague"* Other two participants, FGLM and FGMM highlighted this, when they respectively commented: "*I don't use any smart stuff for anything. I don't even know what that is*" and "*I'm not bothered about smart technology. I don't know about that".* In this sense, the researcher suggests that shaping potential users' knowledge could help in the acceptance and accelerating the uptake of smart homes.

Changes in the physical environment are also worthy of further exploration. Studies revealed that there is a need to better understand housing tenure, homes' design and their impact on cooking and health (Ruiz-Mercado *et al.*, 2013; Simons *et al.*, 2017). Literature, in this sense, shows that being the owner of a house positively impacts the uptake of improved cookstoves since it allows users to do physical changes in households.

The same results are shown in this research regarding smart home technologies. Lack of home ownership was a significant barrier, although not as popular as others; when experts commented on this issue, they said that this by far, represents the biggest barrier. Experts commented that many times people need to own their own property, rather than rent or lease to have any incentive to buy a smart home technologies (Sovacool and Furszyfer Del Rio, 2020a). R17 pointed out to this barrier

in terms of incentives "*One key barrier, is that only around 20 to 30 percent of people actually own their apartments, the rest they just pay the rent. So I'm wondering whether home-owners would be interested in investing in these technologies*" In a similar vein, R31 mentioned home-ownership as a key deterrent: "*There is a lot of people who aren't going to be incentivize to buy this sort of technologies and landlords are not incentivized to give it to tenants either. I think property ownership it has been a huge barrier for us with the smart meters and I think, it's been a huge barrier for other areas. For example, with the rollout of super-fast broadband, governments now have to intervene because landlords didn't give access to broadband fibres to install superfast connections".*

Social Support plays a key role in the adoption of ICSs, in the literature review the researcher found, for instance, that in Uganda and Malawi social networks have been found to be most effective when there are reciprocal relationships between individuals (van der Kroon, Brouwer and van Beukering, 2014; Clark, Heiderscheidt and Peel, 2015). Whilst in Kenya and The Navajo Nation, USA, the reputation of new technologies is positively influenced by favourable opinions among community or family members. (Champion *et al.*, 2017). Word of mouth communication among community members was one of the most effective approaches for their adoption (Clark, Heiderscheidt and Peel, 2015; Rosenbaum, Derby and Dutta, 2015).

Although in this thesis, the researcher was unable to found literature supporting specific cases where social support influenced in the adoption of smart home technologies, the empirical data collected in this PhD further supports the behaviour change literature. For instance, one male participant from London was influenced due to her friends' opinion when he said: "*I ended up doing Alexa because one of my female friends was very excited about being able to turn on Radio 4 just by asking it to. Another piece of home technology was a Hive and that was recommended by another female friend".* Decisions to uptake SHT were also influenced by family members, for instance, FGSF expressed: "*the only reason why I have Alexa is because my son told me it was fantastic. Otherwise, I wouldn't have known what Alexa is. God, I wouldn't have known there was a thing that could do that*".

Goals, planning and monitoring is another behaviour change technique that seems to be one of the key drivers for technology adoption. In this sense, the researcher found that time savings associated with ICS are critical and need better promotion. Moreover, these benefits could be better directed towards individual and household goals and aspirations. For example, targeting how opportunities from time saved – say from laborious wood collecting – can be directed towards aspirations in the form of other work-related and recreational goals.

Here, improved cookstoves could teach another lesson to smart home technologies developers, policy makers and industry. The researcher thus suggests that these groups should stress how these

technologies could lead to time savings. Since regardless of the location (London, Surrey or Manchester), focus groups participants mentioned that is the technologies' main purpose. For instance, FGLM mentioned: "the audience for smart home technologies are *people who don't have enough time for what they want to do".* This was corroborated by FGMF and FGSM when they stated: *I'd say busy professionals. Definitely not for those retired that spend most of their time home"* and "*People who've got a very hectic lifestyle, spending not the regular hours at home".*

Although there is very little evidence on how lifestyle drivers impact on choice, in this research, one study found that aspirational factors (e.g. improving quality of life) was not a driver of ICS adoption (Namagembe *et al.*, 2015). However, in Kenya, social status is connected to fuel choice and the use of improved cookstoves (Treiber, Grimsby and Aune, 2015). Furthermore, other study, suggests that men are more aware of status attached to improved stoves (van der Kroon, Brouwer and van Beukering, 2014).

Participants from focus groups and experts mentioned how these technologies are clearly presume as a status symbol. For example, FGLF mentioned: *"So, [SHTs] are almost like a status symbol, it's like in college, some people are like, 'Oh, I have an Alexa.' And other people are like, 'I'm not rich enough to have that*". Indeed, this notion was further supported by FGSM when he mentioned*: "it's still quite unique to have a smart home and have certain things in your house, it's quite intriguing if you go around someone's house and have these technologies… It has definitely got some sort of status"*. Experts further corroborated in this point when they mentioned R12: "*Smart home technologies are currently driven by status – not environmental motivations. It's technophile, rather than technophobia, with people needing to possess and purchase the coolest gadget to have*." As R14 added "*To some people, the benefits of adoption relate most to aesthetics, to people just being drawn to beautifully designed or new things, to show they are ahead of the curv*e."

The researcher found interesting differences amongst gender responses suggesting, in turn, that carefully targeted messaging has much potential in addressing behavioural change for the adoption of improved cookstoves, particularly looking at identity and belief. For instance, an entrepreneurial program delivering empowerment training for both men and women found that sales of ICS doubled across both gender groups, delivered greatest strides in relation to women's decision-making (Shankar, Onyura and Alderman, 2015).

During the focus groups, there was a tension in identifying technology to a particular gender. In this sense, although some participants expressed their feelings in phrases such as "*boys for toys*", "*men have been allowed to be geeks" and "men are naturally interested in technology".* Other participants

argued that*: "I don't think smart home technology is gendered at this point*". Another female participant defended this point when she said*: "its boys with toys, usually type of thing, but I think that's changing"*. The researcher recommends that within the smart home technology arena, at least, the marketing campaigns, social benefits and cultural factors should be neutral to avoid gender biases such as those presented in Chapter 8.

In this analysis, none of the peer-reviewed academic papers reported regulatory frameworks as being drivers for ICS uptake and or/related behavioural change. In the smart home arena, similarly, the researcher suggests throughout Chapters 5-9 the need to enhance the regulatory framework behind smart home technologies. In this sense, from a policy perspective, the researcher emphasises the need for flexible and adaptable regulation to protect consumers' personal information and data and achieve a low carbon transition. Whilst for the improved cookstoves' sector, looking at the structural determinants of behaviour change is a major omission in the field to date (i.e. the political, legal and institutional conditions) that needs to be addressed. This research, however, recognizes the efforts from the Kenyan government, that although they are not addressing this issue directly, they have implemented a prescribed legislation on domestic biomass cookstoves[12] with the aim of strengthening safety regulations, allowing intensive infrastructure investments and enhancing consumers' knowledge and finance (Global Alliance for Clean Cookstoves, 2013).

All in all, this study demonstrates that energy behaviour and household dynamics are remarkably complex, given that these are influenced by a multitude of factors, from knowledge and attitudes to social norms, gender roles and support networks. Furthermore, this PhD reveals that behaviour, regarding technology adoption will also be influenced by external factors such as infrastructure, access to resources and environmental support. Moreover, as suggested in the discussion above, this work shows that the behaviour change techniques applied in improved cookstoves sector, can not only prevent the use of traditional stoves but also, these techniques can be replicated for the uptake of smart home technologies. In this sense, the author stresses the importance of behaviour in the use and adoption of technologies. For instance, proper use of improved cookstoves must lead to substantial improvements in life expectancy and enhanced users' quality of life. Whilst for smart home technologies, this PhD, based on the evidence collected, suggests that while the technical potential of net energy savings from ICT is 'likely positive' it will be users' interaction with the systems which will have the greatest influence in this domain.

The researcher places special emphasis in the previous idea, that on the interaction between humans and technologies to debate more in-depth the results discussed in the previous chapters. As presented

[12] The exact number and title is: KS 1814-1:2005 - Biomass stoves - Performance requirements and test methods - Part 1

throughout chapters 5-9, the author revealed that different technologies change depending on who the users are, for instance, users' gender, knowledge, and whether these are business and/or customers. Regarding tech savviness and knowledge, this research have shown that this is not only a key enabler for adoption, but also deployment and use. In this sense, many participants during the focus groups and the survey instrument, were unaware of what these technologies are, and which applications do they have. Partially, one could blame the marketing campaigns and advertisers' messages since they are not transmitting what these technologies are capable of. In this sense, a common view during the focus groups was related to Alexa and its limited features to command it to play a song, answer questionnaires' questions, create reminders and set up timers. Users, in this sense, were unwilling to pay for a device to deliver limited applications, since people could easily perform them themselves.

However, manufacturers are perhaps realising that customers are using smart home technologies without untapping its full potential. It is under these circumstances, in which industry may push to greater levels of smartness (see figure 14 in chapter 6), where smart home technologies integrate with each other and with the system in order to reach a fully connected home and possibly a "sentient" city. In would be under this context that greater levels of smartness are achieved, where technologies do not only anticipate users' needs and make more efficient their routines and everyday lives, but also, they enhance the current energy system to transition towards a low-carbon economy. However, and as it for now, how governments, manufacturers and even users envisioned smart home technologies' automation skills and capabilities of making more efficient users' routines to improve energy consumption, appears distant from a sustainable future.

Manufactures also need to change their business models and listened to the voices that criticise that the current 'smart technology agenda', in relation to its vision creators are overwhelmingly male. In these circumstances, the qualitative data obtained via this research, strongly indicates that smart home technology dynamics are gendered and that most of its users are males. The findings from the researcher could also be corroborated by a current US industry study, which suggests, that most consumers of smart devices are more likely to be males (57%) and technophilic, (i.e. those that want to make every aspect of their home with automation systems) are most typically men (Banker, 2016). In turn, the use of smart home technologies may generate imbalances that affects other household members (mostly women) in which they may be non – or partial -users of home connected products, placing this group in a more vulnerable position towards the transition to a smarter future.

Another issue that was brought throughout this thesis was lack of knowledge/ignorance or not been tech savvy enough to properly use these technologies. Indeed, the results from this PhD indicate that

the skills to access, use and manipulate smart home technologies is far from been universal. In fact, more than one participant commented: FGMM: "*I'm not bothered about Smart Technology. I don't know about that*" or FGSF who commented: "*I don't use any smart stuff for anything".* In this sense and as showed in chapters 7-9, through the instalment of such systems, the control of the home shifts to the hands of the most tech savvy user (Nicholls, Strengers and Sadowski, 2020). In turn, this could potentially lead to exacerbate existing power imbalances. In other words, household members who are not as tech engaged as other users, may lose control over the home. In this context, partial users of smart devices may not be able to interact with other technologies; perhaps, these were never set-up according to their preferences, or maybe, they never had access to the passwords, to the software or even they lacked interest or skills to interact with these technologies. In this way and linking back to the levels of smartness (see chapter 6), losing control within a smart home may inhibit less tech savvy users to setup indoor temperatures, control lighting and security system not recognizing the user's face or their fingerprint. In a level 5 of smartness, for example, it may be the case that a non-user is in fact excluded from the home and it would be conceivably perceived as an alien or an intruder within their own home.

Moreover, the author recognizes that both technologies highly affect households' dynamics. For example, given girls and women's central role managing household energy and cooking needs and as main consumers and users of cookstoves. These devices ought to change domestic life by providing increase access to finance, developing novel business model that empower women and contributing in turn, to poverty alleviation. Whilst smart home technologies are changing the very meaning of the home and domestic life in subtle but important ways. For instance, as explored in chapter 6, the traditional concept of what the home is a space for private domestic life seems to be changing. Instead, people can begin to control their home remotely through an app, altering the notion of home occupancy and privacy. Smart home technologies are also altering the ability for a house to operate as a social space to receive friends and family, to protect occupants from intrusion, to keep private life private. The researcher in this context, argues that the impact of smart technology regarding users' privacy and what a home entails will be the most prosaic, but also, the most lasting.

In the same vein, this research suggests that with the introduction of these technologies (ICS and SHT) homes and domestic spaces could undergone important technological transitions, and these affects, and are affected by, gendered knowledge, practices, risks, and emotions. These changes could continue to erode so-called "traditional" gender norms—such as men wanting to control or pay for services and women keep doing housekeeping. Whilst the previous applies in both dimensions cookstoves and smart homes, for the latter, results from the survey indicate:

- Knowledge, awareness, and adoption: men state they are more likely to use smart home technology themselves, by a considerable margin, and men are less likely to say that their partner uses the technology;
- Housekeeping and daily domestic life: women state they prefer to use smart home technologies for cooking, preparing food, and eating as well as doing laundry, learning, and studying, whereas men prefer to focus on control and mastery of technology;
- Environmental sustainability: women express more concern about both cost and the environmental implications of smart home technologies, whereas men are more concerned with comfort. More importantly, the environment is ranked behind issues such as convenience, security, saving money, saving energy, and saving time. Women also express a greater desire to control heat services and energy within the household, contrary to much of the literature.
- Trust and risk tolerance: women state to have more trust in smart home technology and service providers, social media platforms, and energy supplies more than men, also contrary to the literature.
- Emotions and feelings: smart home technologies provoke intense emotions from both men and women, with women reporting affiliated emotions that smart homes make them feel lazy, exposed, dependent on technology, and unsafe. Men feel more protected, empowered and in control, and safe. More complicatedly, a fraction of respondents also either held mixed emotions (positive and negative) or were uncertain and ambivalent about their emotions. Some even found the technologies amusing and funny.

Furthermore, the literature review and experts' interviews foresee potential downsides regarding energy rebounds, privacy invasion, misuse of personal information, and hassle to use SHTs along with interoperability. In contrast, their promise to reduce energy demand, improve the system and ease users' life it is still unclear. This research concludes that if we get smart home technologies right, we could achieve the further decarbonisation of electricity and enhance our energy system and services; however, if we get it wrong, this could lead to huge downsides. To avoid this, the researcher suggest further research ought to focus on developing regulatory frameworks addressing sustainability, looking particularly at using smart home technologies to better integrate with and optimize energy systems, and ensuring consumer protection. On sustainability, regulation should focus on ensuring these technologies do not induce energy rebound effects as to date there is no clear evidence as to whether SHT will reduce overall energy demand. Regarding energy systems, the researcher considers smart home technologies come as technically disruptive devices that have the

potential to turn the energy market into a more dynamic one, where more players will be involved instead of just a few. Regulation, thus, should focus on how to make this market more open and transparent. Whilst for consumers, research should focus on how to enhance regulation to protect users in a connected home with bundled services and on standards for interoperability to avoid misspent capital.

In this sense, further research into improved cookstoves ought to focus on issues related to maintenance or replacement to support maintained use, given that during the literature review undertaken, little evidence was found in this area. Moreover, given the dimension of this issue –3 billion people are daily exposed to household air pollution! – it is imperative to conduct further research in which implementation strategies for ICS are the most successful, since this could generate massive health improvements, reduce environmental impacts and aid vulnerable communities, particularly girls and women.

In the smart home dimension, topically, more attention to gendering vs. use value would generate practical information for marketing efforts on behalf of designers, manufacturers, and retailers. Furthermore, the focus of the research here is on the "demand side," on users, but a focus on the "supply side," on industry and manufacturers, could also be fruitful to explore. In addition, more research should also investigate the implications of IoT consumer device functionality for specific user communities, and other forms of abuse relating to specific groups, whether this is related to gender-based, or otherwise, based on culture, tech literacy, or other attributes. In this sense, further efforts from industry and regulatory frameworks should urgently address issues related to cyber abuse and offer victims of such crimes with accurate guidance and protection. Finally, the introduction of smart home technologies has led to unintended consequences, mostly affecting users' privacy and autonomy, which in turn, has resulted in slowing the pace of innovation (Calvo, Peters and Cave, 2020). In this sense, this PhD suggests that further research should focus on developing frameworks that predicts and evaluate how the introduction of certain technologies are going to affect household dynamics as with this, it could be ensured that human interests, such as but not limited to ethics, privacy, and wellbeing are prioritised as humans' relationship with technology grows.

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Appendix 1

Smart Home Technologies (SHT) Survey

We would like to find out what you know and think about 'smart home technologies'. This simple questionnaire should take no more than 15 minutes to complete.

Part 1. Socioeconomic and demographic dimensions

Q1. How many people, including yourself, live in your current home? [numeric box 1 to 99]

[Enter

number]

[OE1]

Q2. How many children live in your current home? [numeric box 0 to 99]

[Enter

number]

[OE2] [if Q1=1, then HIDE Q2]

Q3. What is your age? [numeric box 1 to 100]

[Enter

number]

[OE3] Re-code 18-24 / 25-34 / 35-44 / 45-54 / 55-64 / 65+ || **[TERMINATE if UNDER 18]**

Q4. What is your gender?

(1) Male

(2) Female

(3) Something else

Q5. What is your annual household income before tax? [numeric box 0 to 1000000]

[Enter

number]

[OE4]	[MIN 0 / MAX 1,000,000]

Q6. My home is…

(1)	Owned-outright
(2)	Owned with a mortgage
(3)	Rented from a private landlord
(4)	Rented from social housing / local authority

Q6A. In which region do you currently live?

(1) Scotland

(2) Northern Ireland

(3) Wales

(4) North East

(5) North West

(6) Yorkshire and the Humber

(7) West Midlands

(8) East Midlands

(9) South West

(10) South East

(11) East of England

(12) Greater London

(13) Outside UK **[TERMINATE]**

Q7. How much would you say you know about smart home technologies?

(1) Nothing at all, I have no idea what they are.

(2) I have a vague idea of what they are.

(3) I have a good idea what they are.

(4) I have a very good idea of what they are.

Q8. Do you own or use any smart home technologies? If so, how many? Smart home technologies are a large category of products that includes everything from smart meters and smart appliances to voice activated controls such as Alexa, programmable heating, and more. (Enter 0 for none).

[Insert number] [OE5] [numeric box from 0 to 999]

Q9. Who would be most likely to use smart home technology in your household? (Please select all options that apply) [MULTIPLE SELECT]

(1) Myself

(2) My partner

(3) My children

(4) Other family members

(5) Guests and visitors

(6) Others [Please specify] [OE6]

Please state how much you agree or disagree with the following statements. If you do not have a clear opinion or are unsure what to answer, please just tick 'don't know'. There are no right or wrong answers!

[NEW SCREEN]

Q10. Thinking about smart home technologies <u>generally</u>, the main purposes of smart home technologies are ...

Note: You may have an answer to this question whether or not you own any smart home technologies and regardless of how much knowledge you have of smart home technologies. However, it is also fine to not know the answer and to select 'I don't know.'

		Strongly	Disagree	Neither agree nor	Agree	Strongly	[Don't know]
Q10_1	Enhancing entertainment	☐	☐	☐	☐	☐	[☐]
Q10_2	Making life at home more convenient	☐	☐	☐	☐	☐	[☐]
Q10_3	Controlling smart appliances	☐	☐	☐	☐	☐	[☐]
Q10_4	Monitoring family members	☐	☐	☐	☐	☐	[☐]
Q10_5	Managing energy use and heat	☐	☐	☐	☐	☐	[☐]
Q10_6	Enhancing communication	☐	☐	☐	☐	☐	[☐]
Q10_7	Supporting assisted living or health	☐	☐	☐	☐	☐	[☐]

Q10_8	Managing home security and safety	☐	☐	☐	☐	☐	[☐]

Q11. Thinking about smart home technologies <u>generally</u>, the potential benefits of smart home technologies are to ...

Note: You may have an answer to this question whether or not you own any smart home technologies and regardless of how much knowledge you have of smart home technologies. However, it is also fine to not know the answer and to select 'I don't know.'

		Strongly	Disagree	Neither agree nor	Agree	Strongly	[Don't know]
Q11_1	Save time	☐	☐	☐	☐	☐	[☐]
Q11_2	Save money	☐	☐	☐	☐	☐	[☐]
Q11_3	Save energy	☐	☐	☐	☐	☐	[☐]
Q11_4	Save the environment	☐	☐	☐	☐	☐	[☐]
Q11_5	Enhance leisure	☐	☐	☐	☐	☐	[☐]
Q11_6	Provide comfort	☐	☐	☐	☐	☐	[☐]
Q11_7	Improve security	☐	☐	☐	☐	☐	[☐]
Q11_8	Provide care	☐	☐	☐	☐	☐	[☐]
Q11_9	Improve quality of life	☐	☐	☐	☐	☐	[☐]
Q11_10	Increase property value	☐	☐	☐	☐	☐	[☐]
Q11_11	Make life easier	☐	☐	☐	☐	☐	[☐]

Q12. Thinking about smart home technologies <u>generally</u>, Smart home technologies are relevant for certain activities such as ...

Note: You may have an answer to this question whether or not you own any smart home technologies and regardless of how much knowledge you have of smart home technologies. However, it is also fine to not know the answer and to select 'I don't know.'

		Strongly	Disagree	Neither agree nor	Agree	Strongly	[Don't know]
Q12_1	Cooking, preparing food, eating	☐	☐	☐	☐	☐	[☐]
Q12_2	Showering, washing	☐	☐	☐	☐	☐	[☐]
Q12_3	Working, studying, learning	☐	☐	☐	☐	☐	[☐]
Q12_4	Entertaining, socializing	☐	☐	☐	☐	☐	[☐]
Q12_5	Relaxing, leisure, hobbies, games	☐	☐	☐	☐	☐	[☐]
Q12_6	Doing laundry, cleaning, housework	☐	☐	☐	☐	☐	[☐]
Q12_7	Parenting, caring for household members	☐	☐	☐	☐	☐	[☐]
Q12_8	Mobility	☐	☐	☐	☐	☐	[☐]
Q12_9	Improving health	☐	☐	☐	☐	☐	[☐]

Q13. Thinking about smart home technologies <u>generally</u>, for there to be personal trust in smart home technologies, it is important that they …

Note: You may have an answer to this question whether or not you own any smart home technologies and regardless of how much knowledge you have of smart home technologies. However, it is also fine to not know the answer and to select 'I don't know.'

		Strongly	Disagree	Neither agree nor	Agree	Strongly	agree [Don't know]
Q13_1	Are reliable and easy to use	☐	☐	☐	☐	☐	[☐]
Q13_2	Can be controlled and over-ridden	☐	☐	☐	☐	☐	[☐]
Q13_3	Protect personal data/information	☐	☐	☐	☐	☐	[☐]
Q13_4	Guarantee privacy and confidentiality	☐	☐	☐	☐	☐	[☐]
Q13_5	Come with performance warranties	☐	☐	☐	☐	☐	[☐]
Q13_6	Are made by credible manufacturers	☐	☐	☐	☐	☐	[☐]
Q13_7	Are compatible with other devices in the home	☐	☐	☐	☐	☐	[☐]

Q14. Thinking about smart home technologies <u>generally</u>, when I think about who is trustworthy in the smart homes technology sector, I trust...

Note: You may have an answer to this question whether or not you own any smart home technologies and regardless of how much knowledge you have of smart home technologies. However, it is also fine to not know the answer and to select 'I don't know.'

		Strongly	Disagree	Neither agree nor	Agree	Strongly	agree [Don't know]
Q14_1	Technology suppliers (e.g. Apple, Samsung)	☐	☐	☐	☐	☐	[☐]
Q14_2	Service providers (e.g., Netflix and Amazon)	☐	☐	☐	☐	☐	[☐]
Q14_3	Energy suppliers (e.g. EDF or British Gas)	☐	☐	☐	☐	☐	[☐]
Q14_4	Government departments (BEIS, Ofgem)	☐	☐	☐	☐	☐	[☐]
Q14_5	Researchers and scientists (universities)	☐	☐	☐	☐	☐	[☐]
Q14_6	Friends	☐	☐	☐	☐	☐	[☐]
Q14_7	Family	☐	☐	☐	☐	☐	[☐]
Q14_8	Neighbours	☐	☐	☐	☐	☐	[☐]
Q14_9	Traditional media (newspapers, TV)	☐	☐	☐	☐	☐	[☐]
Q14_10	Social media (Twitter, Facebook, Instagram)	☐	☐	☐	☐	☐	[☐]

Q15. Thinking about smart home technologies <u>generally</u>, there is a risk that smart home technologies…

Note: You may have an answer to this question whether or not you own any smart home technologies and regardless of how much knowledge you have of smart home technologies. However, it is also fine to not know the answer and to select 'I don't know.'

		Strongly	Disagree	Neither agree nor	Agree	Strongly	agree [Don't know]
Q15_1	Increase dependency on technology	☐	☐	☐	☐	☐	[☐]
Q15_2	Increase dependency on electricity networks	☐	☐	☐	☐	☐	[☐]
Q15_3	Increase dependency on outside experts	☐	☐	☐	☐	☐	[☐]
Q15_4	Result in a loss of control	☐	☐	☐	☐	☐	[☐]
Q15_5	Disrupt daily routines	☐	☐	☐	☐	☐	[☐]
Q15_6	Make household members lazy	☐	☐	☐	☐	☐	[☐]
Q15_7	Are intrusive	☐	☐	☐	☐	☐	[☐]
Q15_8	Reveal sensitive data	☐	☐	☐	☐	☐	[☐]
Q15_9	Are an invasion of privacy	☐	☐	☐	☐	☐	[☐]
Q15_10	Are non-essential luxuries	☐	☐	☐	☐	☐	[☐]
Q15_11	Make households worry more	☐	☐	☐	☐	☐	[☐]
Q15_12	Waste household income and money	☐	☐	☐	☐	☐	[☐]

Q16. Thinking about smart home technologies generally, I am comfortable with smart home technologies monitoring …

Note: You may have an answer to this question whether or not you own any smart home technologies and regardless of how much knowledge you have of smart home technologies. However, it is also fine to not know the answer and to select 'I don't know.'

		Strongly	Disagree	Neither agree nor	Agree	Strongly agree	[Don't know]
Q16_1	My basic health (steps, heartrate, sleeping)	☐	☐	☐	☐	☐	[☐]
Q16_2	Home energy or heat use (e.g. smart meter, smart thermostats)	☐	☐	☐	☐	☐	[☐]
Q16_3	Household security (e.g. burglars and crime)	☐	☐	☐	☐	☐	[☐]
Q16_4	Entertainment preferences (e.g. BT, SKY)	☐	☐	☐	☐	☐	[☐]
Q16_5	Young children (e.g. portable parent)	☐	☐	☐	☐	☐	[☐]
Q16_6	The elderly or ill (e.g. assisted living)	☐	☐	☐	☐	☐	[☐]
Q16_7	Tracking cars and vehicles	☐	☐	☐	☐	☐	[☐]
Q16_8	Household objects (forks, spoons)	☐	☐	☐	☐	☐	[☐]
Q16_9	Clothing and laundry (smart washing machines)	☐	☐	☐	☐	☐	[☐]
Q16_10	Food and diet (smart refrigerators)	☐	☐	☐	☐	☐	[☐]
Q16_11	Pets	☐	☐	☐	☐	☐	[☐]
Q16_12	Financial history (e.g. banking)	☐	☐	☐	☐	☐	[☐]
Q16_13	Menstruation and pregnancy	☐	☐	☐	☐	☐	[☐]
Q16_14	Tracking all family members	☐	☐	☐	☐	☐	[☐]

Q17. Thinking about smart home technologies <u>generally</u>, smart home technologies could lead to conflict in the home related to …

Note: You may have an answer to this question whether or not you own any smart home technologies and regardless of how much knowledge you have of smart home technologies. However, it is also fine to not know the answer and to select 'I don't know**.'**

		Strongly	Disagree	Neither agree nor	Agree	Strongly	[Don't know]
Q17_1	Housemates	☐	☐	☐	☐	☐	[☐]
Q17_2	Couples and partners	☐	☐	☐	☐	☐	[☐]
Q17_3	Children and parents	☐	☐	☐	☐	☐	[☐]
Q17_4	Landlords and tenants	☐	☐	☐	☐	☐	[☐]
Q17_5	Hosts and guests	☐	☐	☐	☐	☐	[☐]
Q17_6	Neighbours	☐	☐	☐	☐	☐	[☐]

Q18. Thinking about smart home technologies generally, smart home technology makes me feel overall … [MULTIPLE SELECT]

Note: You may have an answer to this question whether or not you own any smart home technologies and regardless of how much knowledge you have of smart home technologies. However, it is also fine to not know the answer and to select 'I don't know.'

(1) Safe

(2) Unsafe

(3) Empowered/In control of the house

(4) Dependent on technologies

(5) Lazy

(6) Ambivalent

(7) Exposed

(8) Protected

(7) Other: [Please specify]

(8) None of these - [EXCLUSIVE]

Q19. Do you have an insightful story or anecdote to tell regarding smart home technologies?

[open ended] [OE7]

Completion screen [not visible]

Thank you for participating in our survey!

If you would like to find out more about smart home technologies, please click here [https://www.creds.ac.uk/digital-society/]

Would you be willing to be contacted in the future by the research team for the opportunity to be contacted by a follow-up interview or to have the opportunity to participate in a similar survey?

(1) Yes

(2) No

[If (1)YES]

Please enter your email address: [OPEN BOX]

Appendix 2

Respondent	Definition
R1	There is a range of different smart devices, but the distinguishing factors that make them smart are system functionality and how their systems communicate and operate.

R2	SHTs are a diverse constellation of technologies which provide households with greater controllability over a variety of domestic systems, processes and services. This can range from heating and lighting to electricity use and appliances, to security, safety, and so forth.
R3	Smart home technologies are intelligent operating systems which allow users to operate different parts of the house, the environment and ambient. With the goal of easing the life of users.
R4	Smart home technologies are eclectic products that are installed at homes through internet or external networks connected. They are everyday objects enabled by smart services that should do more than they could do before.
R5	Smart home technologies are devices that are able to make decisions; thus, the smartness. These devices should be able to make those decisions based on users' behaviours, commands and preferences.
R6	I see two categories of smart home technologies. The first, is the smart home with an emphasis on what happens in the home; there are sensors around the place and could be remotely controlled. The key elements in this category are "switching and sensing," with what used to be the province of human beings in the home getting delegated to the technology. The second category is how smart technology changes the boundaries of the home by bringing the Information Technology (IT) into the electricity system. Here, the key word is "Connectivity" and should provide users with the possibility of changing local network operation as the result of what happens in the home
R7	Smart home technology is any device that helps the user to do certain tasks more efficiently; whether these tasks are related to security, improving the energy efficiency of the house or by adjusting to users' daily routines. So basically, anything that is useful for the user and connected from (IoT).
R8	Smart homes are an extension of an everyday technology. There is an implication that it is digital. If a smart home is digital, then it has the ability to learn and adapt to people and extend the capabilities of people.
R9	Smart home technologies are internet connected technologies which can monitor or control aspects of the home.
R10	Smart home technologies are devices within the home that possess network connectivity. Hence, are able to cooperate through computation to enable things to happen with all the other connected devices in the home.

R11	Smart home technologies are everyday objects and devices that connect to the internet and to each other; not computers, smartphones, or tablets. Smart devices often connect to apps on mobile devices, allowing users to control them remotely.
R12	Smart homes should use information and communication technologies to enhance domestic life. In this sense, a truly smart home is the one which uses ICT through the use of interactive settings and feedback on the domestic environment.
R13	Smart home technologies are internet enabled devices that respond to signals. These could range from price signals to DNR signals.
R14	Smart can refer to how we can use the latest technology. Smart could also encompass ways of thinking, techniques and approaches. However, true smart, is about combining humans with technology to perform activities more effectively, about human software and technological hardware
R15	Smart home technologies are digitally enabled devices that provide opportunities to manage energy better. Where the digital component is key. Currently lots of things are called "smart" but are meaningless, it generally means moving from analogue to digital.
R16	Smart home technologies are connected interfaces or appliances within buildings that can be used to improve energy management.
R17	Smart home technologies need to have a learning algorithm through a machine that is connected to the internet and can-do things like predictive maintenance or predictive behaviour to better manage cooling and heating within buildings
R18	A product or service that reacts to data either related to the households or external information, such as energy prices.
R19	Products or services that involve connectivity, digitalisation and automation. These could apply to energy use, lightning, electricity or gas.
R20	Smart homes technologies typically require a digital intermediary that is connected to the internet and a set of hardware which is by design insecure and not updatable. What smart homes could do, is to automatically manage your energy and automatically configure itself in order to provide the service that the user wants. Smart homes should use energy and –potentially water-- as efficiently, effectively, flexibly and as simple as possible.

R21	Smart home technologies are devices that automatically recognize the behaviour and changes in the environment based on the use of preferences and act on predefine routes to do something. As a result, users do not need to program them anymore. These technologies' main goals are to improve the energy utilisation, comfort and safety of the home.
R22	Smart home technology is whatever the company is telling consumers about what it is manufacturing. Hence, it is usually presented as what kit/ technology the manufacturer has in their portfolio. A smart home should give users a lot of energy services, for little energy use
R23	Smart home technologies is anything that is using data above and beyond of what that piece of kit might usually do. Any device that enables that service.
R24	Smart home technologies are everyday domestic objects that are networked to other technologies.
R25	Smart home technologies are devices that improve the energy service delivered to the consumer and/or maintaining whilst delivering a service to the system. There are two different types of smart technologies. One type, assumes virtually no interaction with the consumer and they will only become widespread if are accepted and adopted by consumers. The second type, consists an additional functionality for the user.
R26	Smart home technologies are pieces of kits; whether a hardware or software that allow someone who lives or stays in the home to control features related to energy. Either the user controls it or delegates control to a system. The system could be within the home or it could be a national, regional or an international system where the smart component aims at enhancing the system.
R27	Smart home technologies are connected devices in one form or another that provide a service that uses available data in a new way. The smartness comes from been able to interpret the data available by an algorithm that brings useful elements in one way or another. The "smartness" comes from recognising what is unusual behaviour and behaviour that should brought to the attention of someone.
R28	Smart home technologies are devices that collect data and send it back to the consumers through different channels of communication, could be through a text message, call, voice, emails or displayed on websites. Smart home

	technologies should also be able to be controlled remotely and provide users with the ability to stay close to the appliances without been physically there. These technologies should also be able to be programmed to provide more comfort to users. I see them as a as a platform of information in which users can be coached whilst delivering better services to the population.
R29	A smart home should allow users to control the energy load in the house by looking at vectors in the following order: heat, motion, lightning and communication. Controlling those in a manner responsive to three elements: the first been commercial signals, essentially energy prices; the second is the ability to deliver the energy requirements to the home in a commercially efficient manner, so it is closely associated to automation; and third, it is responsive not only to commercial signals, but to ambient-environmental signals.
R30	The use of ICT on how we control and manage our homes. The utilisation of ICT by various apps and other technologies to control and manage our homes more intelligently. So it could be linked to energy or not.
R31	Smart home technology is a lifestyle opportunity that enables users to make things simpler and easier whilst improving lifestyles. However, the smartness goes beyond technology, it also entails data services which sit around and are overlooked behind the infrastructure.

Appendix 3

Concept	Definition
Cyberstalking	A continuing mode of conduct where by a person's behaviour intrudes upon another's personal life in a way they perceive is a threatening (Spitzberg and Hoobler, 2002)
Cyberbullying	Use of internet, cell phones or other technology to send or post text or images intended to hurt or embarrass another person(Moessner, 2007)

Online harassment	Threats or other offensive behaviour (not sexual solicitation) sent online to the youth or posted online about the youth for others to see (Finkelhor, Mitchell and Janis, 2000)
Doxing	Releasing someone's personal details onto the internet in an easily and accessible form. These details may include full legal names, residential addresses, unique identifiers for governmental records and services, business records and services and personals photographs (Douglas, 2016)
Sextorsion	Situations in which perpetrators threaten to expose sexual images to coerce victims to provide additional pictures, engage in sexual activity, or agree to other demands, even if exposure of the image never actually occurs (Wolford-Clevenger *et al.*, 2016)
Non-consensual pornography (revenge porn)	Uploading nude or semi-nude images/videos of a person online without their consent. Some non-consensual pornography involves website administrators use computer hacking to obtain nude photos from women, and then extort them be pressuring them to pay a fee to have their photos removed (Bates, 2017)
Deep fakes	Create and insert faces synthesized using deep neural networks into original images/videos. Together with other forms of misinformation shared through the digital social network (Lyu Xin Yang, no date)

Appendix 4

According to Centre for Research & Education on Violence against Women & Children (Baker *et al.*, 2013) each of these elements is defines as followed:

Concept	Definition
Hacking	The use of technology to gain illegal or unauthorized access to systems or resources for the purpose of acquiring personal information, altering or modifying information, or slandering and denigrating the victims
Impersonation	The use of technology to assume the identity of the victim or someone else in order to access private information, embarrass or shame the victim, contact the victim or create fraudulent identity documents.
Surveillance/Tracking	The use of technology to stalk and monitor a victim's activities and behaviours either in real time or historically
Harassment/spamming	The use of technology to continuously contact, annoy, threaten and/or scare the victim. Under an ongoing behaviour and not isolated events.
Recruitment	Use of technology to lure potential victims into violent situations
Malicious Distribution	Use of technology to manipulate and distribute illegal materials related to the victim.